Marine phospholipids: The current understanding of their oxidation mechanisms and potential uses for food fortification

There is a growing interest in using marine phospholipids (PL) as ingredient for food fortification due to their numerous health benefits. However, the use of marine PL for food fortification is a challenge due to the complex nature of the degradation products that are formed during the handling and storage of marine PL. For example, nonenzymatic browning reactions may occur between lipid oxidation products and primary amine group from phosphatidylethanolamine or amino acid residues that are present in marine PL. Therefore, marine PL contain products from nonenzymatic browning and lipid oxidation reactions, namely, Strecker aldehydes, pyrroles, oxypolymers, and other impurities that may positively or negatively affect the oxidative stability and quality of marine PL. This review was undertaken to provide the industry and academia with an overview of the current understanding of the quality changes taking place in PL during their production and their storage as well as with regards to their utilization for food fortification.

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BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.046 SNIP 2.349 CiteScore 5.83
ISI indexed (2013): ISI indexed yes
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Scopus rating (2012): SJR 2.05 SNIP 2.691 CiteScore 5.73
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Web of Science (2012): Indexed yes
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Scopus rating (2007): SJR 1.877 SNIP 2.474
Scopus rating (2006): SJR 1.739 SNIP 2.271
Scopus rating (2005): SJR 1.344 SNIP 2.223
Scopus rating (2004): SJR 0.959 SNIP 1.637
Scopus rating (2003): SJR 0.729 SNIP 1.802
Scopus rating (2002): SJR 0.789 SNIP 1.993
Scopus rating (2001): SJR 1.1 SNIP 1.953
Scopus rating (2000): SJR 1.464 SNIP 2.559
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Quality changes of Antarctic krill powder during long term storage

Krill is a valuable sustainable resource of omega-3 fatty acids and protein, which may be processed into a krill powder for human consumption. The objective of this study was to investigate the stability of krill powder when stored for up to 12 months at room temperature. In addition, the effect of packaging in vacuum was observed. The stability was assessed by changes in concentrations of lipid classes, antioxidants, pyrroles and lipid, and Strecker-derived volatiles. Some degradation occurred during storage at room temperature. Thus, a minor increase in volatiles, an increase in free fatty acids and a concomitant decrease in antioxidants, tocopherol, and astaxanthin was observed. In addition, there was a minor decrease in phospholipids and n-3 fatty acids; however, storage at vacuum improved the oxidative stability of krill powder.

Practical applications: For the use of krill powder in human nutrition, it is important, that the quality and stability is sufficiently high to retain the nutritional value during storage. This study contributes with information about the stability during storage up to 12 months at room temperature and the effect of packaging the powder in vacuum.

Antarctic krill (Euphausia superba) is a shrimp-like marine crustacean. It is rich in omega-3 fatty acids, primarily bound in phospholipids in the sn-2 position of the molecule, making it highly bioavailable. Krill may be processed into powder also rich in protein and astaxanthin. Stability of krill powder, stored for up to 12 months at room temperature, showed slight lipid oxidation.

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Web of Science (2016): Indexed yes
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Scopus rating (2015): SJR 0.642 SNIP 0.881 CiteScore 1.85
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.737 SNIP 1.051 CiteScore 1.98
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Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.873 SNIP 1.207 CiteScore 2.06
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
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Value utilization of discarded fish livers for production of omega-3 rich oil

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Marine Lipids (Omega-3 Oil) - Stability of Oil and Enriched Products During Production and Storage
The awareness of health benefits of marine lipids with a high content of omega-3 poly unsaturated fatty acids from fish and algae oil has led to an increased intake as oil and in products. However, these lipids are highly susceptible to lipid oxidation, which results in the formation of undesirable off-flavours and gives rise to unhealthy compounds such as free radicals and reactive aldehydes. Necessary prerequisites for successful development of omega-3 enriched products are that the oil used for enrichment is of a high quality and low in oxidation products and that oxidation of the lipids is prevented both during production and storage. In complex products, lipid oxidation and antioxidant mechanisms are very complex, due to the many factors that can influence the rate and extent of lipid oxidation. In order to obtain and maintain a good quality and oxidative stability of omega-3 oil and enriched foods, oxidation may be minimised by optimising by both intrinsic (physico-chemical) and extrinsic factors. Intrinsic factors are e.g. addition of antioxidants, choise of emulsifier and
droplet size. Extrinsic factors, such as exposure to light, high temperature and oxygen, cause increased oxidation. As processing will often cause extra oxidative stress to the omega-3 oil, extrinsic factors are especially important to consider during processing. Due to the complexity of multiphase foods, it is very difficult to predict the oxidative stability and therefore the behaviour and efficacy of antioxidants in omega-3 oil enriched products and optimal composition and processing conditions must be evaluated for each product.

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Scopus rating (2013): SJR 0.29 SNIP 0.329 CiteScore 0.94
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Scopus rating (2011): SJR 0.332 SNIP 0.409 CiteScore 0.88
Scopus rating (2010): SJR 0.2 SNIP 0.27
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Comparison of two methods for extraction of volatiles from marine PL emulsions: Short Communication
The dynamic headspace (DHS) thermal desorption principle using Tenax GR tube, as well as the solid phase micro-extraction (SPME) tool with carboxen/polydimethylsiloxane 50/30 µm CAR/PDMS SPME fiber, both coupled to GC/MS were implemented for the isolation and identification of both lipid and Strecker derived volatiles in marine phospholipids (PL) emulsions. Comparison of volatile extraction efficiency was made between the methods. For marine PL emulsions with a highly complex composition of volatiles headspace, a fiber saturation problem was encountered when using CAR/PDMS-SPME for volatiles analysis. However, the CAR/PDMS-SPME technique was efficient for lipid oxidation analysis in emulsions of less complex headspace. The SPME method extracted volatiles of lower molecular weights more efficient than the DHS method. On the other hand, DHS Tenax GR appeared to be more efficient in extracting volatiles of higher molecular weights and it provided a broader volatile spectrum for marine PL emulsion than the CAR/PDMS-SPME method.

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Marine phospholipids, Fish oil, Hydrolytic stability, Oxidative stability, Non-enzymatic browning reaction, Pyrrolization, Strecker degradation, Pyrrole content, Color changes
Effect of emulsifier type, pH and iron on oxidative stability of 5% fish oil-in-water emulsions

The effect of using different emulsifiers on lipid oxidation in 5% w/w fish oil-in-water emulsions was investigated. Emulsifiers included two of milk protein origin (whey protein isolate (Whey) or sodium caseinate (Cas)), soy lecithin (Lec) or emulsifiers high in milk phospholipid (20 or 75%). Forty different emulsions were produced with the five different emulsifiers. For each emulsifier, emulsions were prepared at two concentrations (0.2 and 0.75 wt%) at pH 3 or 7 and with or without added iron. Emulsions were stored in closed bottles in the dark at RT (20°C) for up to 7 days (with added iron) or 42 days (without added iron). Physical parameters and oxidative stability of the emulsions were investigated by analysis of particle size, zeta potential, primary and secondary oxidation products. Increase in emulsifier concentration generally increased the oxidative stability. Type of emulsifier and physical conditions affected the physical and oxidative stability of the emulsions. A general observation was that emulsions produced with the milk protein based emulsifiers were more oxidatively stable compared with the other emulsions. Practical applications: The overall conclusion from this study was that the oxidative stability of 5% o/w emulsions depended on both emulsifier type, concentration, pH and iron content. An analogous conclusion is most likely also valid in more complex food emulsions with similar or higher lipid contents such as milk drink, dressing, etc. Hence, in such foods the emulsifier and the emulsifier concentration should be carefully chosen in order to minimise lipid oxidation. However, milk protein-based emulsifiers could be a better choice than emulsifiers with higher content of phospholipids independent of emulsifier concentration, pH and iron content.
Effect of α-lactalbumin and β-lactoglobulin on the oxidative stability of 10% fish oil-in-water emulsions depends on pH

The objective of this study was to investigate the influence of pH on lipid oxidation and protein partitioning in 10% fish oil-in-water emulsions prepared with different whey protein isolates with varying ratios of α-lactalbumin and β-lactoglobulin. Results showed that an increase in pH increased lipid oxidation irrespective of the emulsifier used. At pH 4, lipid oxidation was not affected by the type of whey protein emulsifier used or the partitioning of proteins between the interface and the water phase. However, at pH 7 the emulsifier with the highest concentration of β-lactoglobulin protected more effectively against oxidation during emulsion production, whereas the emulsions with the highest concentration of α-lactalbumin were most stable to oxidation during storage. These differences were explained by differences in the pressure and adsorption induced unfolding of the individual protein components.
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
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Scopus rating (2016): CiteScore 4.85 SJR 1.706 SNIP 2.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.597 SNIP 1.962 CiteScore 4.31
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.595 SNIP 2.027 CiteScore 3.92
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.548 SNIP 2.069 CiteScore 3.87
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ISI indexed (2012): ISI indexed yes
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BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.909 SNIP 2.395 CiteScore 4.17
ISI indexed (2011): ISI indexed yes
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Scopus rating (2010): SJR 1.965 SNIP 2.261
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.776 SNIP 2.024
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.488 SNIP 1.703
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.467 SNIP 2.095
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.383 SNIP 1.848
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.017 SNIP 1.543
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Scopus rating (2004): SJR 1.057 SNIP 1.449
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Web of Science (2002): Indexed yes
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Homogenization Pressure and Temperature Affect Protein Partitioning and Oxidative Stability of Emulsions

The oxidative stability of 10 % fish oil-in-water emulsions was investigated for emulsions prepared under different homogenization conditions. Homogenization was conducted at two different pressures (5 or 22.5 MPa), and at two different temperatures (22 and 72 °C). Milk proteins were used as the emulsifier. Hence, emulsions were prepared with either a combination of α-lactalbumin and β-lactoglobulin or with a combination of sodium caseinate and β-lactoglobulin. Results showed that an increase in pressure increased the oxidative stability of emulsions with caseinate and β-lactoglobulin, whereas it decreased the oxidative stability of emulsions with α-lactalbumin and β-lactoglobulin. For both types of emulsions the partitioning of proteins between the interface and the aqueous phase appeared to be important for the oxidative stability. The effect of pre-heating the aqueous phase with the milk proteins prior to homogenization did not have any clear effect on lipid oxidation in either of the two types of emulsions.

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Web of Science (2015): Indexed yes
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Scopus rating (2014): SJR 0.767 SNIP 1.043 CiteScore 1.68
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.809 SNIP 1.074 CiteScore 1.71
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.871 SNIP 1.236 CiteScore 1.81
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.833 SNIP 1.292 CiteScore 1.98
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.763 SNIP 1.056
Web of Science (2010): Indexed yes
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Scopus rating (2009): SJR 0.863 SNIP 1.183
The main objective of this study was to investigate the oxidative stability and non-enzymatic browning reactions of marine phospholipids liposomal dispersions prepared from two authentic standards (phosphatidylcholine and phosphatidylethanolamine) and two purified PL from marine sources with and without addition of amino acids (leucine, methionine and lysine). Samples were incubated at 60 °C for 0, 2, 4 and 6 days. Non-enzymatic browning reactions were investigated through measurement of (i) Strecker derived volatiles, (ii) yellowness index (YI), (iii) hydrophobic and (iv) hydrophilic pyrroles content. The oxidative stability of the samples was assessed through measurement of secondary lipid derived volatile oxidation products. The result showed that the presence of PE and amino acids caused the formation of pyrroles, generated Strecker derived volatiles, decreased the YI development and lowered lipid oxidation. The lower degree of lipid oxidation in liposomal dispersions containing amino acids might be attributed to antioxidative properties of pyrroles or amino acids.
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Web of Science (2017): Indexed yes
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Scopus rating (2016): CiteScore 4.85 SJR 1.706 SNIP 2.091
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Web of Science (2015): Indexed yes
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Scopus rating (2014): SJR 1.595 SNIP 2.027 CiteScore 3.92
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.548 SNIP 2.069 CiteScore 3.87
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Scopus rating (2012): SJR 1.805 SNIP 2.357 CiteScore 3.98
ISI indexed (2012): ISI indexed yes
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Web of Science (2009): Indexed yes
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Scopus rating (2008): SJR 1.488 SNIP 1.703
Web of Science (2008): Indexed yes
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Scopus rating (2006): SJR 1.383 SNIP 1.848
Web of Science (2006): Indexed yes
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Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.057 SNIP 1.449
Scopus rating (2003): SJR 0.893 SNIP 1.258
Web of Science (2003): Indexed yes
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Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 0.805 SNIP 0.99
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Scopus rating (2000): SJR 0.728 SNIP 0.979
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Oxidative Stability and Sensory Attributes of Fermented Milk Product Fortified with Fish Oil and Marine Phospholipids

Marine phospholipids (PL) are potential ingredients for food fortification due to its numerous advantages. The main objective of this study was to investigate whether a fermented milk product fortified with a mixture of marine PL and fish oil had better oxidative stability than a fermented milk product fortified with fish oil alone. Fortification of a fermented milk product with marine PL was performed by incorporating 1 % w/w lipids, either in the form of neat oil or in the form of a pre-emulsion. Lipid oxidation was investigated in the neat emulsions and fortified products by the measurements of primary, secondary volatile oxidation products and tocopherol content upon 32 days storage at 2 °C and 28 days storage at 5 °C, respectively. Analyses of particle size distribution, viscosity and microbial growth were also performed. In addition, sensory attributes such as sour, fishy and rancid flavor/odor were evaluated in fortified products by a trained panel. The results obtained showed that incorporation of a mixture of marine PL and fish oil into fermented milk products decreased the oxidative stability and sensory quality of fortified products. The pH-dependent behavior of iron seemed to be the main factor that influenced the lipid oxidation in the marine PL emulsion and fermented milk system. In addition, both oxidative stability and sensory acceptability of fortified products varied depending on the quality of the marine PL used for fortification.

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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.682 SNIP 0.997 CiteScore 1.66
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.767 SNIP 1.043 CiteScore 1.68
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.809 SNIP 1.074 CiteScore 1.71
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BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.871 SNIP 1.236 CiteScore 1.81
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.833 SNIP 1.292 CiteScore 1.98
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
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Physico-chemical properties, oxidative stability and non-enzymatic browning in marine phospholipid emulsions and their use in food applications

Marine phospholipids (PL) contain a high level of eicosapentaenoic acids (EPA) and docosahexaenoic acids (DHA), which have documented beneficial effect on human health. In addition, marine PL are more advantageous than crude or refined fish oils. Marine PL are more resistant to oxidation, provide better bioavailability and ability to form liposomes. All these unique properties of marine PL make them an attractive choice as ingredients for food fortification. Nowadays, a wide range of food products fortified with n-3 triglycerides (TAG) are available worldwide. However, the feasibility of using marine PL for food fortification has not been explored. The main objective of the present Ph.D. study was to explore the feasibility of using marine PL for food fortification. The secondary objective was to study the physical and oxidative stability of marine PL emulsions while identifying the important factors affecting their stability.

Marine PL contain a high level of phosphatidycholine (PC), which has amphiphilic properties. Therefore it is feasible to prepare marine PL emulsions without addition of other emulsifiers. Emulsions containing solely marine PL with a high physical stability could be prepared by using 2-10 % marine PL. The high physical stability of these emulsions was most likely due to the coexistence of micelles, liposomes and emulsified oil droplets. However, there was a requirement for at least 3 % of marine PL (equivalent to 0.8 - 1.3 % of PC depending on the marine PL sources) to avoid phase separation and to form physically stable emulsions containing both marine PL and fish oil.

Emulsions with high oxidative stability could be prepared by using marine PL of high quality with a high content of PL, cholesterol, antioxidants and a low content of prooxidants such as transition metals and initial hydroperoxides. In addition, the presence of other antioxidative compounds such as residues of free amino acids and pyrroles (formed via nonenzymatic browning reactions) in marine PL most likely have improved the oxidative stability of marine PL emulsions. In addition, hydrolysis of PL in marine PL emulsions was minimal at pH 7. In general, both physical and oxidative stability of marine PL emulsions varied in relation to the chemical composition of the marine PL used for emulsion preparation. Therefore, marine PL were purified through acetone precipitation in order to eliminate the effect of other factors such as the content of TAG, antioxidant or other minor components on lipid oxidation in marine PL. The oxidative stability of emulsions prepared from different levels of purified marine PL was investigated. Results obtained seem to suggest that the oxidative stability of
purified marine PL emulsions was greatly improved by the addition of α-tocopherol.

Non-enzymatic browning reactions were observed in marine PL emulsions through the a) measurements of Strecker degradation (SD) products of amino acid residues, and b) measurements of hydrophobic and hydrophilic pyrroles (which are pyrrolisation products of phosphatidylethanolamine (PE) and amino acids), respectively. Several mechanisms were proposed for non-enzymatic browning reactions in marine PL. It is speculated that these reactions might have occurred in marine PL mainly during their manufacturing process due to the interactions between lipid oxidation products with the primary amine groups from PE and residues of amino acids/protein that are present in marine PL. In addition, the content of pyrroles, SD products and the degree of browning in marine PL might be influenced by chemical compositions of marine PL and their manufacturing processes. In order to further investigate if the presence of pyrroles or degradation products of amino acids have any influence on oxidative stability of marine PL, liposomal dispersions were prepared from pure PC and PE compounds and purified marine PL with and without addition of amino acids. The obtained result from this model study confirmed the proposed mechanisms of non-enzymatic browning reactions in marine PL. The presence of PE and amino acids led to formation of pyrroles, generation of SD products and decreases in both browning development and lipid oxidation in liposomal dispersions. The low lipid oxidation in dispersions containing amino acids might be attributed to the antioxidative properties of pyrroles or amino acids. In addition, it is speculated that PE and amino acids pyrrolisation or oxypolymerisation of lipid oxidation products in marine PL might be the cause of browning development.

Incorporation of marine PL into fermented milk product adversely affected the oxidative stability and sensory quality of fortified products despite the use of a low percentage of marine PL in combination with fish oil for fortification. This unexpected result was mainly due to the quality of current marine PL that was used for emulsion preparation and food application. In addition, the oxidative stability and sensory quality of marine PL fortified products varied depending on the quality and source of marine PL used for fortification. Although the attempts to incorporate marine PL into food system did not produce the expected results, the findings from the present Ph.D. study provide food industries and academia with new insights into the oxidative stability of marine PL and further inspirations for improving the quality of current marine PL.

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Physico-chemical properties, oxidative stability and non-enzymatic browning reactions in marine phospholipids emulsions and their applications for food enrichment
Marine phospholipids (PL) are more advantageous than fish oil. They seem to have better bioavailability, better resistance and higher content of eicosapentaenoic acids and docosahexaenoic acids than fish oil. The main objective of this study was to explore the possibilities of using marine PL for food enrichment. The secondary objective was to investigate the different aspects of marine PL emulsions including: physico-chemical properties, oxidative stability and non-enzymatic browning reactions while identifying the important factors affecting their stability. The physical and oxidative stability of marine PL emulsions was significantly influenced by the chemical composition of marine PL used. Emulsions with a high oxidative stability could be obtained when using marine PL of high purity with a high content of PL, cholesterol and α-tocopherol. Non-enzymatic browning reactions (Strecker degradation and pyrrolization) seemed to influence the oxidative stability of marine PL emulsions. Similar to marine PL emulsions, the oxidative stability and sensory acceptability of marine PL enriched products varied depending on the quality and chemical composition of marine PL used. Overall, this study provided new insights into the oxidative stability of marine PL and preliminary knowledge on the quality of marine PL fortified foods.

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Retardation Of Lipid Oxidation In Fish Oil-Enriched Fish Pâté- Combination Effects

The oxidative stability during storage of fish pâté made from cod and enriched with 5% oil was investigated. Pâtés were produced with neat fish oil, pre-emulsified fish oil, microencapsulated fish oil, inert medium chain triacylglycerol (MCT) oil or a fish/rapeseed oil mixture. Addition of fish oil decreased the oxidative stability. Fish pâté with microencapsulated fish oil or MCT oil did not oxidize, whereas oxidation was slower in fish pâté with pre-emulsified oil compared with fish pâté with neat oil. Packaging in vacuum did not decrease oxidation. Fish pâtés with emulsified oil stored at 2 or 10°C were equally stable. Mixing fish oil with rapeseed oil before emulsification slightly increased the stability of the fish pâtés. Addition of antimicrobial agents, sodium benzoate and potassium sorbate increased oxidative stability. It is recommended to produce enriched fish pâté by adding pre-emulsified fish oil or microencapsulated fish oil and store at preferentially 2-10°C. Practical Applications: The results from this study can directly be transferred to practical applications in the food industry. Thus, the study showed that fish oil-enriched fish pâté with an acceptable shelf life and good sensory properties can be produced if one or more of the following strategies are used: Use microencapsulated or pre-emulsified fish oil or pre-emulsified fish oil/rapeseed oil mixture as the fish oil delivery system and add antimicrobial agents to increase both microbial and oxidative stability. The fish pâté can be stored at temperatures up to 10°C. © 2011 Wiley Periodicals, Inc.
Ultra structure of oil-in-water emulsions a comparison of different microscopy- and preparation methods

We compare chemical fixation/ room temperature embedding in resin, cryofixation/ freeze substitution, and cryofixation/cryo imaging (freeze-fracture cryo-SEM) on several oil-in-water food emulsions. This is for visualization of the structure and thickness of the emulsifying layers consisting of food grade emulsifiers such as whey protein, sodium caseinate and milk phospholipids; layers that are expected to be in the range of only a few nm. Furthermore, the liquid nature and high water content of the samples further complicates the preparation process; especially since water is a major component of the samples. Concerning chemical fixation we adapted conventional protocols for preserving the emulsions by developing agar pockets for encapsulation or embedding in capillary tubes. Indeed, to use chemical fixation with these samples is challenging because we need to minimize alterations of the samples while ensuring at the same time that the samples are stabilized so they do not collapse when the water is removed. These protocols give an interesting view of the emulsions and the organisation of the interface layer surrounding the oil droplets. With cryofixation we could image more details of this interface and even the protein in the water phase. We observed that freeze substituted material seems to correspond very well to images of freeze fractured frozen samples in cryo-SEM where protein aggregates seems to be visible in the water phase.

With this work, we want to demonstrate the importance of combining different microscopic approaches to access the ultra structure of the oil-in-water emulsions due to their complexity and instablity.

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Ultra structure of oil-in-water emulsions a comparison of different microscopy- and preparation methods

We compare chemical fixation/ room temperature embedding in resin, cryofixation/ freeze substitution, and cryofixation/cryo imaging (freeze-fracture cryo-SEM) on several oil-in-water food emulsions. This is for visualization of the structure and thickness of the emulsifying layers consisting of food grade emulsifiers such as whey protein, sodium caseinate and milk phospholipids; layers that are expected to be in the range of only a few nm. Furthermore, the liquid nature and high water content of the samples further complicates the preparation process; especially since water is a major component of the samples. Concerning chemical fixation we adapted conventional protocols for preserving the emulsions by developing agar pockets for encapsulation or embedding in capillary tubes. Indeed, to use chemical fixation with these samples is challenging because we need to minimize alterations of the samples while ensuring at the same time that the samples are stabilized so they do not collapse when the water is removed. These protocols give an interesting view of the emulsions and the organisation of the interface layer surrounding the oil droplets. With cryofixation we could image more details of this interface and even the protein in the water phase. We observed that freeze substituted material seems to correspond very well to images of freeze fractured frozen samples in cryo-SEM where protein aggregates seems to be visible in the water phase.

With this work, we want to demonstrate the importance of combining different microscopic approaches to access the ultra structure of the oil-in-water emulsions due to their complexity and instability.
Ultra structure of oil-in-water emulsions - a comparison of different microscopy- and preparation methods

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Addition of Fish Oil to Cream Cheese Affects Lipid Oxidation, Sensory Stability and Microstructure

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Emulsification technique affects oxidative stability of fish oil-in-water emulsions
In oil-in-water emulsions, lipid oxidation is expected to be initiated at the oil-water interface. The properties of the emulsifier used, and the structure at the interface is therefore expected to be of great importance for lipid oxidation in emulsions. Previous studies have shown that e.g. homogenization pressure can affect how proteins locate themselves at the interface of an emulsion. The hypothesis is therefore that emulsions produced with different emulsification equipments differ in their oxidative stability due to differences in the behaviour of the proteins at the interface.
The aim of this study was to compare lipid oxidation in 10% fish oil-in-water emulsions prepared by two different kinds of high pressure homogenizers i.e. a microfluidizer and a two valve high pressure homogenizer. Emulsions were made with equal droplet sizes, and with either 1% sodium caseinate or 1% whey protein isolate. Emulsions were characterised and investigated by microscopy. Lipid oxidation was assessed by PV and the formation of secondary volatile oxidation products. Results showed that the different emulsification techniques had an influence on lipid oxidation and that the effect of the emulsification technique depended on the type of protein used as an emulsifier.
Factors affecting the oxidative stability of omega-3 emulsions prepared with milk proteins

Omega-3 fatty acids are prone to lipid oxidation due to their unsaturated nature. In oil-in-water emulsions, lipid oxidation is expected to be initiated at the oil-water interface. The properties of the emulsifier used and the structure at the interface are therefore expected to be of great importance for the resulting oxidation.

This presentation will give an overview of parameters that are expected to change the properties and structure of milk protein components at the interface of 10% fish oil-in-water emulsions. Results from three different studies will be included. The first study compared the effect of two different high pressure homogenizers on oxidation in caseinate and whey protein isolate emulsions. The second study evaluated the effect of homogenization pressure and temperature on emulsions prepared either with whey proteins or a combination of caseinate and β-lactoglobulin. Finally, the third study investigated the influence of pH on emulsions prepared with α-lactalbumin, β-lactoglobulin or a combination of the two. In all three studies the adsorption of individual protein components were shown to be of great importance to lipid oxidation. Thus, the effect of various conditions for emulsion production will be discussed in relation to protein adsorption and their structure at the interface.

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 highest 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 macrostructure 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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**Food enrichment with marine phospholipid emulsions**
Many studies have shown that marine phospholipids (PL) provide more advantages than fish oil. They seem to have better bioavailability, better resistance towards oxidation and higher content of eicosapentaenoic acids and docosahexaenoic acids than fish oil, which essentially contains triglycerides. The main objective of this study was to explore the possibilities of using marine PL for food enrichment. In order to achieve the objective, the study was divided into 4 stages: i) evaluation of physico-chemical properties of marine PL emulsions, ii) evaluation of hydrolytic and oxidative stability of marine PL emulsions, iii) evaluation of non-enzymatic browning reactions in marine PL emulsions, iv) evaluation of sensory properties and oxidative stability of yoghurt enriched with marine PL. The obtained results showed that marine PL have good emulsifying properties and it was feasible to prepare marine PL emulsions with and without addition of fish oil. The oxidative stability of marine PL emulsions was significantly influenced by the chemical composition of marine PL used for...
emulsions preparation. For instance, emulsions with good oxidative stability could be obtained when using raw materials with high purity, low fish oil content and high PL, cholesterol and α-tocopherol content. In addition, non-enzymatic browning reactions may also affect the oxidative stability of the marine PL emulsion. These reactions included Strecker degradation and pyrrolization, and their occurrence were due to the interaction between lipid oxidation products with amine group either from phosphatidylethanolamine or residues of amino acids/proteins in marine PL. The study on enrichment of yoghurt with marine PL showed that the oxidative stability and sensory acceptability was highly dependent on the quality and composition of the marine PL.

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Individual whey protein components influence lipid oxidation dependent on pH
In emulsions, lipid oxidation is expected to be initiated at the oil-water interface. The properties of the emulsifier used and the composition at the interface is therefore expected to be of great importance for the resulting oxidation. Previous studies have shown that individual whey protein components (α-lactalbumin and β-lactoglobulin) adsorb differently to the interface depending on pH. In addition, differences has been shown to exists between the oxidative stability provided by α-lactalbumin and β-lactoglobulin. The hypothesis is that pH influences the oxidative stability of emulsions by affecting the preferential adsorption of whey protein components at the interface.

The aim of the study was to compare lipid oxidation in 10% fish oil-in-water emulsions prepared with 1% whey protein having either a high concentration of α-lactalbumin, a high concentration of β-lactoglobulin or equal amounts of the two. Emulsions were prepared at pH4 and pH7. Emulsions were characterized by their droplet sizes, viscosities, and contents of proteins in the water phase. Lipid oxidation was assessed by PV and secondary volatile oxidation products. Results showed that pH greatly influenced the oxidative stability of emulsions. At high pH β-lactoglobulin emulsions were more stable than α-lactalbumin emulsions, whereas at low pH the opposite was the case.

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Investigation of lipid oxidation and non-enzymatic browning reactions in marine PL emulsions
Marine phospholipids (PL) have received much attention recently due to their numerous advantages. One of these advantages is their better resistance towards oxidation as compared to fish oil. In addition to the antioxidative properties of α-tocopherol and phospholipids, the better oxidative stability of marine PL might be attributed to antioxidative properties of pyrroles formed between oxidised lipids with amine groups from phosphatidylethanolamine (PE) or residues amino acids that are present in marine PL. The main objective of this study was to investigate if the presence of amine group from PE or amino acids affected the oxidative stability of purified marine PL emulsions. The secondary objective was to study the non-enzymatic browning reactions in the emulsions which included both Strecker degradation (SD) and pyrroles formation. Emulsions were prepared with and without addition of amino acids (leucine, methionine and lysine) from 2 authentic
standards (PC and PE) and 2 purified marine PL (LC and MPL) through sonication method. Emulsions were incubated at 60 °C for 0, 2, 4 and 6 days. Non-enzymatic browning reactions were investigated through measurement of i) Strecker aldehydes, ii) yellowness index (YI), iii) hydrophobic and hydrophilic pyrroles content. On the other hand, the oxidative stability of emulsion was measured through secondary lipid derived volatiles. The result showed that the presence of PE and amino acids caused the formation of pyrroles, generated the Strecker aldehydes, decreased the YI development and lowered the lipid oxidation. The lower lipid oxidation in emulsions containing amino acids might be attributed to antioxidative properties of pyrroles or amino acids.

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Iron-mediated lipid oxidation in 70% fish oil-in-ater emulsions: effect of emulsifier type and pH
The objective of this study was to investigate the protective effect of five different emulsifiers on iron-mediated lipid oxidation in 70% fish oil-in-water emulsions. The emulsifiers were either based on protein (whey protein isolate and sodium caseinate) or based on phospholipid (soy lecithin and two milk phospholipids with different phospholipid contents, MPL20 and MPL75). Lipid oxidation was studied at pH 4.5 and 7.0, and results were compared to lipid oxidation in neat fish oil. Results showed that all emulsions oxidised more than neat oil. Furthermore, emulsions prepared with proteins oxidised more at low pH than at high pH, and casein emulsions oxidised the least (Peroxide value (PV) at day 7 was 0.5–0.7 meq kg−1). Among emulsions prepared with phospholipids, emulsions with MPL75 were the most oxidised followed by emulsions prepared with lecithin and MPL20. Thus, PV in MPL75 emulsions was 5.0–5.5 meq kg−1 at day 7 compared with 0.9–1.9 meq kg−1 in MPL20 emulsions.

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Lipid oxidation in fish oil enriched oil-in-water emulsions and cream cheese with pre-emulsified fish oil is affected differently by the emulsifier used

It is well-documented that a high intake of long chain omega-3 polyunsaturated fatty acids has several health beneficial effects in humans. Consequently, the interest in food products enriched with marine oils has increased during recent years. However, addition of these highly unsaturated fatty acids to foods invariably increases the risk of lipid oxidation. A possible strategy to avoid lipid oxidation and the consecutive development of unpleasant off-flavours is to protect the oil in a delivery emulsion in which the oil droplets are shielded from its possible pro-oxidative surroundings by an emulsifier. The antioxidative properties of milk proteins make them an obvious choice as emulsifiers in delivery emulsions. Previous studies have furthermore shown that a combination of proteins and phospholipids may increase the thickness of the interfacial layer in an emulsion.

This presentation will include results from studies on lipid oxidation in simple oil-in-water emulsions prepared with milk proteins alone or combinations of milk proteins and phospholipids. In addition, a study on fish oil enriched cream cheese will be presented. In this study, the cream cheese was enriched with either neat fish oil or a fish oil-in-water delivery emulsion prepared with whey protein isolate, sodium caseinate or a commercially available emulsifier that consisted of ~20% milk phospholipids and ~50% milk proteins. Results showed that simple emulsions prepared with a combination of milk proteins and phospholipids as emulsifier had lower oxidative stability compared with emulsions prepared with milk proteins only. In cream cheese the opposite was the case. Furthermore, delivery emulsions prepared with milk proteins only were even found to increase oxidation compared to cream cheese prepared with neat fish oil. The findings in cream cheese could to some extent be explained by differences in the microstructure as observed from confocal laser scanning microscopy.

Lipophilization of dihydrocaffeic acid affects its antioxidative properties in fish-oil-enriched emulsions

The aim of the present study was to evaluate the antioxidative effect of lipophilized dihydrocaffeic acid, i.e., octyl dihydrocaffeate and oleyl dihydrocaffeate. Furthermore, the relationship between the measured efficacy of the antioxidants in emulsions, their partitioning into different phases of an emulsion system and their in vitro antioxidrant properties was also evaluated. Lipid oxidation in the emulsions was affected by the antioxidants applied. Thus, despite a reduced antioxidant activity of lipophilized dihydrocaffeic acid in the antioxidant assays, lipophilized dihydrocaffeic acid was more efficient than caffeic and dihydrocaffeic acids. Octyl dihydrocaffeate had a significantly higher antioxidative effect than oleyl dihydrocaffeate in emulsions. The results partly supported the polar paradox hypothesis, since lipophilized compounds resulted in increased oxidative stability. However, the decreased antioxidative efficacy with increasing alkyl chain length esterified to dihydrocaffeic acid supported a newly suggested cut-off effect hypothesis. This hypothesis suggests that when a certain level of hydrophobicity is obtained for lipophilized phenolic acids, the ester forms micelles in the aqueous phase rather than being located at the interface or oil phase. This phenomenon is suggested to explain the reduced antioxidant activity of oleyl dihydrocaffeate compared with octyl dihydrocaffeate. Practical application: The finding that
lipophilization of phenolic compounds increase their efficacy opens up new possibilities for producing new and more efficient antioxidants for food systems. However, the results also show that optimization of the chain length for each type of phenolic compound may be necessary. Since these compounds may have a much higher efficacy against lipid oxidation a lower amount of antioxidant will be necessary to obtain the same effect. This would decrease the costs. In addition, the use of synthetic antioxidants, that might have toxic effect in vivo, can be avoided. The raw materials used for the lipophilized compounds are natural compounds, however the fate of the lipophilized compounds in vivo should eventually be evaluated.

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Oxidative degradation and non-enzymatic browning due to the interaction between oxidised lipids and primary amine groups in different marine PL emulsions

Due to the beneficial health effects of marine phospholipids (PL) there is an increasing industrial interest in using them for nutritional applications including emulsified foods. This study was undertaken to investigate both oxidative and hydrolytic stability of marine PL emulsions in relation to the chemical composition of the marine PL used. Moreover, non-enzymatic browning reactions were also investigated. Emulsions were prepared by high pressure homogenizer using different concentrations and sources of marine PL. In some formulations, fish oil was added in order to study the effect of increasing levels of triglycerides in the emulsions. The oxidative and hydrolytic stability of emulsions was investigated through measurement of peroxide value, free fatty acids, and 31P NMR during storage at 2°C for up to 32 days. The oxidative stability of marine PL emulsions during storage was further investigated through the measurement of secondary volatile compounds by solid-phase microextraction (SPME) and dynamic headspace (DHS) connected to gas chromatography (GC–MS). Non-enzymatic browning reactions were investigated through the measurement of Strecker derived volatiles, colour changes and pyrrole content. The results suggested that the oxidative stability of marine PL emulsions was significantly influenced by the chemical composition and the concentration of marine PL used to prepare them. Emulsions with good oxidative stability could be prepared from marine PL of high purity and high content of PL and antioxidant and low TAG content. © 2012 Elsevier Ltd. All rights reserved.
Oxidative Stability of Dispersions Prepared from Purified Marine Phospholipid and the Role of α-Tocopherol

The objective of this study was to investigate the oxidative stability of dispersions prepared from different levels of purified marine phospholipid (PL) obtained by acetone precipitation, with particular focus on the interaction between α-tocopherol and PL in dispersions. This also included the investigation of nonenzymatic browning in purified marine PL dispersions. Dispersions were prepared by high-pressure homogenizer. The oxidative and hydrolytic stabilities of dispersions were investigated by determination of hydroperoxides, secondary volatile oxidation products, and free fatty acids, respectively, during 32 days of storage at 2 °C. Nonenzymatic browning was investigated through measurement of Strecker aldehydes,
color changes, and pyrrole content. Dispersions containing α-tocopherol or higher levels of purified marine PL showed a lower increment of volatiles after 32 days storage. The results suggested that tocopherol is an efficient antioxidant in PL dispersions or that the presence of α-tocopherol and pyrroles may be the main reason for the high oxidative stability of purified marine PL dispersions.
Many studies have shown that marine phospholipids (PL) have better bioavailability, better resistance towards oxidation and contain higher polyunsaturated fatty acids such as eicosapentaenoic (EPA) and docosahexaenoic acids (DHA) than triglycerides (TAG) present in fish oil. The objective of this study was to investigate the emulsifying properties of various commercial marine PL and the feasibility of using them to prepare stable emulsions prepared with or without addition of fish oil. In addition, this study also investigated the relationship between chemical composition of marine PL and the stability of their emulsions. Physical stability was investigated through particle size distribution (PSD), zeta potential, microscopy inspection and emulsion separation (ES); while the oxidative and hydrolytic stability of emulsions were investigated through peroxide value (PV) and free fatty acids value (FFA) after 32 days storage at room temperature and at 2 °C. In conclusion, marine PL showed good emulsifying properties and it was possible to prepare marine PL emulsions with and without addition of fish oil. Emulsion with both good oxidative stability and physical stability could be prepared by using marine PL of high purity, less TAG, more PL, cholesterol and higher antioxidant content.

Physico-chemical Properties of Marine Phospholipid Emulsions
Many studies have shown that marine phospholipids (PL) have better bioavailability, better resistance towards oxidation and contain higher polyunsaturated fatty acids such as eicosapentaenoic (EPA) and docosahexaenoic acids (DHA) than triglycerides (TAG) present in fish oil. The objective of this study was to investigate the emulsifying properties of various commercial marine PL and the feasibility of using them to prepare stable emulsions prepared with or without addition of fish oil. In addition, this study also investigated the relationship between chemical composition of marine PL and the stability of their emulsions. Physical stability was investigated through particle size distribution (PSD), zeta potential, microscopy inspection and emulsion separation (ES); while the oxidative and hydrolytic stability of emulsions were investigated through peroxide value (PV) and free fatty acids value (FFA) after 32 days storage at room temperature and at 2 °C. In conclusion, marine PL showed good emulsifying properties and it was possible to prepare marine PL emulsions with and without addition of fish oil. Emulsion with both good oxidative stability and physical stability could be prepared by using marine PL of high purity, less TAG, more PL, cholesterol and higher antioxidant content.

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Organisations: National Food Institute, Division of Industrial Food Research
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The antioxidative effect of lipophilized rutin and dihydrocaffeic acid in fish oil enriched milk

The antioxidative effect of phenolipids was evaluated in fish oil enriched milk emulsions as a model for a complex food system. Two different phenolipids modified from dihydrocaffeic acid (with C8 or C18:1) and rutin (with C12 or C16) were evaluated. Both dihydrocaffeate esters and rutin laurate showed significantly better antioxidant properties in milk emulsion compared with the original phenolics. However, rutin palmitate only performed slightly better as antioxidant than rutin. The results with rutin indicated that a cut-off effect exists in relation to the alkyl chain length with respect to optimal antioxidant activity in milk emulsions. Thus, the optimal alkyl chain length is at least below 16 carbon atoms, and maybe even less for rutin esters. For dihydrocaffeate esters it was not possible to conclude on a cut-off effect in relation to alkyl chain length and antioxidative effect due to the almost similar antioxidant effect of the two phenolipids. However, there was a tendency towards octyl dihydrocaffeate being slightly more efficient than oleyl dihydrocaffeate. Practical application: The finding that
phenolipids are better antioxidants in milk emulsions than the original phenolic acid provides new knowledge that can be used to develop new antioxidant strategies to protect foods against lipid oxidation. However, the results indicate that both optimization of alkyl chain length for each type of phenolic, and optimization for each type of emulsion will be necessary in order to get the best oxidative stability of an emulsion with these phenolipids. Use of efficient antioxidants may lower the amount of antioxidant needed to protect against lipid oxidation and may in addition decrease the costs.

**General information**

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Scopus rating (2008): SJR 0.606 SNIP 0.815
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The choice of homogenisation equipment affects lipid oxidation in emulsions

Milk proteins are often used by the food industry because of their good emulsifying properties. In addition, they can also provide oxidative stability to foods. However, different milk proteins or protein components have been shown to differ in their antioxidative properties, and their localisation in emulsions has been shown to be affected by the emulsification conditions. The objective of this study was to investigate the influence of homogenisation equipment (microfluidizer vs. two-stage valve homogeniser) on lipid oxidation in 10% fish oil-in-water emulsions prepared with two different milk proteins. Emulsions were prepared at pH 7 with similar droplet sizes. Results showed that the oxidative stability of emulsions prepared with sodium caseinate was not influenced by the type of homogeniser used. In contrast, the type of homogenisation equipment significantly influenced lipid oxidation when whey protein was used as emulsifier, with the microfluidizer resulting in lower levels of oxidation.

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The structure of omega3 food emulsions

Fish oil is rich in polyunsaturated omega-3 fatty acids (omega-3 PUFAs) which are generally recognized as being beneficial to the health [1]. The addition of fish oil to food products is attractive to both the consumers and the food industry. Indeed, these components will improve nutritional value and add product value. Omega-3 PUFAs are rich in double bonds in their fatty acid chains and this attribute renders them highly susceptible to lipid oxidation. Omega-3 PUFAs can be added to food products as neat oil or as a delivery system such as oil-in-water emulsions. In this last configuration, the oil is surrounded by an emulsifier e.g. proteins, phospholipids or hydro-colloids. This emulsifier layer is important and may protect the oil inside the droplets against prooxidants in the surrounding water phase; the emulsifier should act as a physical barrier between the omega-3 PUFAs and the prooxidants. But this protective aspect is a really complex process and it is dependent on the food matrix to which the oil is added [2]. Oxidation is presumed to be initiated at the emulsifier layer, i.e. the interface layer between the oil and water where the oil is most likely to come into contact.
with the proxidants in the water phase. Hence the structure, thickness and composition of the interface layer is expected to have a great impact on the oxidative stability of the emulsion. These layers are consisting of food grade emulsifiers such as milk phospholipids, casein and whey protein and are estimated to be in the range of a few nm which is why we used several electron microscopy techniques to visualize and characterize them. For this work we compare chemical fixation/room temperature embedding in resin, cryofixation/freeze substitution and cryofixation/cryo imaging (freeze-fracture cryo-SEM) on several oil-in-water emulsions. Concerning chemical fixation, we adapted conventional protocols for preserving the emulsions, by developing agar pockets for encapsulation or embedding in capillary tubes (figure 1). Indeed to use chemical fixation with these samples is challenging because we need to minimize alterations of the samples while ensuring at the same time that the samples are stabilized so they do not collapse when the water is removed, e.g. milk encapsulated in agar capsules [3]. These new protocols give an interesting view of the emulsions and the organisation of the interface layer surrounding the oil droplets. With cryofixation we could image more details of this interface and we observed that cryo substituted material seems to correspond very well to images of freeze fractured frozen samples in cryo-SEM where protein aggregates seems to be visible in the water phase, see figure 2.

With this work, we want to demonstrate the importance of combining different microscopic approaches to access the ultrastructure of the oil-in-water emulsions due to their complexity and instability [5].

Cryo-FIB SEM for Characterization of the Structure of Fish Oil Emulsions

The addition of fish oil to industrial food products is appealing both to the food industry and consumers for reasons such as health benefits and the extra commercial value. Fish oil is rich in long chain omega-3 fatty acids, which contain a large number of double bonds. This feature causes the omega-3 fatty acids to be highly susceptible to oxidation, thus their incorporation into foods is limited by the development of unpleasant off-flavours. Strategies for limiting oxidation which implies increasing the shelf-life of potential products are necessary for commercial production. One such strategy is to add the oil as an emulsion rather than as neat oil. Studies so far have indicated that emulsification of the fish oil changes the oxidative stability of the product but whether emulsification is an advantage seems to be dependent on the food matrix to which the emulsion is added [1, 2]. It is therefore of interest to look at the emulsions to assess what determines the oxidation. It has been proposed that oxidation is to some extent dependent on the structure of the emulsion; including oil droplet sizes, size distribution and the thickness of the interface between oil and water. This interface can be stabilized by food grade emulsifiers such as proteins and phospholipids from milk. The main objective of this study is to characterize fish oil in water emulsions with respect to oil droplet size, size distribution, and ultimately to view the thickness, structure and morphology of the interface layers. The emulsion fractures are random and impossible to control when using freeze-fracture cryo-SEM. We have previously shown that some types of emulsifiers tend to break along the interface layer, while others cause the fractures to be perpendicular to the interface layer [3]. To control the field of view more specifically and to ensure the access to the desired part of the sample, we propose now the use of cryo-FIB SEM. This method allows us to access the interface layers as needed, see figure 1. Emulsions with high oil content, i.e. 70%, and relatively large oil droplets, i.e. μm range, have been frozen in slush nitrogen, fractured and ice has been sublimated from the surface in a Quorum Polar Prep 2000 Cryo Transfer System. Platinum has been sputtered onto the sample prior to sectioning. The sample is imaged in a Quanta 3D FEG (FEI) with a with ETD, 15 kV and WD 10 mm. Figure 1 shows a sectioned oil droplet from an emulsion, which is emulsified with phospholipids from milk. On the micrograph it can be observed a contrast on the surface of the oil droplet that faces the interior below the original fracture plane, which has not been covered in platinum. The contrast is seen as a lighter line on the bottom side and the sliced oil droplet, visualised in figure 2. This could possibly be attributed to the phosphorous in the emulsifier.
Cryo-FIB SEM for Characterization of the Structure of Fish Oil Emulsions

Addition of fish oil to food products to improve nutritional quality by the addition of omega-3 fatty acids is attractive both to the consumers and the food industry for reasons such as health benefits and added product value. The long chain omega-3 fatty acids contain a large number of double bonds which causes the fish oil to be susceptible to oxidation. The shelf lives of fish oil enriched products are thus limited by fast oxidation rates of the fish oil which causes development of off flavours as well as degeneration of the beneficial health effects of the fish oil. At the present moment this is a barrier for their access to the market and it is necessary to develop techniques to protect the oil against oxidation. Emulsification of the oil has been put forward as a strategy for protection against oxidation, but whether that is beneficial seems to depend on the food matrix to which the oil is added [1,2]; see figure 1. It is thus interesting to investigate the pure emulsions to gain knowledge about the oxidation without the effects of an external food matrix. It has been seen that some factors that influence the oxidation in pure emulsions are the type of emulsifier, the oil droplet size and the pH [3]. This dependence has led to the belief that the oxidation is initiated at the interface between oil and water and that the thickness or composition of the interface can be controlled to ensure optimum stability of the emulsions.

Deodorization optimization of Camelina sativa oil: Oxidative and sensory studies

Camelina sativa oil (CO) is characterized by a high content (up to 40 wt %) of essential α-linolenic acid and characteristic odour and flavour. Deodorization of highly unsaturated oils requires great attention as the refining process involves thermal treatment which affects oil integrity. In the present study RSM and principal component analysis (PCA) were used to optimize bench-scale deodorization of CO. Mathematical models were generated through multiple regressions with backward elimination, describing the effects of process parameters (temperature, steam flow, time) on oil quality indicators [peroxide value (PV), p-anisidine value (p-AV), γ-tocopherol (γ-T) and oxidative stability (OS)]. Additionally, sensory evaluation was performed. RSM analysis showed a significant effect of deodorization temperature and to a lesser extent, deodorization steam flow and time on removal of oxidative compounds, flavour and odour. PCA of chemical and sensory results showed that deodorization temperature affected the sensory properties in the samples. The best conditions for removing undesirable flavour and odour were achieved by using a deodorization temperature of 195–210°C.
Emulsification technique affects oxidative stability of fish oil-in-water emulsion

In oil-in-water emulsions, lipid oxidation is expected to be initiated at the oil-water interface. The properties of the emulsifier used, and the structure at the interface is therefore expected to be of great importance for lipid oxidation in emulsions. Previous studies have shown that e.g. homogenization pressure can affect how proteins locate themselves at the interface of an emulsion. The hypothesis is therefore that emulsions produced with different emulsification equipments differ in their oxidative stability due to differences in the behaviour of the proteins at the interface. The aim of this study was therefore to compare lipid oxidation in 10% fish oil-in-water emulsions prepared by two different kinds of high pressure homogenizers i.e. a microfluidizer and a two valve high pressure homogenizer. Emulsions were made with equal droplet sizes, and with either 1% sodium caseinate or 1% whey protein isolate. Emulsions were characterised and investigated by microscopy. Lipid oxidation was assessed by PV and the formation of secondary volatile oxidation products. Results showed that the different emulsification techniques had an influence on lipid oxidation and that the effect of the emulsification technique depended on the type of protein used as an emulsifier.

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Lipid oxidation in omega-3 emulsions prepared with milk proteins

An increasing body of evidence supports the health beneficial effects of omega-3 polyunsaturated fatty acids. Therefore, incorporation of marine oils into foods has also gained an increasing interest. However, the highly unsaturated lipids present in marine oils are prone to lipid oxidation, and their addition to foods is therefore limited by the development of unpleasant off-flavors. Hence, efficient strategies are necessary to protect the lipids and thereby make fish oil-enriched food products successful in the marketplace. In an attempt to increase the oxidative stability of fish oil-enriched food products several studies have been carried out where fish oil has been introduced to different foods through delivery emulsions instead of as neat oil. However, contradicting results have been obtained between individual foods on whether the neat oil or the delivery emulsion gave the most oxidatively stable product. Thus, a better understanding of factors influencing lipid oxidation in delivery emulsions themselves is therefore needed to understand the differences observed between food systems. In oil-in-water emulsions, lipid oxidation is expected to be initiated at the oil-water interface. The properties of the emulsifier used and the structure at the interface are therefore expected to be of great importance for oxidation in emulsions. This presentation will include results from mainly three different studies of lipid oxidation in omega-3 emulsions prepared with milk proteins and protein components. In these three studies different parameters that are expected to change the properties and structure of the proteins at the interface were investigated. The first study compares 70% emulsions with either sodium caseinate or whey protein isolate at two pH values with and without iron addition. The second study evaluates the effect of two different high pressure homogenizers on oxidation in 10% emulsions with the same emulsifiers as in the first study. Finally, the third study considers the effect of changing pH on oxidation in emulsions prepared with different whey protein components. Results on lipid oxidation as affected by the different parameters will be discussed and related to the differences between the proteins and their structure at the interfacial layer. Results will be complimented by micrographs of the emulsions.

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Oxidative stability of 70% fish oil-in-water emulsions: Impact of emulsifiers and pH

The objective of this study was to evaluate the protective effects of five different emulsifiers on lipid oxidation in 70% fish oil-in-water emulsions to be used as delivery systems for long chain polyunsaturated omega-3 fatty acids to foods. The emulsifiers were either phospholipid (PL) based or protein based. The PL-based emulsifiers were soy lecithin and two milk PL concentrates (with either 20 or 75% PL). The protein-based emulsifiers were whey protein isolate and sodium caseinate. Lipid oxidation was studied at two pH values (pH 4.5 and 7.0) and results were compared to lipid oxidation in neat fish oil. Lipid oxidation was followed by determination of peroxide values and volatile oxidation products. Emulsions were furthermore imaged by confocal and cryo-scanning electron microscopy. Results showed that emulsions prepared at high pH with proteins oxidized less than or equally to neat oil, whereas, all other emulsions oxidized more. In addition, there was a tendency toward a faster progression in lipid oxidation at low pH compared to high pH for emulsions prepared with protein-based emulsifiers. The opposite was observed for emulsions prepared with PL-based emulsifiers. Hence, at low pH PL-based emulsions may be more suitable as delivery systems than protein-based emulsions. Moreover, the quality of the PL-based emulsifiers seemed to affect lipid oxidation. Practical applications: Results from the present study give an insight into the physical and oxidative stability of 70% fish oil-in-water emulsions prepared with whey protein isolate, sodium caseinate, milk phospholipids, or soy lecithin. The emulsions can be used as delivery systems for fish oil to foods. However, only emulsions prepared with proteins at high pH offered advantages with respect to better oxidative stability during storage compared to neat fish oil. Thus, when fish oil is added to a food product in a delivery emulsion, the type of emulsion used should be carefully considered.
Oxidative stability of marine phospholipids

Many studies have shown that marine phospholipids (MPL) provide more advantages than fish oil. They have better bioavailability, better resistance towards oxidation and higher content of eicosapentaenoic acids (EPA) and docosahexaenoic acids (DHA) than oily triglycerides (fish oil). The objective of this study is to investigate the oxidative and hydrolytic stability of MPL. In addition, this study also investigates the effect of chemical composition of MPL and Maillard reaction (interaction between lipids oxidation products with the residue of amino acids) on MPL emulsions’ stability. Firstly, MPL were prepared in the form of emulsions by high pressure homogenizer. Then, the oxidative and hydrolytic stability of phospholipids was investigated by measurement of simple chemical analyses such as Peroxide Value and Free Fatty Acids, and 31PNMR after 32 days storage at 2°C. The oxidative stability of MPL was further investigated through measurement of secondary volatile compounds by Solid Phase Microextraction at several time intervals. On the other hand, the Maillard reaction was investigated through the measurement of color changes and pyrrole content before and after 32 days storage. Preliminary result suggested that MPL emulsions have good hydrolytic stability and relatively good oxidative stability as compared to fish oil containing emulsions. As a conclusion, MPL with different chemical compositions have affected emulsions' stability differently.
Oxidative Stability of Marine Phospholipids in the Liposomal Form and Their Applications

Marine phospholipids (MPL) have attracted a great deal of attention recently as they are considered to have a better bioavailability, a better resistance towards oxidation and a higher content of eicosapentaenoic (EPA) and docosahexaenoic acids (DHA) than oily triglycerides (fish oil) from the same source. Due to their tight intermolecular packing conformation at the sn-2 position and their synergism with α-tocopherol present in MPL extracts, they can form stable liposomes which are attractive ingredients for food or feed applications. However, MPL are still susceptible to oxidation as they contain large amounts polyunsaturated fatty acids and application of MPL in food and aquaculture industries is therefore a great challenge for researchers. Hence, knowledge on the oxidative stability of MPL and the behavior of MPL in food and feed systems is an important issue. For this reason, this review was undertaken to provide the industry and academia with an overview of (1) the stability of MPL in different forms and their potential as liposomal material, and (2) the current applications and future prospects of MPL in both food and aquaculture industries with special emphasis on MPL in the liposomal form.
Phenolics and Lipophilized Phenolics as Antioxidants in Fish Oil Enriched Emulsions,

Emulsions containing omega-3 LC PUFA are highly susceptible to oxidation. This causes formation of undesirable flavors and loss of health beneficial fatty acids. Many omega-3 enriched food products on the market are oil-in-water emulsions. According to the so called “polar paradox”, polar compounds work better as antioxidants in bulk oil, whereas lipophilic compounds are better antioxidants in emulsions. This presentation is an overview of our previous work in the area of fish oil enriched emulsions with antioxidants. Our studies have shown that the lipophilicity of the compounds is not the only factor determining their efficacy as antioxidants in simple model systems. Interactions between the antioxidants, emulsifier and pH also influence the antioxidant behavior. Moreover, studies with lipophilized phenolics in a food emulsion showed that there is no linear increase of antioxidant activity with increased lipophilicity. Instead a cut-off effect was observed in relation to the alkyl chain length lipophilized to the phenolic compound. Furthermore, the efficacy of lipophilic antioxidants is influenced by the type of food system. Thus, our results show that the antioxidant behavior may not be as simple as stated by the “polar paradox” hypothesis. According to our research results in this area, this hypothesis deserves reconsideration.

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Storage stability of marine phospholipids emulsions
Marine phospholipids (MPL) are believed to provide more advantages than fish oil from the same source. They are considered to have a better bioavailability, a better resistance towards oxidation and a higher content of polyunsaturated fatty acids such as eicosapentaenoic (EPA) and docosahexaenoic acids (DHA) than oily triglycerides (fish oil). Therefore,
the objective of this study is to explore the feasibility of using marine phospholipids emulsions as delivery system through investigation of the physical, oxidative and hydrolytic stability of MPL emulsions with or without addition of fish oil. The effect of initial Peroxide Value, total lipids, phospholipids and antioxidants content on stability of MPL emulsions were studied. The physical stability was investigated through measurement of particle size distribution and creaming stability, which involve measurement of changes (%) in emulsion volume. In addition, preliminary investigation of the oxidative and hydrolytic stability was carried out through determination of Peroxide Value and Free Fatty Acids Value after 32 days storage at room temperature and 2°C, respectively. Oxidative stability of MPL emulsions were also investigated through measurement of secondary volatile compounds by Solid Phase Microextraction at several time intervals at 2°C storage. Preliminary results showed that marine phospholipids emulsion has a good oxidative stability.

The efficacy of compounds with different polarities as antioxidant in emulsions with omega-3 lipids
According to the so-called polar paradox hypothesis, the efficacy of an antioxidant in emulsions is highly affected by its polarity and thereby location in the different phases. However, other factors also affect the efficacy of antioxidants in multiphase systems. The aim of this study was to evaluate the efficacy of antioxidants [ascorbic acid, ascorbyl palmitate, ascorbyl CLA and CLA (conjugated linoleic acid)] with different polarities in two different emulsion systems: o/w emulsion (5% oil) and w/o emulsion (98% oil) stabilized with citrem and PGPR, respectively. The efficacy of the antioxidants was compared to their partitioning in an o/w emulsion system and to results obtained from different antioxidant assays: iron reducing power, chelating activity and radical scavenging activity. For the w/o emulsions the efficacy of the antioxidants followed the polar paradox hypothesis: ascorbyl palmitate = ascorbyl CLA > ascorbic acid ≥ CLA > reference. For the o/w emulsion the antioxidative effects were not in accordance with the polar paradox. In the beginning of the storage, ascorbyl palmitate and ascorbic acid were most efficient, however in the end they acted as prooxidants. Ascorbyl CLA was located at the interface but was inactive as an antioxidant. This may be due to impurities or interaction with citrem.
Antioxidant Activity of Potato Peel Extracts in a Fish-Rapeseed Oil Mixture and in Oil-in-Water Emulsions

The objectives of the present work were (a) to extract the phenolic fraction from the peels of two Danish varieties of potatoes, viz. Sava and Bintje, and examine their antioxidant capacity in in-vitro systems (b) to evaluate the effect of these extracts on the storage stability of a fish-rapeseed oil mixture and oil-in-water emulsions. Multiple antioxidant activity of the potato peel extracts was evident from in-vitro systems as they showed strong reducing power, radical scavenging ability, ferrous ion chelating activity and prevented oxidation in a liposome model system. The Sava variety, which showed strong antioxidant activity in in-vitro systems, was tested in oil and oil-in-water emulsions. Ethanolic extracts of Sava (C1,600 mg/kg) prevented lipid oxidation in emulsions and in oil. Water extracts showed no antioxidant activity in oil whereas it showed pro-oxidant activity in emulsions. Thus, the results of the present study show the possibility of utilizing waste potato peel as a promising source of natural antioxidants for retarding lipid oxidation.
The aim of the present study was to elucidate previous findings showing that peptide fractions isolated from yoghurt had antioxidant effects. Therefore, peptides and free amino acids released during fermentation of milk were characterised. Yoghurt samples were stripped from sugars and lactic acid and subsequently fractionated by ultra filtration using membranes with cut off sizes of 30, 10 and 3 kDa. The peptides in these fractions were identified by LC–MS/MS. The identified peptides comprised a few Nterminal fragments of αs1-, αs2-, and β-casein, and several fragments from β-casein. Almost all the peptides identified contained at least one proline residue. Some of the identified peptides included the hydrophobic amino acid residues Val or Leu at the N-terminus and Pro, His or Tyr in the amino acid sequence, which is characteristic of antioxidant peptides. In addition, the yoghurt contained a considerable amount of free amino acids such as His, Tyr, Thr and Lys, which have been reported to have antioxidant properties. Thus, our findings confirm that the antioxidant effects of the peptide fractions from yoghurt are due to the presence of certain peptides and free amino acids with recognised antioxidant activity in these fractions.
Antioxidant properties of modified rutin esters by DPPH, reducing power, iron chelation and human low density lipoprotein assays

Practical limitations exist regarding the effectiveness of flavonoids as antioxidants in many food systems, possibly due to their poor solubility and miscibility in lipidic environments. Current strategies to improve these properties include enzymatically acylating flavonoids with lipophilic moieties. Herein, two derivatives of rutin (possessing C12:0 or C16:0 acyl groups) were assessed for their antioxidant properties, and compared with their parent compound, rutin and with butylated hydroxytoluene (BHT). While all compounds exhibited relatively strong radical scavenging abilities, modified rutin compounds exhibited decreased reducing power and metal chelating abilities as compared to rutin. Conversely, investigations on the oxidation of human low density lipoprotein (LDL) revealed that rutin laurate was most effective in inhibiting oxidation by prolonging LDL lag time for an in vitro system. With regards to in vivo considerations, a pre-treatment step confirmed that the ester bond linking rutin and acyl moieties was most susceptible to hydrolysis by digestive enzymes, while rutin itself was not degraded. Thus, acylation of rutin with medium or long chain fatty acids may result in improved antioxidant abilities in more complex systems, including LDL-oxidation assays. Likely reasons may include improved lipophilic solubility and partitioning properties allowing for better accessibility to the actual site of oxidation. (C) 2010 Elsevier Ltd. All rights reserved.
Characterization of Emulsions of Fish Oil and Water by Cryo Scanning Electron Microscopy
Addition of fish oil to industrially prepared food products is attractive to the food industry because of the well-documented health effects of the omega 3 fatty acids in the fish oil [1]. Polysaturated Fatty Acids including omega 3 fatty acids are highly susceptible to lipid oxidation due to the many double bonds. Emulsions of fish oil in water are potential candidates for a delivery system of fish oil to food products. It has been suggested that oxidation of oil-in-water emulsions is initiated at the interface between oil and water. It has also been proposed that oxidation is to some extent dependent on the ultrastructure of the emulsion; including the size of oil droplets, their distribution and the thickness of the interface between oil and water. This interface is stabilized by macromolecules such as proteins, phospholipids and hydrocolloids. The main objective of this study is to characterize fish oil in water emulsions with respect to oil droplet size, distribution, and ultimately to view the structure and thickness of the interface layer.

A freeze-fractured surface viewed at low temperatures under the scanning electron microscope is a promising strategy to reveal variations in the microstructures of the emulsions. Freeze-fractured emulsions tend to break along the oil and water interface which provides direct access to the surface of the interface layer. The interface layer can be either viewed directly or water can be sublimated from the surface to reveal more of the oil droplets. A second option is to view droplets that are broken across the interface. This will display the actual interface layer, which can be seen after etching for a short period of time.

We have found this method to show promising results for characterization of emulsions with oil droplet sizes ranging from 100 nm - 20 µm, various distribution of droplets and diverse amounts and types of emulsifiers. Here we present results for emulsions with different amounts of fish oil and different protein or milk phospholipid based emulsifiers.

We aim to refine the technique further in order to enable us to derive a correlation between the oil/water interface thickness and microstructure and the stability against oxidation of the fish oil.

General information
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Organisations: Center for Electron Nanoscopy, National Food Institute, Division of Industrial Food Research, Department of Mechanical Engineering, Materials and Surface Engineering
Authors: Jensen, L. H. S. (Intern), Horn, A. F. (Intern), Jacobsen, C. (Intern), Nielsen, N. S. (Intern), Horsewell, A. (Intern)
Number of pages: 2
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Main Research Area: Technical/natural sciences
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Poster presentation.
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Effect of emulsifiers and physical structure on lipid oxidation in omega-3 emulsions
The body of evidence supporting health beneficial effects of long-chain omega-3 polyunsaturated fatty acids has increased over the last decades. Consequently, the interest in fish oil-enriched foods has also increased. However, addition of these
lipophilized compounds. Our study aimed at evaluating rutin and dihydrocaffeic acid and their esters as antioxidants in o/w emulsion systems. Our hypothesis is that lipophilization of such polar phenolic compounds may improve their efficacy in fish oil enriched food systems. This phenomenon has been explained by the affinity of the compounds towards the different phases in bulk oil and emulsions. The hydrophilic character of many naturally occurring antioxidants may cause a low efficacy in inhibiting lipid oxidation in food emulsions. However, lipophilization of the antioxidants with a fatty alcohol may alter their location in the emulsion matrix and thereby improve their efficacy. Evaluation of the effect of lipophilisation of selected antioxidants revealed that generally, lipophilized dihydrocaffeic acid and rutin increased the oxidative stability of o/w emulsions and fish oil enriched milk compared with their parent compound. The results supported a cut-off effect in relation to the acyl chain length esterified to the phenolic compound. Octyl dihydrocaffeate (C8 acyl chain) was a stronger antioxidant than oleyl dihydrocaffeate (C18 acyl chain) and rutin laurate (C12 acyl chain) was a stronger antioxidant than rutin palmitate (C16 acyl chain). Interestingly, it seemed that the cut-off effect not only is specific for the individual lipophilized phenolic compounds, but that it also depends on the emulsion system, i.e. the optimal chain length seems to vary between different emulsion systems.

**Effect of lipophilization of dihydrocaffeic acid on its antioxidative properties in fish oil enriched emulsion**

The relative low intake of fish and the health beneficial n-3 polyunsaturated fatty acids (PUFA) in the Western countries has created a growing market for food products enriched with eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Since EPA and DHA are more susceptible to lipid oxidation than PUFAs from vegetable oils due to their highly polyunsaturated nature, it is necessary to develop methods to protect these PUFAs. Many food systems are emulsions. Due to the so-called polar paradox phenomenon, hydrophilic antioxidants may in many cases be better antioxidants in bulk oil than lipophilic compounds, whereas lipophilic antioxidants are more efficient than hydrophilic antioxidants in emulsions. This phenomenon has been explained by the affinity of the compounds towards the different phases in bulk oil and emulsions. The hydrophilic character of many naturally occurring antioxidants may cause a low efficacy in inhibiting lipid oxidation in food emulsions. However, lipophilization of the antioxidants with a fatty alcohol may alter their location in the emulsion matrix and thereby improve their efficacy. Evaluation of the effect of lipophilisation of selected antioxidants revealed that generally, lipophilized dihydrocaffeic acid and rutin increased the oxidative stability of o/w emulsions and fish oil enriched milk compared with their parent compound. The results supported a cut-off effect in relation to the acyl chain length esterified to the phenolic compound. Octyl dihydrocaffeate (C8 acyl chain) was a stronger antioxidant than oleyl dihydrocaffeate (C18 acyl chain) and rutin laurate (C12 acyl chain) was a stronger antioxidant than rutin palmitate (C16 acyl chain). Interestingly, it seemed that the cut-off effect not only is specific for the individual lipophilized phenolic compounds, but that it also depends on the emulsion system, i.e. the optimal chain length seems to vary between different emulsion systems.

**Lipophilized phenolics as antioxidants in fish oil enriched food systems**

Food products containing long chain omega-3 PUFA are highly susceptible to oxidation, which causes undesirable flavors and loss of health beneficial fatty acids. Many omega-3 enriched food products on the market are oil-in-water emulsions. According to the so-called ‘polar paradox’, polar compounds work better as antioxidants in bulk oil, whereas lipophilic compounds are better antioxidants in emulsions. Phenolics have in general shown to possess antioxidative properties, which depend upon their structure i.e. number and location of –OH groups. However, many of these compounds are polar. Our hypothesis is that lipophilization of such polar phenolic compounds may improve their efficacy in fish oil enriched food systems. Our study aimed at evaluating rutin and dihydrocaffeic acid and their esters as antioxidants in o/w emulsion model system and milk enriched with fish oil. Moreover, the effect of the chain length of the fatty acid was investigated. The effect of the compounds was evaluated by determination of primary and secondary oxidation products. Further, these findings were combined with antioxidant assay and partitioning studies. Preliminary data showed that the lipophilization improve the antioxidative effect depending on the system, and that the chain length influenced the efficacy of the lipophilized compounds.
Oxidative stability of fish oil-enriched mayonnaise-based salads
The oxidative stability of fish oil-enriched mayonnaise-based salads and the influence of different vegetables in shrimp and tuna salads were evaluated. Moreover, the lipid oxidation in the presence of 1% oregano, rosemary, or thyme in fish oil-enriched tuna salad was assessed. The results obtained showed that the mayonnaise itself was more oxidatively stable without vegetables and tuna or shrimp, in spite of the higher oil content in mayonnaise (63 and 6.3% fish oil, respectively) compared to salads (~24 and 2.4% fish oil, respectively). Surprisingly, the fish oil-enriched mayonnaise was only significantly different from the standard mayonnaise in the volatile concentration during the end of storage. In fish oil-enriched shrimp salad, asparagus had an anti-oxidative effect and shrimp a pro-oxidative effect, where the anti-oxidative effect of asparagus was strong enough to prevent the pro-oxidative effect of shrimp. The effect of ingredients in tuna salads was inconclusive, possibly due to a high content of volatiles in the vegetables themselves. However, the addition of spices increased the oxidative stability of tuna salad (oregano>rosemary>thyme).
The influence of emulsifier type on lipid oxidation in fish-oil-enriched light mayonnaise

The oxidative stability of fish oil-enriched light mayonnaise (40% oil) and the influence of two different emulsifiers, egg yolk and milk protein-based emulsifier, were evaluated. Moreover, the effects of different fish oil concentrations (4, 10 and 14%) and storage temperatures (2 and 20 degrees C) were investigated. As expected, the results showed that lipid oxidation increased with storage temperature, and at 20 degrees C with increasing fish oil concentrations. On the basis of the findings in this study, a storage temperature of 20 degrees C for 4 months cannot be recommended for light mayonnaise due to significant lipid oxidation even in mayonnaises without fish oil. However, enrichment of light mayonnaises with 4% fish oil without adding antioxidant did not result in increased oxidation when stored at 2 degrees C, and thus seems feasible; however, this has to be confirmed by sensory analysis. Surprisingly, our hypothesis that substitution of egg yolk with a less iron-containing emulsifier (milk protein-based emulsifier) could increase the oxidative stability of fish oil-enriched mayonnaises was not confirmed. These findings suggest that the initial quality of the emulsifiers was more important than its iron content in terms of lipid oxidation.

General information
State: Published
Organisations: Division of Seafood Research, National Food Institute
Authors: Sørensen, A. M. (Intern), Nielsen, N. S. (Intern), Hyldig, G. (Intern), Jacobsen, C. (Intern)
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Ratings:
Additions of caffeic acid, ascorbyl palmitate or gamma-tocopherol to fish oil-enriched energy bars affect lipid oxidation differently

The objectives of the study were to investigate the effects of caffeic acid, ascorbyl palmitate and gamma-tocopherol on protection of fish oil-enriched energy bars against lipid oxidation during storage for 10 weeks at room temperature. The lipophilic gamma-tocopherol reduced lipid oxidation during storage when added at a concentration above 440 μg/g fish oil. However, the best antioxidative effect was observed when it was added at a concentration of 660 μg/g fish oil. In contrast, prooxidative effects were observed when using either gamma-tocopherol at concentrations below 220 μg/g fish oil, or the hydrophilic caffeic acid, or the amphiphilic ascorbyl palmitate at concentrations of 75, 150 and 300 μg/g fish oil. Prooxidative effects were observed as an increase in the formation of lipid hydroperoxides and volatile secondary oxidation products, as well as the development of rancid off-flavours. The differences in the efficacies of the three antioxidants examined are expected to be related to their different localisations and mechanisms of action. (C) 2008 Elsevier Ltd. All rights reserved.

General information
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Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Horn, A. F. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
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Main Research Area: Technical/natural sciences

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Web of Science (2017): Indexed yes
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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.597 SNIP 1.962 CiteScore 4.31
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.595 SNIP 2.027 CiteScore 3.92
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.548 SNIP 2.069 CiteScore 3.87
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.805 SNIP 2.357 CiteScore 3.98
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.909 SNIP 2.395 CiteScore 4.17
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.965 SNIP 2.261
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.776 SNIP 2.024
Antioxidant properties of modified rutin esters following lipase-catalyzed esterification

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, National Food Institute
Authors: Lue, B. (Intern), Jacobsen, C. (Intern), Nielsen, N. S. (Intern), Guo, Z. (Intern), Xu, X. (Intern)
Publication date: 2009
Main Research Area: Technical/natural sciences
Source: orbit
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Publication: Research › Journal article – Annual report year: 2009

Antioxidant strategies to prevent lipid oxidation in omega-3 enriched food emulsions

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Jacobsen, C. (Intern), Nielsen, N. S. (Intern), Sørensen, A. M. (Intern), Timm Heinrich, M. (Intern), Bruni Let, M. (Intern)
Publication date: 2009
Event: Abstract from 3rd Joint Trans-Atlantic Fisheries Technology Conference, Copenhagen, Denmark.
Main Research Area: Technical/natural sciences
Source: orbit
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Publication: Research › Conference abstract for conference – Annual report year: 2009

Effect of emulsifier type, iron and pH on the oxidative stability of 5% fish oil-in-water emulsions

General information
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Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Effect of fish oil concentration and emulsifier on lipid oxidation in fish oil enriched mayonnaise

General information
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Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Sørensen, A. M. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
Publication date: 2009
Event: Abstract from 100th Annual AOCS meeting, Orlando, Florida, May 2009, Orlando, FL. USA.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 253230
Publication: Research › Conference abstract for conference – Annual report year: 2009

The oxidative stabilities of fish oil-enriched milk and fish oil-enriched drinking yoghurt were compared by following the development of lipid oxidation in plain milk, plain yoghurt and yoghurt to which ingredients present in drinking yoghurt were added one by one. All samples were enriched with 1 wt-% fish oil. After 3 weeks of storage, development of peroxide values, volatile secondary oxidation products and fishy offflavors were much more pronounced in the milk compared to any of the yoghurt samples, irrespective of any added ingredients used to prepare flavored drinking yoghurt. Thus, pectin, citric acid or glucconodelta- lactone did not affect the oxidative stability of fish oil-enriched yoghurt emulsions. Furthermore, the fruit preparation and added sugar did not lead to increased antioxidative activity. It is concluded that yoghurt as the dairy component in the fish oil-enriched emulsion was responsible for the remarkably high oxidative stability and was able to protect the n-3 PUFA against oxidative deterioration. It should be considered that this strong antioxidative effect of yoghurt might mask potential antioxidative effects of the other ingredients in the drinking yoghurt.

Effect of ingredients on oxidative stability of fish oil-enriched drinking yoghurt

The oxidative stabilities of fish oil-enriched milk and fish oil-enriched drinking yoghurt were compared by following the development of lipid oxidation in plain milk, plain yoghurt and yoghurt to which ingredients present in drinking yoghurt were added one by one. All samples were enriched with 1 wt-% fish oil. After 3 weeks of storage, development of peroxide values, volatile secondary oxidation products and fishy offflavors were much more pronounced in the milk compared to any of the yoghurt samples, irrespective of any added ingredients used to prepare flavored drinking yoghurt. Thus, pectin, citric acid or glucconodelta- lactone did not affect the oxidative stability of fish oil-enriched yoghurt emulsions. Furthermore, the fruit preparation and added sugar did not lead to increased antioxidative activity. It is concluded that yoghurt as the dairy component in the fish oil-enriched emulsion was responsible for the remarkably high oxidative stability and was able to protect the n-3 PUFA against oxidative deterioration. It should be considered that this strong antioxidative effect of yoghurt might mask potential antioxidative effects of the other ingredients in the drinking yoghurt.

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Division of Seafood Research
Authors: Nielsen, N. S. (Intern), Klein, A. (Ekstern), Jacobsen, C. (Intern)
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Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.06 SJR 0.71 SNIP 1.024
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.642 SNIP 0.881 CiteScore 1.85
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.737 SNIP 1.051 CiteScore 1.98
BFI (2013): BFI-level 1
Foods enriched with fish oil: Stability – nutrition – consumer acceptance

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Center for Biological Sequence Analysis, Department of Systems Biology
Publication date: 2009
Event: Abstract from Presentation at 25th LipidForum Symposium, Elsinore, Denmark.
Main Research Area: Technical/natural sciences
Lipid oxidation in fish oil enriched energy bars is affected by means of oil addition and addition of antioxidants

Methods for reducing lipid oxidation in fish-oil-enriched energy bars

Fish oil (FO) enrichment of foods is relevant owing to the beneficial effects of omega-3 polyunsaturated fatty acids on human health. However, the susceptibility of FO to oxidation necessitates careful control to avoid this oxidation. In this study, energy bars were successfully supplemented with 5% FO. Heating of bars during baking did, apparently, not increase oxidation. Energy bars produced with neat FO were oxidatively unstable as measured by peroxide value, secondary volatile oxidation products and sensory analysis. Pre-emulsification of the FO with sodium caseinate in water offered similar protection towards oxidation as packaging the energy bars in modified atmosphere. These protection methods were although not as efficient as addition of FO as micro-encapsulated powder. Addition of the metal chelator ethylene diamine tetra-acetic acid (EDTA) (100-2000 ppm) to emulsified FO decreased the oxidative stability of the energy bars compared with the energy bars with emulsified FO but without EDTA.
Potato peel extract - A natural antioxidant for retarding lipid oxidation in bulk fish oil and oil in water emulsions

**General information**

State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Farvin, S. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
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Event: Abstract from 25th lipid symposium, 15-17 June, Elsinore, Denmark.
Main Research Area: Technical/natural sciences

Preventing lipid oxidation in foods enriched with fish oil

**General information**

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Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Nielsen, N. S. (Intern), Horn, A. F. (Intern), Jacobsen, C. (Intern)
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Main Research Area: Technical/natural sciences

Processing of marine lipids and factors affecting their quality when used for functional foods

**General information**

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Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Jacobsen, C. (Intern), Rustad, T. (Ekstern), Nielsen, N. S. (Intern), Falch, E. (Ekstern), Jansson, S. (Ekstern), Storr, I. (Ekstern)
Number of pages: 176
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Title of host publication: Marine functional food
The efficacy of compounds with different polarities as antioxidant in fish oil enriched emulsions

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Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Sørensen, A. M. (Intern), Nielsen, N. S. (Intern), Decker, E. (Ekstern), Jacobsen, C. (Intern)
Publication date: 2009
Main Research Area: Technical/natural sciences
Source: orbit
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The protective effect of emulsifiers on 70% oil-in-water emulsions, to be used as delivery system of omega-3s to food

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Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Horn, A. F. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
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Publication: Research › Poster – Annual report year: 2009

Antioxidant activity of potato peel extracts in bulk fish oil and oil in water emulsions

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Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Farvin, S. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
Publication date: 2008
Event: Abstract from 38th Annual WEFTA meeting-Seafood from catch and aquaculture for a sustainable supply, 16-19 September, Florence, Italy.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 253109
Publication: Research › Conference abstract for conference – Annual report year: 2008

Antioxidant strategies for preventing oxidative flavour deterioration of foods enriched with n-3 polyunsaturated lipids: a comparative evaluation

The aim of this review is to provide a better base for predicting the ability of antioxidants to prevent lipid oxidation in food emulsions in general and in functional food systems enriched with n-3 PUFA in particular. Therefore, the antioxidant efficacies of a range of commercially available antioxidants in a number of fish oil enriched real food emulsions (milk, milk drink, salad dressing, mayonnaise and selected model emulsions) are compared. This comparison clearly shows that the same antioxidant exerts different effects in different systems. EDTA is a very efficient antioxidant in salad dressing and mayonnaise, but not in milk; while ascorbyl palmitate efficiently reduces oxidation in milk. Furthermore, the comparative data evaluation confirms that the same antioxidant in some cases may exert opposite effects on peroxide levels and on formation of individual volatiles and fishy odour and flavours. Therefore, antioxidant effects should always be evaluated by more than one method.

General information
Application of structured lipids in food

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Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Jacobsen, C. (Intern), Timm Heinrich, M. (Intern), Nielsen, N. S. (Intern)
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Main Research Area: Technical/natural sciences

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Applications of natural antioxidants in omega-3-enriched foods

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Authors: Jacobsen, C. (Intern), Bruni Let, M. (Intern), Sørensen, A. M. (Intern), Horn, A. F. (Intern), Timm Heinrich, M. (Intern), Nielsen, N. S. (Intern)
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Scopus rating (2013): SJR 0.172 SNIP 0.523
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Scopus rating (2012): SJR 0.244 SNIP 0.484
ISI indexed (2012): ISI indexed no
Scopus rating (2011): SJR 0.25 SNIP 0.438
ISI indexed (2011): ISI indexed no
Scopus rating (2010): SJR 0.224 SNIP 0.521
Scopus rating (2009): SJR 0.184 SNIP 0.362
Scopus rating (2008): SJR 0.112 SNIP 0.089
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Impact of emulsifiers on the oxidative stability of 70% fish oil-in-water emulsions

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Authors: Horn, A. F. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
Publication date: 2008
Event: Poster session presented at Phospholipids seminar: Nutrition, application and technology, October 23-24, Copenhagen.
Main Research Area: Technical/natural sciences
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Publication: Research › Poster – Annual report year: 2008

Investigation of dairy components responsible for resistance of omega-3 enriched yoghurt to lipid oxidation

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Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Farvin, S. (Intern), Baron, C. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
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Main Research Area: Technical/natural sciences
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Abstract and oral presentation at 6th EuroFedLipid Congress, Athens, Greece, Sept 2008
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Source-ID: 238844
Publication: Research › Poster – Annual report year: 2008

Investigation of dairy components responsible for resistance of omega-3 enriched yoghurt to lipid oxidation

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Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Farvin, S. (Intern), Baron, C. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
Publication date: 2008
Main Research Area: Technical/natural sciences
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Publication: Research › Conference abstract for conference – Annual report year: 2008

Oxidative stability of mayonnaise based salads enriched with fish oil

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Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Sørensen, A. M. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
Publication date: 2008
Event: Poster session presented at 99th AOCS Annual Meeting & Expo, Seattle, WA, United States.
Main Research Area: Technical/natural sciences
Bibliographical note
Abstract and oral presentation at the 99th Annual AOCS meeting Seattle, USA May 2008
Source: orbit
Source-ID: 238842
Publication: Research › Poster – Annual report year: 2008
Application of antioxidants during short-path distillation of structured lipids

A specific structured lipid was produced from sunflower oil and caprylic acid. The antioxidative effect of adding alpha-tocopherol, ascorbyl palmitate or citric acid (each in three different concentrations) was investigated before and after the purification process (short-path distillation), and was compared with a control without addition of antioxidant. The oxidative status and stability were characterized by peroxide and anisidine values, secondary volatile oxidation products and induction period. The antioxidants affected the oxidative status compared with the control: citric acid was prooxidative at low concentrations, but antioxidative at high concentrations. Addition of ascorbyl palmitate had an antioxidative effect at all concentrations employed. alpha-Tocopherol showed less antioxidative activity compared with ascorbyl palmitate and citric acid, and its efficacy was slightly decreased with increasing concentration. Combinations of citric acid with ascorbyl palmitate were tested in a later part of the study. No additive or synergistic effect was found between citric acid and ascorbyl palmitate.

Comparison of oxidative stability in omega-3 PUFA enriched dairy products

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Food matrices affect the bioavailability of (n-3) polyunsaturated fatty acids in a single meal study in humans

The aim of this study was to investigate the role of the food matrix on bioavailability of (n-3) PUFA and oxidative stress in plasma. The study was a randomized, cross-over study and included 12 healthy male participants. The participants ingested a test meal, which consisted of a fitness bar, a yoghurt drink, eight oil capsules, bread and butter; 4 g of fish oil was incorporated into one of the matrices. Blood samples were collected and fatty acid composition of chylomicrons was determined together with plasma levels of conjugated dienes and alpha-tocopherol. Fish oil incorporated into food products were absorbed differently from those simply administered as supplements alongside of food products, and yoghurt was the best matrix for providing fast absorption of lipids in general, including (n-3) fatty acids. No significant difference was observed in the level of plasma alpha-tocopherol after ingestion of test meals. (c) 2007 Elsevier Ltd. All rights reserved.

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Systems Biology, Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Center for Biological Sequence Analysis, Technical University of Denmark
Authors: Schram, L. B. (Ekstern), Nielsen, C. J. (Ekstern), Porsgaard, T. (Intern), Nielsen, N. S. (Intern), Holm, R. (Ekstern), Mu, H. (Intern)
Pages: 1062-1068
Publication date: 2007
Main Research Area: Technical/natural sciences

Publication information
Journal: Food Research International
Volume: 40
Issue number: 8
ISSN (Print): 0963-9969
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.87 SJR 1.589 SNIP 1.682
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.518 SNIP 1.641 CiteScore 3.66
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.496 SNIP 1.761 CiteScore 3.52
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.522 SNIP 1.818 CiteScore 3.68
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.597 SNIP 1.774 CiteScore 3.31
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.515 SNIP 1.701 CiteScore 3.42
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.356 SNIP 1.434
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.46 SNIP 1.525
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.299 SNIP 1.429
Scopus rating (2007): SJR 1.262 SNIP 1.688
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.017 SNIP 1.317
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.79 SNIP 1.347
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.834 SNIP 1.201
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.667 SNIP 1.089
Scopus rating (2002): SJR 0.691 SNIP 1.084
Scopus rating (2001): SJR 0.629 SNIP 0.808
Scopus rating (2000): SJR 0.474 SNIP 0.644
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 0.572 SNIP 0.645
Original language: English
DOIs:
10.1016/j.foodres.2007.06.005
Source: orbit
Source-ID: 219788
Publication: Research - peer-review › Journal article – Annual report year: 2007

Optimization of oxidative stability of omega-3 enriched foods

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Jacobsen, C. (Intern), Nielsen, N. S. (Intern)
Pages: 197-217
Publication date: 2007

Host publication information
Title of host publication: Long-chain omega-3 specialty oils
Place of publication: Dundee
Publisher: Oily Press
Editor: Breivik, H.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 225899
Publication: Research - peer-review › Book chapter – Annual report year: 2007

Oxidative stability in a variety of omega-3 PUFA enriched products

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
Publication date: 2007
Main Research Area: Technical/natural sciences
Source: orbit
Oxidative stability of fish oil enriched drinking yoghurt

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Department of Systems Biology
Authors: Nielsen, N. S. (Intern), Debnath, D. (Ekstern), Jacobsen, C. (Intern)
Pages: 1478-1485
Publication date: 2007
Main Research Area: Technical/natural sciences

Publication information
Journal: International Dairy Journal
Volume: 17
Issue number: 12
ISSN (Print): 0958-6946
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 2.34 SJR 1.125 SNIP 1.255
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 0.978 SNIP 1.17 CiteScore 2.18
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.061 SNIP 1.175 CiteScore 2.24
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.238 SNIP 1.408 CiteScore 2.79
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.282 SNIP 1.467 CiteScore 2.55
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.269 SNIP 1.499 CiteScore 2.73
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.323 SNIP 1.471
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.622 SNIP 1.751
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.457 SNIP 1.519
Scopus rating (2007): SJR 1.223 SNIP 1.633
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.362 SNIP 1.774
Scopus rating (2005): SJR 1.2 SNIP 1.507
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.427 SNIP 1.715
Scopus rating (2003): SJR 1.199 SNIP 1.354
Scopus rating (2002): SJR 0.906 SNIP 1.173
Scopus rating (2001): SJR 0.881 SNIP 1.039
Oxidative stability of mayonnaise based salads enriched with fish oil

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Sørensen, A. M. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
Publication date: 2007
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 229406
Publication: Research › Poster – Annual report year: 2007

Oxidative stability of mayonnaise based salads enriched with fish oil

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Sørensen, A. M. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
Publication date: 2007
Event: Poster session presented at 98th AOCS Annual Meeting & Expo, Quebec, Canada.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 229405
Publication: Research › Poster – Annual report year: 2007

Application of functional lipids in foods

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Jacobsen, C. (Intern), Timm Heinrich, M. (Intern), Nielsen, N. S. (Intern)
Pages: 341-364
Publication date: 2006

Host publication information
Title of host publication: Nutraceutical and speciality lipids and their co-products
Place of publication: Boca Raton
Publisher: CRC Press
Editor: Shahidi, F.
Main Research Area: Technical/natural sciences

Bibliographical note
I følge forlaget udgives denne 15. marts 2006
Source: orbit
Source-ID: 225885
Publication: Research - peer-review › Book chapter – Annual report year: 2006

Oxidative stability of diacylglycerol oil and butter blends containing diacylglycerols
Diacylglycerol (DAG) oils produced from sunflower oil and traditional sunflower oil were stored for 20 wk at 38 degrees C, and their oxidative stability was measured. Moreover, two butter blends were produced containing 40 wt-% DAG oil made from sunflower oil or rapeseed oil, respectively, as well as two control butter blends with sunflower oil or rapeseed oil. Their oxidative stability during storage at 5 degrees C for up to 12 wk was examined by similar means as for the pure oils.
The storage study of the oils indicated that the DAG oil was oxidatively less stable as compared to sunflower oil, but that they had similar sensory quality. Storage of the butter blends revealed that blends with the two types of rapeseed oil (triacylglycerol (TAG) or DAG oil) were oxidatively more stable than the blends containing oils from sunflower. There was no unambiguous indication of DAG butter blends having a different stability than their respective control TAG blends. However, they had a significantly less salty and buttery flavour, which was ascribed to a much smaller water droplet size causing a delayed sensory perception in the mouth. The butter blend with DAG oil from rapeseed had a very neutral flavour. On the contrary, the butter blend with DAG oil from sunflower had a more rancid aroma and flavour than its control blend with sunflower oil.

**General information**

State: Published
Organisations: Department of Systems Biology, Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Center for Biological Sequence Analysis
Authors: Kristensen, J. B. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern), Mu, H. (Intern)
Pages: 336-350
Publication date: 2006
Main Research Area: Technical/natural sciences

**Publication information**

Journal: European Journal of Lipid Science and Technology
Volume: 108
Issue number: 4
ISSN (Print): 1438-7697
Ratings:
- BFI (2018): BFI-level 1
- Web of Science (2018): Indexed yes
- BFI (2017): BFI-level 1
- Web of Science (2017): Indexed yes
- BFI (2016): BFI-level 1
- Scopus rating (2016): CiteScore 2.06 SJR 0.71 SNIP 1.024
- Web of Science (2016): Indexed yes
- BFI (2015): BFI-level 1
- Scopus rating (2015): SJR 0.642 SNIP 0.881 CiteScore 1.85
- Web of Science (2015): Indexed yes
- BFI (2014): BFI-level 1
- Scopus rating (2014): SJR 0.737 SNIP 1.051 CiteScore 1.98
- BFI (2013): BFI-level 1
- Scopus rating (2013): SJR 0.852 SNIP 1.124 CiteScore 2.16
- ISI indexed (2013): ISI indexed yes
- Web of Science (2013): Indexed yes
- BFI (2012): BFI-level 1
- Scopus rating (2012): SJR 0.873 SNIP 1.207 CiteScore 2.06
- ISI indexed (2012): ISI indexed yes
- Web of Science (2012): Indexed yes
- BFI (2011): BFI-level 1
- Scopus rating (2011): SJR 0.732 SNIP 0.945 CiteScore 1.75
- ISI indexed (2011): ISI indexed yes
- Web of Science (2011): Indexed yes
- BFI (2010): BFI-level 1
- Scopus rating (2010): SJR 0.791 SNIP 1.049
- Web of Science (2010): Indexed yes
- BFI (2009): BFI-level 1
- Scopus rating (2009): SJR 0.838 SNIP 1.077
- Web of Science (2009): Indexed yes
- BFI (2008): BFI-level 1
- Scopus rating (2008): SJR 0.606 SNIP 0.815
- Web of Science (2008): Indexed yes
- Scopus rating (2007): SJR 0.598 SNIP 0.801
Production and oxidative stability of a human milk fat substitute produced from lard by enzyme technology in a pilot packed-bed reactor

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Department of Systems Biology
Authors: Nielsen, N. S. (Intern), Yang, T. (Intern), Xu, X. (Intern), Jacobsen, C. (Intern)
Pages: 53-60
Publication date: 2006
Main Research Area: Technical/natural sciences

Publication information
Journal: Food Chemistry
Volume: 94
Issue number: 1
ISSN (Print): 0308-8146
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.85 SJR 1.706 SNIP 2.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.597 SNIP 1.962 CiteScore 4.31
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.595 SNIP 2.027 CiteScore 3.92
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.548 SNIP 2.069 CiteScore 3.87
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Effect of structured lipids based on fish oil on the growth and fatty acid composition in Rainbow Trout (Oncorhynchus mykiss)

The aim of the study was to investigate whether it was possible a) to increase the relative incorporation of n-3 very long chain polyunsaturated fatty acids (n-3 VLCPUFA) in a low VLCPUFA diet by feeding trout structured triacylglycerols and b) to reduce fat accumulation by feeding trout a diet containing DAG. A feeding experiment where groups of rainbow trout were fed six diets containing different types of oils for 61 days was performed. The lipid fraction of the six diets was as follows: 1) Fish oil and rapeseed oil (FO diet), 2) Specific structured lipid and rapeseed oil (SL diet), 3) Randomised structured lipids and rapeseed oil (RL diet), 4) Medium chain triglyceride and fish oil (MCT diet), 5) Diacylglycerol and fish oil (DAG diet), 6) Fish oil (FOmax diet). Five of the diets (1-5) contained mixed oils blended to contain the same amount of EPA and DHA. Three of these diets (2, 3, and 4) contained medium chain fatty acids incorporated in TAG to be positioned either intentionally as specific (SL), by chance as randomised (RL) or added as medium chain TAG (MCT). Diet 1 contained fish oil (FO) in order to investigate the effect of MCFA and diet 4 contained diacylglycerol (DAG). Diet 6 was a reference diet containing pure fish oil (FOmax). After the feeding period, FO and FOmax fed fish were significantly larger than SL fed fish. Digestibility, measured by adding yttrium oxide as inert marker was significantly lowest for the MCT diet. Fish on the RL and MCT diets had significantly higher protein contents than fish fed FO and FOmax diets. The total fatty acid compositions of the fillet, liver, carcass and viscera were similar and reflected closely that of the diet, also in the sn-2 position. In conclusion, addition of MCT to the diet increased protein content of the fish. There was no additional effect of incorporating the medium chain fatty acids in specific positions and no weight reducing effect of adding DAG to the diets. (C) 2005 Elsevier B.V. All rights reserved.
Effects of antioxidants on the lipase-catalyzed acidolysis during production of structured lipids

In the production process of structured lipids, the influence of the addition of antioxidants before enzymatic acidolysis was investigated. Eight different antioxidants were screened: butylated hydroxyanisole, butylated hydroxytoluene, propyl gallate, ascorbyl palmitate, citric acid, EDTA, a tocopherol blend and lecithin. As substrates, oils with different degrees of unsaturation (rapeseed, safflower or fish oil) as well as caprylic and capric acids were used. Enzyme activity (measured as percent incorporation of caprylic/capric acid into the oils) as well as caprylic and capric acids were used. Enzyme activity (measured as percent incorporation of caprylic/capric acid into the oils) was not significantly influenced by the addition of antioxidants, neither in a batch process nor in a packed-bed reactor operation. α-Tocopherol concentrations remained stable for those mixtures where tocopherols were added. Primary oxidation products (measured as peroxide values) were reduced after acidolysis in the packed-bed reactor, likely due to the adsorption in the enzyme bed. The study shows that the addition of antioxidants before enzymatic reactions has no negative effects on the reaction progress. None of the antioxidants chosen had a significant positive effect on either the reaction process or the oxidative status of the structured lipid produced.

General information
State: Published
Organisations: Department of Biotechnology, Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Department of Systems Biology
Pages: 464-468
Publication date: 2005
Main Research Area: Technical/natural sciences

Publication information
Journal: European Journal of Lipid Science and Technology
Volume: 107
Issue number: 7-8
ISSN (Print): 1438-7697
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.06 SJR 0.71 SNIP 1.024
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.642 SNIP 0.881 CiteScore 1.85
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.737 SNIP 1.051 CiteScore 1.98
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.852 SNIP 1.124 CiteScore 2.16
Lipolysis of Different Oils using Crude Enzyme Isolate from the Intestinal Tract of Rainbow Trout, Oncorhynchus mykiss

General information
State: Published
Organisations: Department of Systems Biology, Enzyme and Protein Chemistry, Danish Institute for Fisheries Research
Authors: Gøttsche, J. (Intern), Nielsen, N. S. (Intern), Nielsen, H. H. (Ekstern), Mu, H. (Intern)
Pages: 1273-1279
Publication date: 2005
Main Research Area: Technical/natural sciences

Publication information
Journal: Lipids
Volume: 40
Original language: English
Source: orbit
Source-ID: 184508
Lipolysis of different oils using crude enzyme isolate from the intestinal tract of rainbow trout, Oncorhynchus mykiss

Crude enzyme isolate was prepared from the intestine of rainbow trout. Positional specificity of the crude enzyme isolate was determined from both 1(3)- and 2-MAG products after in vitro lipolysis of radioactive-labeled triolein. The ratio of 2-MAG/1(3)-MAG was 2:1, suggesting that the overall lipase specificity of the enzyme isolate from rainbow trout tended to be 1,3-specific; however, activity against the sn-2 position also was shown. In vitro lipolysis of four different unlabeled oils was performed with the crude enzyme isolate. The oils were: structured lipid [SL; containing the medium-chain FA (MCFA) 8:0 in the sn-1,3 positions and long-chain FA (LCFA) in the sn-2 position], DAGoil (mainly 1,3-DAG), fish oil (FO), and triolein (TO). MCFA were rapidly hydrolyzed from the SL oil. LCFA including n-3 PUFA were, however, preserved in the sn-2 position and therefore found in higher amounts in 2-MAG of SL compared with 2-MAG of FO, DAG, and TO. Lipolysis of the DAG oil produced higher amounts of MAG than the TAG oils, and 1(3)-MAG mainly was observed after lipolysis of the DAG oil. The positional specificity determined and the results from the hydrolysis of the different oils suggest that n-3 very long-chain PUFA from structured oils may be used better by aquacultured fish than that from fish oils.

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Section for Aquatic Protein Biochemistry
Authors: Göttsche, J. (Ekstern), Nielsen, N. S. (Intern), Nielsen, H. H. (Intern), Mu, H. (Ekstern)
Pages: 1273-1279
Publication date: 2005
Main Research Area: Technical/natural sciences

Publication information
Journal: Lipids
Volume: 40
Issue number: 12
ISSN (Print): 0024-4201
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.693 SNIP 0.77 CiteScore 1.94
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.782 SNIP 0.744 CiteScore 1.96
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.792 SNIP 0.876 CiteScore 2.07
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.903 SNIP 0.976 CiteScore 2.59
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.888 SNIP 1.048 CiteScore 2.5
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.765 SNIP 0.931 CiteScore 2.3
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.798 SNIP 0.898
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.694 SNIP 0.892
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.707 SNIP 0.841
Scopus rating (2007): SJR 0.741 SNIP 0.904
Effects of lactoferrin, phytic acid, and EDTA on oxidation in two food emulsions enriched with long-chain polyunsaturated fatty acids

The influence of the addition of metal chelators on oxidative stability was studied in a milk drink and in a mayonnaise system containing highly polyunsaturated lipids. Milk drinks containing 5% (w/w) of specific structured lipid were supplemented with lactoferrin (6-24 M) and stored at 2 °C for up to 9 weeks. Mayonnaise samples with 16% fish oil and 64% rapeseed oil (w/w) were supplemented with either lactoferrin (8-32 M), phytic acid (16-124 M), or EDTA (16-64 M) and were stored at 20 °C for up to 4 weeks. The effect of the metal chelators was evaluated by determination of peroxide values, secondary volatile oxidation products, and sensory analysis. Lactoferrin reduced the oxidation when added in concentrations of 12 M in the milk drink and 8 M in the mayonnaise, whereas it was a prooxidant at higher concentrations in both systems. In mayonnaise, EDTA was an effective metal chelator even at 16 M, whereas phytic acid did not exert a distinct protective effect against oxidation. The differences in the equimolar effects of the metal chelators are proposed to be due to differences in their binding constants to iron and their different stabilities toward heat and low pH.

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Department of Biotechnology
Pages: 7690-7699
Publication date: 2004
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Agricultural and Food Chemistry
Volume: 52
Issue number: 25
ISSN (Print): 0021-8561
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.45 SJR 1.291 SNIP 1.344
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.236 SNIP 1.253 CiteScore 3.23
Web of Science (2015): Indexed yes
Oxidative stability during storage of structured lipids produced from fish oil and caprylic acid

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Department of Biochemistry and Nutrition
Authors: Nielsen, N. S. (Intern), Xu, X. (Intern), Timm Heinrich, M. (Intern), Jacobsen, C. (Intern)
Pages: 375-384
Publication date: 2004
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of the American Oil Chemists Society
Volume: 81
Issue number: 4
ISSN (Print): 0003-021X
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.64 SJR 0.696 SNIP 0.905
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.682 SNIP 0.997 CiteScore 1.66
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.767 SNIP 1.043 CiteScore 1.68
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.809 SNIP 1.074 CiteScore 1.71
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.871 SNIP 1.236 CiteScore 1.81
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.833 SNIP 1.292 CiteScore 1.98
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.763 SNIP 1.056
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.863 SNIP 1.183
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.667 SNIP 1.037
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.663 SNIP 0.891
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.658 SNIP 0.851
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.706 SNIP 0.973
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.73 SNIP 0.993
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.761 SNIP 1.145
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 0.977 SNIP 1.172
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 0.911 SNIP 1.245
Web of Science (2001): Indexed yes
Oxidative stability of mayonnaise and milk drink produced with structured lipids based on fish oil and caprylic acid

The oxidative stabilities of traditional fish oil (FO), randomized lipids (RFO), or specific structured lipids (SFO) produced from fish oil were compared when incorporated into either milk drink or mayonnaise. Furthermore, the effect of adding the potential antioxidants EDTA (240 mg/kg) or lactoferrin (1000 mg/kg) to the milk drink based on SFO was investigated. The lipid type significantly affected the oxidative stability of both mayonnaises and milk drinks: The oxidative stability decreased in the order RFO>FO>SFO. The reduced oxidative stability in the SFO food emulsions could not be ascribed to a single factor, but was most likely influenced by the structure of the lipids and differences in the processes used to produce and purify the lipids. In milk drinks based on SFO, EDTA slightly reduced oxidation, while lactoferrin did not exert a distinct antioxidative effect.

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Department of Biotechnology
Authors: Timm Heinrich, M. (Intern), Xu, X. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
Pages: 32-41
Publication date: 2004
Main Research Area: Technical/natural sciences

Publication information
Journal: European Food Research and Technology
Volume: 219
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Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.742 SNIP 0.882 CiteScore 1.81
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.732 SNIP 0.822 CiteScore 1.55
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.828 SNIP 0.908 CiteScore 1.71
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.791 SNIP 0.901 CiteScore 1.71
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.872 SNIP 1.038 CiteScore 1.68
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.009 SNIP 1.097 CiteScore 1.87
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.931 SNIP 0.901
Web of Science (2010): Indexed yes
Oxidative stability of structured lipids containing C18:0, C18:1, C18:2, C18:3 or CLA in sn 2-position - as bulk lipids and in milk drinks

In this study, we compared the oxidative stability of a specific structured lipid (SL) containing conjugated linoleic acid (CLA) in the sn2-position with SL containing other C18 fatty acids of different degree of unsaturation (stearic, oleic, linoleic or linolenic acid). SL was produced by enzymatic interesterification with caprylic acid. Oxidative stability was compared in the five lipids themselves and in milk drinks containing 5% of the different SL. During storage, samples were taken for chemical and physical analyses. Moreover, sensory assessments were performed on milk drinks. The oxidative stability of our SL was very different when comparing (a) bulk lipids and milk drink and (b) the five different batches of each product. SL based on oleic acid was the most unstable as bulk lipid, while SL based on linoleic acid was the most unstable in milk drink. SL based on CLA was the second most unstable in both products.

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Department of Biotechnology
Authors: Timm Heinrich, M. (Intern), Nielsen, N. S. (Intern), Xu, X. (Intern), Jacobsen, C. (Intern)
Pages: 249-261
Publication date: 2004
Main Research Area: Technical/natural sciences

Publication information
Journal: Innovative Food Science & Emerging Technologies
Volume: 5
Issue number: 2
ISSN (Print): 1466-8564
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
Comparison of wet-chemical methods for determination of lipid hydroperoxides

Five methods for determination of lipid hydroperoxides were evaluated, including two iodometric procedures involving a titration and a spectrophotometric micro method, and three other spectrophotometric methods namely the ferro, International Dairy Federation (IDF) and FOX2 (ferrous oxidation in xylenol orange). Peroxide values determined in a range of food products by these five methods gave different results. The ferro method required large amounts of solvent (50 mL/sample); the FOX2 method had a low range (0.005-0.04 mumol hydroperoxide); the end point detection of the titration method was subjective and required a large amount of sample (1 g); and the micro method was sensitive to interruptions during execution. Therefore, only the modified IDF method was chosen for further testing and validation. Stability tests of the standard curve showed a variation coefficient of 4% and within runs the highest variation was 5.9% (for blank) and a maximum of 9.6% between runs variation for the lowest concentration. Among the antioxidants tested, only ethylenediaminetetraacetic acid (EDTA) affected the peroxide determinations.

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Department of Systems Biology
Authors: Nielsen, N. S. (Intern), Timm Heinrich, M. (Intern), Jacobsen, C. (Intern)
Pages: 35-50
Influence of fish oil supplementation on in vivo and in vitro oxidation resistance of low-density lipoprotein in type 2 diabetes

Objective: Fish oil supplement has been proposed as a non-pharmacological strategy to correct the atherogenic lipid profile associated with type 2 diabetes mellitus. However, fish oil may have deleterious effects on lipid peroxidation and glycemic control.

Design: In this study, 44 type 2 diabetic patients were randomized to vitamin E standardized (53.6 mg/day) supplementation (capsules) with 4 g daily of either fish oil (n = 23) or corn oil (n = 21) for 8 weeks preceded by a 4 week run-in period of corn oil supplementation. LDL was isolated by density gradient ultracentrifugation and oxidized in vitro with Cue(2+). As a marker of in vivo oxidation malondialdehyde concentration in LDL (LDL-MDA) was measured.

Results: Fish oil reduced both mean lag time (before, 57.8; after, 48.8 min, P <0.001) and mean propagation rate (before, 0.018 &u03b8/OD/min; after, 0.015 &u03b8/OD/min, P <0.001), whereas corn oil had no influence on lag time and propagation rate. The changes in lag time and propagation rate differed significantly between fish oil and corn oil treatment. LDL-MDA changes differed borderline significantly between groups (FO, 110.4 pmol/mg protein; CO, 6.7 pmol/mg protein; P = 0.057). Fish oil supplementation had no influence on glycemic control as assessed from HbA(1c) and fasting blood glucose.

Conclusion: According to our findings, fish oil supplementation leads to increased in vivo oxidation and increased in vitro oxidation susceptibility of LDL particles. More studies are needed to clarify the clinical importance of this finding. Sponsorship: Financially supported by The Danish Heart Association and Dansk Droge A/S. Dansk Droge A/S generously provided the fish oil and corn oil capsules.

General information
State: Published
Organisations: Enzyme and Protein Chemistry, Department of Systems Biology
Authors: Pedersen, H. (Ekstern), Petersen, M. (Ekstern), Major-Pedersen, A. (Ekstern), Jensen, T. (Ekstern), Nielsen, N. S. (Intern), Lauridsen, S. (Ekstern), Marckmann, P. (Ekstern)
Pages: 713-720
Publication date: 2003
Main Research Area: Technical/natural sciences
Oxidative stability of mayonnaise containing structured lipids produced from sunflower oil and caprylic acid

Mayonnaise based on enzymatically produced specific structured lipid (SL) from sunflower oil and caprylic acid was compared with mayonnaise based on traditional sunflower oil (SO) or chemically randomized lipid (RL) with respect to their oxidative stability, sensory and rheological properties. Furthermore, the potential antioxidative effect of adding lactoferrin, propyl gallate or EDTA to the mayonnaise with SL was also investigated. Mayonnaise based on SL oxidized faster than mayonnaise based on RL or SO. The reduced oxidative stability in the SL mayonnaise could not be ascribed to a single factor, but was most likely influenced by the structure of the lipid, the lower tocopherol content and the higher initial levels of lipid hydroperoxides and secondary volatile oxidation compounds in the SL itself compared with the RL and traditional sunflower oil employed. EDTA was a strong antioxidant, while propyl gallate and lactoferrin did not exert any antioxidative effect in the SL mayonnaise
Oxidative stability of milk drinks containing structured lipids produced from sunflower oil and caprylic acid

Milk drinks containing 5% traditional sunflower oil (SO), randomized lipid (RL) or specific structured lipid (SL) (both produced from SO and tricaprylin/caprylic acid) were compared with respect to their particle size, viscosity and oxidative stability during storage. Furthermore, the effect of adding potential antioxidants EDTA or gallic acid to the milk drink based on SL was investigated. The lipid type significantly affected the oxidative stability of the milk drinks: Milk drink based on SL oxidized faster than milk drink based on RL or SO. The reduced oxidative stability in the SL milk drink could not be ascribed most likely influenced by the structure of the lipid and to a single factor, differences in the process applied to produce and purify the lipids. EDTA was a strong antioxidant, while gallic acid did not exert a distinct antioxidative effect in the milk drink based on SL.

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Department of Systems Biology
Authors: Timm Heinrich, M. (Intern), Xu, X. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
Pages: 459-470
Publication date: 2003
Main Research Area: Technical/natural sciences

Publication information
Journal: European journal of lipid science and technology
Volume: 105
Issue number: 8
ISSN (Print): 1438-7697
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
Oxidative stability of structured lipids produced from sunflower oil and caprylic acid

Traditional sunflower oil (SO), randomized lipid (RL) and specific structured lipid (SL), both produced from SO and tricaprylin/caprylic acid, respectively, were stored for up to 12 wk to compare their oxidative stabilities by chemical and...
sensory analyses. Furthermore, the effect of adding a commercial antioxidant blend Grindox 117 (propyl gallate/citric acid/ascorbil palmitate) or gallic acid to the SL was investigated. The lipid type affected the oxidative stability: SL was less stable than SO and RL. The reduced stability was most likely caused by both the structure of the lipid and differences in production/purification, which caused lower tocopherol content and higher initial levels of primary and secondary oxidation products in SL compared with RL and SO. Grindox 117 and gallic acid did not exert a distinct antioxidative effect in the SL oil samples during storage.

**General information**

State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Department of Biotechnology
Authors: Timm Heinrich, M. (Intern), Xu, X. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
Pages: 436-448
Publication date: 2003
Main Research Area: Technical/natural sciences

**Publication information**

Journal: European Journal of Lipid Science and Technology
Volume: 105
Issue number: 8
ISSN (Print): 1438-7697
Ratings:
- BFI (2018): BFI-level 1
- Web of Science (2018): Indexed yes
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- Web of Science (2017): Indexed yes
- BFI (2016): BFI-level 1
- Web of Science (2016): Indexed yes
- BFI (2015): BFI-level 1
- Web of Science (2015): Indexed yes
- BFI (2014): BFI-level 1
- Web of Science (2014): SJR 0.737 SNIP 1.051 CiteScore 1.98
- BFI (2013): BFI-level 1
- Web of Science (2013): SJR 0.852 SNIP 1.124 CiteScore 2.16
- ISI indexed (2013): ISI indexed yes
- Web of Science (2012): Indexed yes
- BFI (2012): BFI-level 1
- Web of Science (2012): Indexed yes
- BFI (2011): BFI-level 1
- Web of Science (2011): Indexed yes
- BFI (2010): BFI-level 1
- Web of Science (2010): Indexed yes
- BFI (2009): BFI-level 1
- Web of Science (2009): Indexed yes
- BFI (2008): BFI-level 1
- Web of Science (2008): Indexed yes
- Scopus rating (2007): SJR 0.598 SNIP 0.801
- Web of Science (2007): Indexed yes
Different effects of diets rich in olive oil, rapeseed oil and sunflower-seed oil on postprandial lipid and lipoprotein concentrations and on lipoprotein oxidation susceptibility

Elevated concentrations of fasting and non-fasting triacylglycerol-rich lipoproteins (TRL) as well as oxidative changes of lipoproteins may increase the risk of ischaemic heart disease. To compare the effects of different diets rich in unsaturated fatty acids on the concentrations and in vitro oxidation of fasting and postprandial lipoproteins eighteen males consumed diets enriched with rapeseed oil (RO), olive oil (OO), or sunflower-seed oil (SO) in randomised order for periods of 3 weeks followed by a RO test meal. In the postprandial state the concentrations of cholesterol and triacylglycerol (TAG) in TRL were higher after consumption of OO compared with RO and SO (P

General information
State: Published
Organisations: Enzyme and Protein Chemistry, Department of Systems Biology
Authors: Nielsen, N. S. (Intern), Pedersen, A. (Ekstern), Sandstrøm, B. (Ekstern), Marckmann, P. (Ekstern), Høy, C. (Intern)
Pages: 489-499
Publication date: 2002
Main Research Area: Technical/natural sciences

Publication information
Journal: British Journal of Nutrition
Volume: 87
Issue number: 5
ISSN (Print): 0007-1145
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.46 SJR 1.983 SNIP 1.533
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.583 SNIP 1.446 CiteScore 3.52
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.468 SNIP 1.278 CiteScore 3.18
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.72 SNIP 2.521 CiteScore 3.61
ISI indexed (2013): ISI indexed yes
Purification and deodorization of structured lipids by short path distillation

Purification of structured lipids (SL), produced from lipase-catalyzed acidolysis of rapeseed oil and capric acid, and deodorization of randomized SL, produced from chemical randomization of fish oil and tricaprin, were studied in a bench-scale short path distillation (SPD). SL obtained from enzymatic acidolysis usually contain a large proportion of medium-chain and long-chain free fatty acids. Two SPD steps have been applied for the removal of free fatty acids. Parameters such as evaporator temperature, feeding flow rate, stirring roller speed, and the content of free fatty acids (FFA) added to the starting materials were optimized with respect to FFA left in the product residuals and to tocopherol loss from the starting oil. Evaporator temperature and flow rate were optimized using response surface methodology and two models were obtained for the FFA content left and loss of tocopherols. An applicable parameter zone was created to obtain a certain FFA (0.5% for example) content. In general, conditions that result in a lower FFA content will lead to a higher loss of tocopherols. In most parts of the parameter zone, 50% loss of tocopherols will be expected. The deodorization study of randomized SL from fish oils and tricaprin indicated that SPD in comparison with batch deodorization gave a product of a poorer sensoric quality.

General information

State: Published
Organisations: Department of Biotechnology, Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Effect of fish-oil-enriched margarine on plasma lipids, low-density-lipoprotein particle composition, size, and susceptibility to oxidation

General information
State: Published
Organisations: Department of Biochemistry and Nutrition, Technical University of Denmark, Gaubius Laboratory
Authors: Sørensen, N. S. (Intern), Marckmann, P. (Ekstern), Duyvenvoorde, W. V. (Ekstern), Princen, H. M. (Ekstern)
Pages: 235-241
Publication date: 1998
Main Research Area: Technical/natural sciences

Publication information
Journal: The American Society for Clinical Nutrition
Volume: 68
Issue number: 2
Original language: English
Source: orbit
Source-ID: 169843
Publication: Research - peer-review › Journal article – Annual report year: 1998

Enzymatic release of antioxidants for human low-density lipoprotein from grape pomace

General information
State: Published
Organisations: Department of Biotechnology, Department of Biochemistry and Nutrition
Authors: Meyer, A. M. B. (Intern), Jepsen, S. M. (Intern), Sørensen, N. S. (Intern)
Pages: 2439-2446
Publication date: 1998
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Agricultural and Food Chemistry
Volume: 46
Issue number: 7
ISSN (Print): 0021-8561
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.45 SJR 1.291 SNIP 1.344
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.236 SNIP 1.253 CiteScore 3.23
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.278 SNIP 1.421 CiteScore 3.25
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.423 SNIP 1.479 CiteScore 3.44
The effect of fish oil enriched margarine on plasma lipids, low density lipoprotein particle composition, size and susceptibility to oxidation

We investigated the effect of incorporating n-3 polyunsaturated fatty acids (PUFAs) into the diet on the lipid-class composition of LDLs, their size, and their susceptibility to oxidation. Forty-seven healthy volunteers incorporated 30 g sunflower-oil (SO) margarine/d into their habitual diet during a 3-wk run-in period and then used either SQ or a fish-oil-enriched sunflower oil (FO) margarine for the following 4 wk. Plasma concentrations of total cholesterol, triacylglycerols, HDL cholesterol, LDL cholesterol, and apolipoproteins A-I and B did not differ significantly between the groups during intervention. The FO margarine increased the concentration of n-3 very-long-chain PUFAs in the LDL particles, showing 93% (P less than or equal to 0.0001), 8% (P = 0.05), and 35% (P = <0.0001) increases in eicosapentaenoic acid, docosapentaenoic acid, and docosahexaenoic acid, respectively, in the FO group compared with 3%, 7%, and 7%, respectively, in the SO group during the intervention. The cholesterol content of the LDL particles increased in the FO group [total cholesterol: 6% (P = 0.008); cholesterol ester: 12% (P = 0.014)], although it was not significantly different from that in the control group, whereas the other lipid classes and the size of the LDL particles remained unchanged in both groups. A reduction in the alpha-tocopherol content in LDL (6%, P = 0.005) was observed in the FO group. Ex vivo oxidation of LDL induced with Cu2+ showed a significantly reduced lag time (from 91 to 86 min, P = 0.003) and lower maximum rate of oxidation (from 10.5 to 10.2 nmol.mg(-1).min(-1), P = 0.003) after intake of the FO margarine. The results indicate that consumption of the FO compared with the SO margarine had no effect on LDL size and lipid
composition and led to minor changes in LDL alpha-tocopherol content and oxidation resistance.

General information
State: Published
Organisations: Department of Biochemistry and Nutrition, Royal Veterinary and Agricultural University, Gaubius Laboratory
Authors: Nielsen, N. S. (Intern), Marckmann, P. (Ekstern), Høy, C. (Intern), van Duyvenvoorde, W. (Ekstern), Princen, H. (Ekstern)
Pages: 234-244
Publication date: 1998
Main Research Area: Technical/natural sciences

Publication information
Journal: American Journal of Clinical Nutrition
Volume: 68
Issue number: 2
ISSN (Print): 0002-9165
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 5.97 SJR 3.664 SNIP 2.355
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 4.06 SNIP 2.379 CiteScore 5.87
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 3.799 SNIP 2.417 CiteScore 5.71
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 4.045 SNIP 2.579 CiteScore 6.38
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 3.675 SNIP 2.435 CiteScore 6.05
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 3.519 SNIP 2.473 CiteScore 6.23
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 3.261 SNIP 2.231
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 3.213 SNIP 2.457
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 3.291 SNIP 2.265
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 3.343 SNIP 2.503
Web of Science (2007): Indexed yes
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 2.773 SNIP 2.364
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 2.475 SNIP 2.453
Projects:

**Innovative Applications of marine phospholipids for development of healthy foods**

National Food Institute  
Period: 15/10/2009 → 24/04/2013  
Number of participants: 7  
PhD Student:  
Lu, Henna Fung Sieng (Intern)  
Supervisor:  
Baron, Caroline P. (Intern)  
Nielsen, Nina Skall (Intern)  
Main Supervisor:  
Jacobsen, Charlotte (Intern)  
Examiner:  
Hellgren, Lars (Intern)  
Løvaas, Erik (Ekstern)  
Olsen, Karsten (Ekstern)

**Financing sources**
Source: Internal funding (public)  
Name of research programme:  1/3 DTU-stip, 2/3 FUR/andet  
Project: PhD

**Omega-3 food emulsions: Control and Investigation of Molecular Structure in Relation to Lipid Oxidation**

National Food Institute  
Period: 01/04/2008 → 28/03/2012  
Number of participants: 7  
PhD Student:  
Horn, Anna Frisenfeldt (Intern)  
Supervisor:  
Nielsen, Nina Skall (Intern)  
Szabo, Peter (Intern)  
Main Supervisor:  
Jacobsen, Charlotte (Intern)  
Examiner:  
Hellgren, Lars (Intern)  
Andersen, Mogens Larsen (Ekstern)  
Genot, Claude (Ekstern)

**Financing sources**
Source: Internal funding (public)  
Name of research programme: Institut stipendie (DTU) Samf.
Nutritional Immunology
This project runs under the FoodDTU umbrella, and one of its purposes is to create new collaborations between different DTU institutes with ongoing research related to food science. The participating institutes are DTU-Food, DTU-Biosys and DTU-Aqua. The purpose is to elucidate the impact of specific dietary components including e.g. fish oil on the intestinal microbiota and thereby on the development of the immune system in early life. The results are expected to create a basis for better nutritional advice for pregnant women.

National Food Institute
Department of Systems Biology

University of Copenhagen
Number of participants: 14
Project participant:
Kristensen, Matilde Bylov (Intern)
Wilcks, Andrea (Intern)
Bergström, Anders (Intern)
Nellemann, Christine (Intern)
Kølln, Charlotte (Intern)
Jacobsen, Charlotte (Intern)
Nielsen, Nina Skall (Intern)
Horn, Anna Frisenfeldt (Intern)
Mathiassen, Jakob Hovalt (Intern)
Hellgren, Lars (Intern)
Fink, Lisbeth Nielsen (Intern)
Frøkjær, Hanne (Ekstern)

Broeng Metzdorff, Stine (Ekstern)
Project Manager, organisational:
Licht, Tine Rask (Intern)

Nutritional Immunology
This project runs under the FoodDTU umbrella, and one of its purposes is to create new collaborations between different DTU institutes with ongoing research related to food science. The participating institutes are DTU-Food, DTU-Biosys and DTU-Aqua. The purpose is to elucidate the impact of specific dietary components including e.g. fish oil on the intestinal microbiota and thereby on the development of the immune system in early life. The results are expected to create a basis for better nutritional advice for pregnant women.

National Food Institute
Department of Systems Biology

University of Copenhagen
Period: 01/08/2007 → 31/12/2011
Number of participants: 13
Project participant:
Kristensen, Matilde Bylov (Intern)
Wilcks, Andrea (Intern)
Bergström, Anders (Intern)
Andersen, Jens Bo (Intern)
Nellemann, Christine (Intern)
Kølln, Charlotte (Intern)
Jacobsen, Charlotte (Intern)
Nielsen, Nina Skall (Intern)
Horn, Anna Frisenfeldt (Intern)
Mathiassen, Jakob Hovalt (Intern)
Hellgren, Lars (Intern)
Fink, Lisbeth Nielsen (Intern)
Fish oil enrichments

An increasing amount of evidence suggests that omega-3 fatty acids have a number of positive nutritional benefits in the human body (cardioprotective effect, prevention of inflammatory and various neurological diseases etc.). Increased attention from the media on these issues has lead to an increased consumer knowledge about omega-3 fatty acids, which in turn has lead to a growing intake of fish oil capsules. An alternative way of increasing the consumption of omega-3 fatty acids could be by adding fish oil to foods. Recently, several fish oil enriched foods have been launched in other European countries. This is not the case in Denmark. This may be due to different reasons. At the consumer side a barrier could be a lack of confidence in the taste of the product. In the food industry a barrier could be the uncertain situation w.r.t. health claims as well as problems related to the susceptibility of fish oil enriched foods to lipid oxidation. Finally, more studies are
needed to determine whether the bioavailability of omega-3 fatty acids from fish oil enriched foods is similar to that of fish oil capsules.

National Food Institute
Division of Industrial Food Research
Communications and Management Secretariat
Period: 01/01/2005 → 31/12/2008
Number of participants: 15
Project participant:
Nielsen, Nina Skall (Intern)
Jørgensen, Jane (Ekstern)
Mu, Huiling (Ekstern)
Porsgaard, Trine (Ekstern)
Jensen, Karen (Ekstern)
Scholderer, Joachim (Ekstern)
Hagemann, Kit (Ekstern)
Krutulyte, Rasa (Ekstern)
Elgaard, Peter (Ekstern)
Nielsen, Brian (Ekstern)
Graverholt, Jens Peter (Ekstern)
Affertsholt, Tage (Ekstern)
Pedersen, Pierre (Ekstern)
Brønner, Kirsti Wettre (Ekstern)
Project Manager, organisational:
Jacobsen, Charlotte (Intern)
Project

Structured lipids for fish feed for rainbow trouts
Intake of n-3 polyunsaturated fatty acids (PUFA) from fish is important for human health, due to the positive health effects of these PUFA. Feed for farmed fish has traditionally contained ingredients of marine origin high in n-3 fatty acids. However, marine resources might be in shortage for future feed production due to an increasing aquaculture production and stable or declining catches for fish-meal and -oil production.

Alternative sources of oil for fish feed have been investigated. Substitution of fish oil with vegetable oil may not affect the growth of fish, but will be reflected in the tissue of the fish by a reduced content of n-3 PUFA such as EPA and DHA. A major challenge is to influence fatty acid metabolism to save EPA and DHA for storage.

Medium chain fatty acids may preferably be oxidised to provide energy especially when positioned in the sn-1 and -3 positions as demonstrated in mammals. Due to the high fat content in the diets fat accumulation in trout is sometimes too high. In mammals, addition of diacylglycerols to the diet has been shown to reduce fat accumulation.

Objectives:

To determine the specificity of lipase in trout
To investigate whether it is possible to increase the relative incorporation of EPA in a low n-3 PUFA diet by feeding trout specific structured triacylglycerols with n-3 PUFA in the sn-2 position and medium chain fatty acids in the sn-1,3 positions
To investigate whether addition of diacylglycerols (DAG) in a fish diet could reduce fat accumulation in trout.

National Food Institute
Division of Industrial Food Research
Communications and Management Secretariat
Period: 01/01/2004 → …
Number of participants: 8
Acronym: Lipids for fish feed
Project participant:
Nielsen, Nina Skall (Intern)
Nielsen, Henrik Hauch (Intern)
Jørgensen, Jane (Ekstern)
Mu, Huiling, (Ekstern)
Production and Nutritional Aspects of Butter Enriched with Diacylglycerols

Department of Systems Biology
Period: 15/10/2002 → 27/03/2006
Number of participants: 8
Phd Student:
Kristensen, Janni Brogaard (Intern)
Supervisor:
Jacobsen, Charlotte (Intern)
Nielsen, Nina Skall (Intern)
Xu, Xuebing (Intern)
Main Supervisor:
Mu, Huiling (Intern)
Examiner:
Hellgren, Lars (Intern)
Adlercreutz, Patrick (Ekstern)
Jensen, Merete Myrup (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Offentlig finansiering
Project: PhD

Dietary fats: Technology - Quality - Nutrition
The production of interesterified fats is optimized in laboratory scale as well as in pilot plant. The intestinal absorption of the fats is examined in animal models and the fats are incorporated into food.

Department of Biochemistry and Nutrition

National Institute of Aquatic Resources

Department of Systems Biology
Period: 01/01/1999 → 31/12/2003
Number of participants: 9
Project participant:
Porsgaard, Trine (Intern)
Jensen, Karen (Intern)
Nielsen, Nina Skall (Intern)
Mu, Huiling (Intern)
Børresen, Torger (Ekstern)
Jacobsen, Charlotte (Ekstern)
Adler-Nissen, Jens (Ekstern)
Xu, Xuebing (Ekstern)
Project Manager, organisational:
Høy, Carl-Erik (Intern)

Financing sources
Source: Unknown
Name of research programme: Ukendt
Amount: 14,300,000.00 Danish Kroner
Project
Rapsolies indflydelse på human lipoproteinmetabolismne

Department of Systems Biology
Period: 01/06/1995 → 20/10/1999
Number of participants: 2
Phd Student:
Nielsen, Nina Skall (Intern)
Main Supervisor:
Høy, Carl-Erik (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Sektorministerium, Stip-SU
Project: PhD

Rapeseed oil in human nutrition.
The project aims at substituting a major part of the dietary fats with rapeseed oil. Rapeseed oil is improved by selection of plants. The effects of processing and storage are examined. Rapeseed oil is compared with alternative fats in both animal models for fat absorption and in human studies.

Department of Biochemistry and Nutrition
Department of Biotechnology
Department of Systems Biology
Royal Veterinary and Agricultural University
DLF-TRIFOLIUM A/S

Bioteknologisk Institut
Period: 01/01/1995 → 30/12/1999
Number of participants: 10
Project participant:
Nielsen, Nina Skall (Intern)
Porsgaard, Trine (Intern)
Nielsen, Kirsten (Intern)
Pedersen, Bente (Intern)
Adler-Nissen, Jens (Ekstern)
Marckmann, Peter (Ekstern)
Sandström, Brittmarie (Ekstern)
Okkels, Finn (Ekstern)
Jacobsen, Ejlif (Ekstern)
Project Manager, organisational:
Høy, Carl-Erik (Intern)

Financing sources
Source: Unknown
Name of research programme: Ukendt
Amount: 3,530,000.00 Danish Kroner
Source: Unknown
Name of research programme: Ukendt
Amount: 2,000,000.00 Danish Kroner
Project

Press clippings:

Fedt fra vegetabilier vs. fisk
Nina Skall Nielsen
15/01/2016

Subject
Fedt fra vegetabilier vs. fisk
Fedt fra vegetabilier vs. fisk
15/01/2016
Ing.dk/fokus, Web
Mia Stage
Nina Skall Nielsen
National Food Institute, Research Group for Bioactives – Analysis and Application
Press / Media

Omega-3 olie fra planter
Nina Skall Nielsen
13/01/2014
National Food Institute, Communications and Management Secretariat, Division of Industrial Food Research
Press / Media

Antioxidanter i kartoffelskræller
Nina Skall Nielsen
22/06/2012
National Food Institute, Division of Industrial Food Research
Press / Media