Combination of sodium caseinate and succinyalted alginate improved stability of high fat fish oil-in-water emulsions

Sodium caseinate (CAS) and commercial sodium alginate (CA), long chain modified alginate (LCMA) or short chain modified alginate (SCMA) were used in combination for emulsifying and stabilizing high fat (50–70%) fish oil-in-water emulsions. Physical (creaming, droplet size, viscosity and protein determination) and oxidative (primary and secondary oxidation products) stabilities of the emulsions were studied during 12 days of storage. Creaming stability was higher for emulsions produced with alginates and CAS compared to emulsions prepared with only CAS. Combined use of CAS + LCMA performed better in terms of physical stability compared to emulsions produced with only CAS. However, the oxidative stability of this emulsion was inferior probably due to the presence of an unsaturated carbon chain in LCMA structure. CAS + SCMA emulsions not only showed better physical stability such as smaller droplet size, lower creaming and higher viscosity, but also had an improved oxidative stability than emulsions produced with only CAS.

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Peptides: Production, bioactivity, functionality, and applications

Production of peptides with various effects from proteins of different sources continues to receive academic attention. Researchers of different disciplines are putting increasing efforts to produce bioactive and functional peptides from different sources such as plants, animals, and food industry by-products. The aim of this review is to introduce production methods of hydrolysates and peptides and provide a comprehensive overview of their bioactivity in terms of their effects on immune, cardiovascular, nervous, and gastrointestinal systems. Moreover, functional and antioxidant properties of hydrolysates and isolated peptides are reviewed. Finally, industrial and commercial applications of bioactive peptides including their use in nutrition and production of pharmaceuticals and nutraceuticals are discussed.

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BFI (2015): BFI-level 2
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Web of Science (2013): Impact factor 5.548
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.055 SNIP 2.684 CiteScore 5.73
The effect of rosemary (Rosmarinus officinalis L.) extract on the oxidative stability of lipids in cow and soy milk enriched with fish oil

Lipid oxidation of fish oil enriched cow milk and soy milk supplemented with rosemary extract stored at 2°C was studied. Both peroxide value and volatile secondary lipid oxidation products were determined to monitor the progress of lipid oxidation. Rosemary extract inhibited lipid oxidation in fish oil enriched cow milk. In contrast, soy milk samples having much higher unsaturated fatty acid content showed higher lipid oxidation stability compared to cow milk. Reduction in the content of chlorogenic acid during storage suggested that this compound may contribute to the lipid oxidation stability of fish oil enriched soy milk product. Total carnosic acid and carnosol concentration declined much faster in soy milk than in cow milk. It is suggested from the results that food components could have significant impact on the fate of bioactive antioxidant compounds in a specific food product during storage.

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ISI indexed (2013): ISI indexed yes
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BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.762 SNIP 2.342 CiteScore 3.98
Web of Science (2012): Impact factor 3.334
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.911 SNIP 2.383 CiteScore 4.17
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Scopus rating (2009): SJR 1.789 SNIP 2.023
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Scopus rating (2005): SJR 1.028 SNIP 1.526
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.077 SNIP 1.438
Scopus rating (2003): SJR 0.876 SNIP 1.248
Web of Science (2003): Indexed yes
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Alkyl caffeates as antioxidants in O/W emulsions: Impact of emulsifier type and endogenous tocopherols

Antioxidant addition can be one strategy to limit lipid oxidation in emulsions. Research has proven that an important factor regarding the efficacy of antioxidants is their localization in the emulsion; however, other factors such as interactions with other components can also have an impact. Thus, the aim was to evaluate the impact of emulsifiers (Citrem and Tween80) and presence of endogenous tocopherols on the efficacies of caffeic acid and caffeates (C1–C20) as antioxidants in emulsions. Lipid oxidation was evaluated during storage and partitioning of caffeic acid and caffeates was estimated by measuring their concentrations in the aqueous phase. Partitioning of caffeic acid and caffeates was influenced by emulsifier type and the presence of endogenous tocopherols. Caffeic acid was the most efficient antioxidant in Citrem and Tween stabilized emulsions in the presence of endogenous tocopherol. In contrast, for Tween stabilized emulsions, caffeic acid acted as a prooxidant and the evaluated caffeates acted as strong antioxidants in the absence of endogenous tocopherol. Thus, when endogenous tocopherol was present lipophilization of caffeic acid did not increase its efficacy as an antioxidant. It is suggested that the differences observed in antioxidant efficiency with different emulsifiers and with and without endogenous tocopherols is due to emulsifier–antioxidant interactions and antioxidant–antioxidant interactions in the emulsions.
Antioxidant Efficacies of Rutin and Rutin Esters in Bulk Oil and Oil-in-Water Emulsion

The use of flavonoids as antioxidants in food formulations is limited due to their solubility and thereby their localization in the food products. However, enzymatic alkylation of flavonoids with lipophilic moieties alters their lipophilicity and thereby partitioning within different phases in a food product. This study aimed to evaluate the antioxidative efficiency of two derivatives of rutin, namely rutin laurate (C12:0) and rutin palmitate (C16:0) compared with their parent compound rutin and with butylated hydroxytoluene (BHT). Their efficiency as antioxidants at two different concentrations (25 and 200 µM) was assessed in bulk oil and in an o/w emulsion system without and with iron addition. All evaluated compounds revealed antioxidant effects. However, rutin and BHT were the most efficient antioxidants in bulk oil followed by rutin palmitate, whereas rutin laurate acted as either an antioxidant or a prooxidant at low and high concentrations (25 and 200 µM), respectively. In emulsions, rutin and BHT in high concentration (200 µM) were more efficient than rutin esters. Thus,
Alkylation of rutin with medium chain fatty acids did not improve the antioxidant ability, neither in bulk oil nor in o/w emulsion. Interestingly, rutin had stronger antioxidative effect than BHT upon iron addition to the emulsion.

Practical application: According to the antioxidant hypothesis the polar paradox more amphiphilic antioxidants should perform as better antioxidants in emulsions than more polar antioxidants. The finding in this study revealed that lipophilization of rutin did not improve its antioxidant capacity in emulsions compared to untreated rutin. This stresses the importance of evaluating the antioxidant in each emulsion systems before selecting appropriate antioxidants for optimal protection against lipid oxidation.

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Effects of Different Lipophilized Ferulate Esters in Fish Oil-Enriched Milk: Partitioning, Interaction, Protein, and Lipid Oxidation

Antioxidant effects of ferulic acid and lipophilized ferulate esters were investigated in fish oil-enriched milk. Methyl ferulate (C1) and ethyl ferulate (C2) more efficiently prevented lipid oxidation than dodecyl ferulate (C12) did, followed by ferulic acid (C0). The combination of C1 or C2 with C12 could have a "synergistic" effect indicated by peroxide value, hexanal, and 1-penten-3-ol analysis results. These antioxidants also showed protein oxidation inhibition effects. The most effective antioxidants (C1 and C2) had the highest concentration in the precipitate phase but the lowest concentration in the aqueous phase, which was the opposite of the partitioning of C0. C12 had the highest concentration in the oil and emulsion phase. In particular, the interaction between ferulates esterified with short and medium alkyl chain lengths could lead to their "synergetic" effects in fish oil-enriched milk, which could be caused by the change in their partitioning or localization at the interface.

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Web of Science (2015): Impact factor 2.857
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
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Scopus rating (2012): SJR 1.408 SNIP 1.464 CiteScore 3.2
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BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.42 SNIP 1.391
Web of Science (2010): Impact factor 2.816
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.33 SNIP 1.306
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.327 SNIP 1.338
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.252 SNIP 1.44
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.367 SNIP 1.418
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.298 SNIP 1.517
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.353 SNIP 1.489
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 1.152 SNIP 1.469
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 1.219 SNIP 1.532
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Physical and oxidative stability of fish oil-in-water emulsions fortified with enzymatic hydrolysates from common carp (Cyprinus carpio) roe

Physical and oxidative stability of 5% (by weight) cod liver oil-in-water emulsions fortified with common carp (C. carpio) roe protein hydrolysate (CRPH) were examined. CRPH was obtained by enzymatic hydrolysis of discarded roe by using Alcalase 2.4 L for 30, 60, 90, and 120 min to yield different degrees of hydrolysis (DH). All the hydrolysates showed in vitro antioxidant activity in terms of radical scavenging and chelating properties. CRPH-containing emulsions had significantly smaller droplets than control (p

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Scopus rating (2013): SJR 1.554 SNIP 2.056 CiteScore 3.87
Web of Science (2013): Impact factor 3.259
Physical and oxidative stability of high fat fish oil-in-water emulsions stabilized with combinations of sodium caseinate and sodium alginate

A systematic study was carried out in order to evaluate the physical and oxidative stability of high fat omega-3 delivery fish oil-in-water emulsions stabilized with combinations of sodium caseinate (NaCas) and sodium alginate (NaAlg). The influence of 3 factors related to emulsion composition (fish oil content: 50, 60 and 70%; total amount of NaCas and NaAlg: 1.4, 2.1 and 2.8 %; and ratio NaCas:NaAlg: 0.4, 1.2 and 2) on physical (droplet size, viscosity and zeta potential) and oxidative (primary and secondary oxidation products) parameters was evaluated. It was possible to produce emulsions with a combination of NaCas and NaAlg, except when the ratio between NaAlg and aqueous phase was high (0.047 or...
0.054). Viscosity of the emulsions significantly increased with increasing fish oil and total stabilizer content. Zeta potential was significantly affected by total stabilizer content. The content of primary oxidation products in the emulsions was very low (0.93 meq peroxides/kg oil). Secondary oxidation products were detected in small amounts (<60 ng/g emulsion). Even though the optimum formulation concerning physical parameters was suggested as 61.8% fish oil content, 1.4% total stabilizer and 1.2 ratio NaCas:NaAlg by Box-Behnken’s design, the formulae 70%-1.4%-1.2 was decided due to high fish oil content’s decreasing effect on droplet size and peroxide value. Practical applications: Physically and oxidatively stable high fat (50-70%) omega-3 delivery fish oil-in-water emulsions are of high interest to food industry for the production of omega-3 fortified products. Our results show the feasibility to stabilize high fat delivery fish oil-in-water emulsions using combinations of NaCas and NaAlg. As these emulsions had high amount of fish oil, food products can be enriched with smaller amounts of high fat emulsions when compared to low fat delivery emulsions. This results in minor changes of the product's original structure. Examples for enrichment of food products with omega-3 are dressings, cream cheese, yoghurt and mayonnaise.

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Web of Science (2017): Indexed yes
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Scopus rating (2016): CiteScore 2.06 SJR 0.712 SNIP 1.042
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BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.643 SNIP 0.878 CiteScore 1.85
Web of Science (2015): Impact factor 1.953
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BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.742 SNIP 1.052 CiteScore 1.98
Web of Science (2014): Impact factor 1.812
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.863 SNIP 1.122 CiteScore 2.16
Web of Science (2013): Impact factor 2.033
ISI indexed (2013): ISI indexed yes
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BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.864 SNIP 1.221 CiteScore 2.06
Web of Science (2012): Impact factor 2.266
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
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Scopus rating (2011): SJR 0.742 SNIP 0.94 CiteScore 1.75
Web of Science (2011): Impact factor 1.733
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Supplementation of docosahexaenoic acid (DHA), vitamin \( \text{D}_3 \) and uridine in combination with six weeks of cognitive and motor training in prepubescent children: a pilot study

Background Learning and memory have been shown to be influenced by combination of dietary supplements and exercise in animal models, but there is little available evidence from human subjects. The aim of this pilot study was to investigate the effect of combining a motor- and cognitive exercise program with dietary supplementation consisting of 500 mg docosahexaenoic acid (DHA), 10 μg vitamin D3 and 1000 mg uridine (DDU-supplement) in 16 prepubescent children (age 8–11 years). Methods We designed a randomized, placebo-controlled, double-blinded study lasting 6 weeks in which DDU-supplement or placebo was ingested daily. During the intervention period, all children trained approximately 30 min 3 days/week using an internet-based cognitive and motor training program (Mitii). Prior to and post the intervention period dietary record, blood sampling, physical exercise tests and motor and cognitive tests were performed. Results Fourteen of the 16 children completed the intervention and ingested the supplement as required. 6 weeks DDU-supplementation resulted in a significant increase in the blood concentration of vitamin D2+3 and DHA (\( p = 0.023 \) and \( p < 0.001 \), respectively). Power calculation based on one of the cognitive tasks revealed a proper sample size of 26 children. Conclusion All children showed improved performance in the trained motor- and cognitive tasks, but it was not possible to demonstrate any significant effects on the cognitive tests from the dietary supplementation. However, DDU-supplementation did result in increased blood concentration of DHA and vitamin D2+3. Trial registration Clinical registration ID: NCT02426554 (clinical trials.gov). January 2015 retrospectively registered.
Antioxidant Activity of Protein Hydrolysates Obtained from Common Carp (Cyprinus carpio) Discarded Roe

Lipid oxidation represents a severe challenge in food engineering because it deteriorates quality of foods, especially those containing high contents of polyunsaturated fatty acids (PUFAs). One way to overcome this barrier is application of synthetic antioxidants such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate (PG), and tertiary butylhydroquinone (TBHQ) in PUFA-rich foods. However, recently there have been concerns over health-related risks posed by these synthetic agents. Therefore, obtaining safe antioxidants from natural sources, especially those which are discarded with no use, with potency to retard lipid oxidation has gained sizable attention. Therefore, the present study aimed at obtaining “green” antioxidants from discarded common carp roe via the so-called hydrolysis process by using alcalase and determining their antioxidant activity both in vitro and in food model systems. Four common carp roe protein hydrolysates (CRPH) obtained at different reaction times (i.e. 30, 60, 90, and 120 min) were assayed. In vitro antioxidant activity of the hydrolysates was measured through three different assays (i.e. DPPH radical scavenging, metal ion chelating, and reducing power). Furthermore, the oxidative stability of 5% fish oil-in-water emulsions containing or not the hydrolysates was investigated by monitoring their content of hydroperoxides and volatiles markers. The hydrolysates exhibited high DPPH radical scavenging activity and reducing power when compared to positive controls, i.e. BHT and ascorbic acid, respectively. However, Fe2+ chelating capacity of the hydrolysates was relatively lower than that of Ethylenediaminetetraacetic acid (EDTA), applied as positive control. The antioxidant activity of hydrolysates changed with DH and increased in a dose dependent manner. Unlike CRPH-fortified emulsions, the emulsions without CRPH exhibited significantly increased peroxide value (PV) during the storage period (p<0.05), reaching from 4.7±0.1 at day 0 to 79.2±11.3 at day 7. Moreover, all CRPH-containing emulsions showed negligible amounts of most secondary oxidation products (e.g. 1-penten-3-one and (E,E)-2,4-heptadienal) when compared to the emulsion control at day 7. These results indicate that common carp roe protein hydrolysates exert antioxidant activity both in vitro and in fish oil-in-water emulsions, and can thus be considered as alternative antioxidants to the synthetic ones.

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Comparison of Three Methods for Extraction of Volatile Lipid Oxidation Products from Food Matrices for GC–MS Analysis

The aim of this study was to compare three different collection methods; purge and trap, solid phase micro extraction and automated dynamic headspace/thermal desorption, all followed by GC–MS analysis used for the measurements of concentrations of volatile oxidation products in three different food matrices, namely oil, emulsion and milk. The linearity ranges of calibration curves obtained by the three different methods were compared for oil samples. Overall, the results showed that the three collection methods were comparable, although there were large differences in the linearity range of the calibration curves depending on the collection method. However, some challenges were observed for solid phase micro extraction and automated dynamic headspace/thermal desorption, namely, competition problems and overestimation of concentration by calibration curves, respectively. Based on the results, we suggest mainly to apply solid phase micro extraction on simple matrices and to be cautious with more complex matrices such as enriched milk and highly oxidized oils. Thereby, the study confirmed some challenges observed by other authors regarding competition problems on the fiber when using solid phase micro extraction. Furthermore, we observed that purge and trap, and automated dynamic headspace/thermal desorption calibration curves did provide an overestimation for oil samples so results must be interpreted with caution.
Evaluation of the antioxidant activity in food model system of fish peptides released during simulated gastrointestinal digestion
In the last decade, increasing evidences of the occurrence of lipid oxidation during digestion have been reported, in either in vivo or in vitro studies (1,2,3). As a result, the nutritional quality and safety of foodstuffs could be affected by the decrease of certain lipidic compounds of interest and the generation of potentially toxic oxidation products. Regarding fish composition, the high content in polyunsaturated ω-3 acyl groups renders its lipids especially prone to oxidation. However, fish is also a major source of protein, which could greatly influence the extent of oxidation reactions taking place in the gastrointestinal tract. In fact, several studies have reported antioxidant activity of fish protein hydrolysates, coming from fish industry waste by-products (3,4). Thus, the potential release of peptides showing antioxidant properties during fish digestion cannot be ruled out. In order to shed light on these aspects, in vitro digestates of European sea bass were submitted to ultrafiltration using membranes with different cut off size. Afterwards, the potential antioxidant activity of the peptide fractions obtained was evaluated by comparing the oxidative stability of fish oil-in-water emulsions (5%), containing or not the isolated fractions (2 mg/ml final protein concentration). For this purpose, the occurrence of volatile markers of lipid oxidation, the tocopherol content, and the lipid composition of the emulsions during storage were studied. At day 12 of storage, emulsions made with digested protein fractions showed a higher content of docosahexanoic acyl groups and tocopherol than the emulsion control (without fractions), and also a lower content of volatile oxidation markers.

Seasonal variations of antioxidants in the brown seaweed Saccharina latissima

Mainly the brown seaweeds are known for their high antioxidative capacity within the specific compounds such as phlorotannins, polyphenols, flavonoids, pigments, and these natural antioxidants are of high industrial interest. Previous studies have shown large seasonal variations in biomass composition. The aim of this study was to see if there was a seasonal variation in the antioxidant content of sugar kelp (Saccharina latissima), compare two cultivation sites, REF and IMTA, and test different solvents applied for extractions, methanol or ethyl acetate. Rope cultivated sugar kelp were sampled both in close proximity to a blue mussel and fish farm (IMTA) and at a reference/control site (REF), both outside Horsens fjord in Denmark. Sugar kelp biomass was measured (n=3) at 2 m depth in 2013-2014, and freeze dried and stored frozen for further analyses. In relation to the extraction, two solvents with different polarities were applied. Methanol was generally a better solvent for extracting the more polar compounds i.e. phenolics, whereas ethyl acetate tended more efficient for flavonoid extraction. There was no significant variation in the TAC between the two cultivation sites, ranging between 1,531-5,135 μg GA/g DW, and with no clear pattern of seasonal variation. Within the phenolic content no significant difference was seen (258-3,594 μg GA/g DW), and for IMTA the flavonoid concentration for September 2013 (4,830±1,048 μg rutin/g DW) was significantly higher than the other months. The biological variability had a high impact revealed by large standard deviation. The pigment specimens did not change during the year, however the concentration did, and with fucoxanthin as the most interesting. No clear correlation was found between pigments and the antioxidants. This study showed high concentration of antioxidant in sugar kelp and in 100 times higher range than e.g. microalgae. However, the large variations should be taken into account when aiming for industrial use.
Alkyl chain length impacts the antioxidative effect of lipophilized ferulic acid in fish oil enriched milk

Lipophilization of phenolics by esterification with fatty alcohols may alter their localization in an emulsion and thereby their antioxidant efficacy. In this study, synthesized unbranched alkyl ferulates were evaluated as antioxidants in fish oil enriched milk. Lipid oxidation was determined by peroxide values and concentration of volatile oxidation products. A cut-off effect in the antioxidant efficacy in relation to the alkyl chain length was observed. The most efficient alkyl ferulate was methyl ferulate followed by ferulic acid and butyl ferulate, whereas octyl ferulate was prooxidative and the prooxidative effect increased further with an increment in the alkyl chain length from C8 to C12. Further elongation of the alkyl chain length to C16 and C20 resulted in weak prooxidative effects to weak antioxidative effects depending on the different volatile oxidation compounds developed.

General information

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Antioxidative effect of lipophilized caffeic acid in fish oil enriched mayonnaise and milk

The antioxidative effect of lipophilized caffeic acid was assessed in two different fish oil enriched food products: mayonnaise and milk. In both emulsion systems, caffeic acid esterified with fatty alcohols of different chain lengths (C1–C20) were better antioxidants than the original phenolic compound. The optimal chain length with respect to protection against oxidation was, however, different for the two food systems. Fish oil enriched mayonnaise with caffeates of medium alkyl chain length (butyl, octyl and dodecyl) added resulted in a better oxidative stability than caffeates with shorter (methyl) or longer (octadecyl) alkyl chains. Whereas in fish oil enriched milk emulsions the most effective caffeates were those with shorter alkyl chains (methyl and butyl) rather than the ones with medium and long chains (octyl, docosyl, hexadecyl and eicosyl). These results demonstrate that there might be an optimum alkyl chain length for each phenolipid in each type of emulsion systems.

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Authors: Alemán, M. (Ekstern), Bou, R. (Ekstern), Guardiola, F. (Ekstern), Durand, E. (Ekstern), Villeneuve, P. (Ekstern), Jacobsen, C. (Intern), Sørensen, A. M. (Intern)
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ISI indexed (2013): ISI indexed yes
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Web of Science (2012): Impact factor 3.334
ISI indexed (2012): ISI indexed yes
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Scopus rating (2011): SJR 1.911 SNIP 2.383 CiteScore 4.17
Antioxidant properties and efficacies of synthesized alkyl caffeates, ferulates, and coumarates

Caffeic, ferulic, and coumaric acids were lipophilized with saturated fatty alcohols (C1-C20). The antioxidant properties of these hydroxycinnamic acids and their alkyl esters were evaluated in various assays. Furthermore, the antioxidant efficiency of the compounds was evaluated in a simple o/w microemulsion using the conjugated autoxidizable triene (CAT) assay. All evaluated phenolipids had radical scavenging, reducing power, and metal chelating properties. Only caffeic acid and caffeates were able to form a complex with iron via their catechol group in the phenolic ring. In the o/w emulsion, the medium chain phenolipids of the three homologues series were most efficient. The antioxidant properties and efficacies were dependent upon functional groups substituted to the ring structure and were in the following order: caffeic acid and caffeates > ferulic acid and ferulates > coumaric acid and coumarates. Moreover, the results demonstrated that the test system has an impact on the antioxidative properties measured.
The degree of lipophilization affects antioxidative efficacy of ferulates in omega-3 enriched milk

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Antioxidant efficacy of caffeates in emulsions and the effect of tocopherols
Lipid oxidation is a major issue in foods containing LC PUFA. Lipid oxidation can be inhibited or reduced by the addition of antioxidants. Many food products are emulsions. According to the “polar paradox” hypothesis, polar compounds are more efficient as antioxidants in bulk oil, whereas lipophilic compounds are more efficient antioxidants in emulsions. Lately, extensive work has been performed on phenolipids and their antioxidant efficacy in emulsions. It was found that the “polar paradox” hypothesis was too simple to explain the observed efficacy of the phenolipids. The antioxidant efficacy increased with increasing length of the alkyl chain up to a certain length after which the efficacy decreased. Therefore, a new term, “cut-off effect”, was introduced to describe this behavior. Furthermore, the length of the alkyl chain for optimal antioxidant effect has been shown to be influenced by the type of emulsions.

The aim of this study was to evaluate the antioxidative effect of caffeic acid and its esters C1 – C20, caffeates, in two different emulsion systems. In the first system we used stripped fish-rapeseed oil (50:50) and for the second system we used non-stripped fish-rapeseed oil (50:50) and for both systems Tween80 was used as emulsifier. Hence, the first system was without tocopherol and the second system was with tocopherols from the oil. In addition, caffeates were evaluated as antioxidants in two fish oil enriched food products: milk and mayonnaise. Lipid oxidation was evaluated from three parameters measured over time: peroxide value (PV), secondary volatile oxidation products and tocopherol concentrations. The results demonstrate the efficacy of caffeates in simple emulsions and food emulsions. Furthermore, the two different simple emulsion systems reveal possible interactions between caffeates and tocopherols.

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Organisations: National Food Institute, Division of Industrial Food Research, University of Barcelona, Centre de coopération Internationale en Recherche Agronomique pour le Développement
**Caffeates as antioxidants in emulsions and the effect of tocopherols**

Lipid oxidation is a major issue in foods containing LC PUFA. To protect these food products, antioxidant addition can be a solution. Many food products are emulsions. According to the "polar paradox" hypothesis, polar compounds are more efficient as antioxidants in bulk oil, whereas lipophilic compounds are more efficient antioxidants in emulsions. Lately, extensive work has been performed on phenolipids and their antioxidant efficacy in emulsions. It was found that the "polar paradox" hypothesis was too simple to explain the observed efficacy of the phenolipids. The antioxidant efficacy increased with increasing length of the alkyl chain up to a certain length after which the efficacy decreased. Therefore, a new term, "cut-off effect", was introduced to describe this behavior.

The aim of this study was to evaluate the antioxidative effect of caffeic acid and its ester C1 – C20, caffeates, in two different emulsion systems. In the first system we used stripped fish-rapeseed oil (50:50) and for the second system we used non-stripped fish-rapeseed oil (50:50) and for both systems Tween80 was used as emulsifier. Hence, the first system was without tocopherol and the second system was with tocopherols from the oil. Lipid oxidation was evaluated from three parameters measured over time: peroxide value (PV), secondary volatile oxidation products and tocopherol concentrations. The results demonstrate the efficacy of caffeates in simple emulsions. Furthermore, the two different emulsion systems reveal possible interactions between caffeates and tocopherols in simple emulsions.

**Impact of endogenous canola phenolics on the oxidative stability of oil-in-water emulsions**

The aim of this study was to evaluate the antioxidative effect of phenolics naturally present in canola seeds and meal. Individual phenolics were extracted from ground, defatted canola seeds, and meal. Fractionated extracts rich in sinapic acid, sinapine, or canolol as well as a non-fractionated extract were used. These extracts (100 and 350 µM) were evaluated as antioxidants in stripped canola oil-in-water (o/w) emulsion. For comparison, the antioxidative effect of phenolic standards for sinapic acid and sinapine (as sinapine thiocyanate) and butylated hydroxytoluene (BHT) as a positive control were also evaluated. The concentration of lipid hydroperoxides and selected volatiles measured at different time points was used to evaluate the antioxidative effect. Moreover, the properties of extracts and corresponding phenolic standards were evaluated in three different in vitro antioxidant assays. All extracts and standard antioxidants had radical scavenging activity and reducing power. The antioxidant standards and extracts inhibited lipid oxidation in the emulsions compared to no antioxidant added. At 100 µM the effectiveness of the extracts was as follows: sinapine>whole.
At 350 µM the ranking was as follows: canolol ≥ sinapine ≥ whole extract ≥ sinapic acid > Con2. Sinapine and sinapic acid extracts were more efficient antioxidants than the corresponding pure standards. However, the most efficient antioxidant in this study was BHT. The differences in effectiveness may be ascribed to mainly the different chain attached to the phenolic ring, which results in different polarity and thus different location in the emulsions. Practical applications: The result showed stronger antioxidant activity of canola extracts than phenolic standards. Therefore, these canola extracts can be used for protecting canola oil emulsion or other emulsions against lipid oxidation. However, the results indicate that the antioxidant activity of the extracts rich in sinapine and canolol had a concentration-sensitive effect. In order to get the best antioxidative effect, optimization of the concentration to be used for each specific application is necessary.
Phenolipids as antioxidants in omega-3 enriched food products

Foods containing omega-3 PUFA are highly susceptible to oxidation. This causes formation of undesirable flavors and loss of health-beneficial fatty acids. To protect these food products, antioxidant addition may be a solution. Lately, extensive work has been performed on phenolipids and their efficacy in model emulsion systems. Since the polar paradox hypothesis was a simplified statement of the antioxidant efficacy in emulsions, a new term, “cut-off effect”, was introduced. The cut-off effect describes the efficacy of phenolipids in simple emulsions. However, most food products consist of a complex matrix where several factors may influence the oxidative stability, e.g. type and concentration of emulsifier. Thus, a better understanding of the antioxidative effect of phenolipids in complex foods is of great interest.

The aim of this study was to evaluate the antioxidative effect of caffeic acid and its esters, caffeates, in two different fish-oil-enriched food products: mayonnaise and milk. Lipid oxidation was evaluated from 3 parameters measured over storage time: peroxide value, volatiles and tocopherol concentrations. The results demonstrate the influence of the complex emulsions on the antioxidant efficacy.

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Authors: Sørensen, A. M. (Intern), Aleman, M. (Ekstern), Durand, E. (Ekstern), Villeneuve, P. (Ekstern), Bou, R. (Ekstern), Guardiola, F. (Ekstern), Jacobsen, C. (Intern)
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Lipophlization 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 antioxidiant 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 alky 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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Phenolipids as antioxidants in emulsified systems

Lipid oxidation is a major issue in foods containing LC PUFA and substantial efforts have been made to protect lipids against oxidation. Recent studies carried out with phenolipids (lipophilized phenolics) in emulsified systems have shown that increased lipophilicity did not necessarily lead to an increase of the antioxidative effect. When the phenolic compound reaches a certain point of lipophilicity its antioxidative effect decreases. Thus, the polar paradox hypothesis is not valid when the alkyl chain length is above a certain length. Furthermore, the length of the alkyl chain for optimal antioxidant effect has been shown to be influenced by the specific phenolic compound and the type of emulsion.

The overall aim for our work was to evaluate phenolipids with different lipophilicity as antioxidants in emulsified food. In the study presented here caffeic, ferulic and coumaric acid were selected along with their corresponding alkyl esters (C4-C20). The methods used to evaluate the antioxidative effect of the different phenolipids were the CAT assay (o/w emulsion), antioxidant assays (DPPH, Iron chelating and reducing power) and partitioning studies. Moreover, the results from the CAT assay on caffeates were compared to results (PV and volatiles) from a storage experiment with an o/w emulsion.

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Phenolipids as antioxidants in emulsified systems and the effect of alkyl chain length

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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 palmiate 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.

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Authors: Sørensen, A. M. (Intern), Petersen, L. K. (Ekstern), de Diego, S. (Ekstern), Nielsen, N. S. (Intern), Lue, B. (Ekstern), Yang, Z. (Ekstern), Xu, X. (Ekstern), Jacobsen, C. (Intern)
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Web of Science (2017): Impact factor 2.2
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Scopus rating (2016): CiteScore 2.06 SJR 0.712 SNIP 1.042
Web of Science (2016): Impact factor 2.145
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.643 SNIP 0.878 CiteScore 1.85
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Web of Science (2014): Impact factor 1.812
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ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.742 SNIP 0.94 CiteScore 1.75
Web of Science (2011): Impact factor 1.733
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Canola oil is low in saturated fat, high in monounsaturated fat and has a favourable omega-6:omega-3 ratio. Therefore, canola oil has a healthier fatty acid profile compared to other plant oils such as soy oil. Therefore, canola oil is also an ingredient in many food products. However, the content of unsaturated lipid makes canola oil susceptible towards lipid oxidation. Many food products are lipid containing emulsions and a lot of efforts have been put into developing methods to protect the lipids against oxidation. Since lipid oxidation has a negative influence on the shelf life of the foods, efficient antioxidants will result in increased shelf life and thereby increased quality of the food products. Besides tocopherols, canola oil contains different compounds with antioxidative properties. These compounds are Sinapic acid, Sinapine and Canolol; all belonging to the group of phenolic compounds. However, the effect of these endogenous antioxidants on lipid oxidation in o/w emulsion is yet unknown. Hence, the aim of this study was to evaluate the effect of the endogenous phenolics in canola oil on lipid oxidation in o/w emulsion.

For this purpose individual phenolics were extracted from defatted ground canola seeds. Fractionated extracts of Sinapic acid, Sinapine and Canolol was used as well as a non fractionated extract. These extracts was added (100 and 350 μM) to 10% o/w emulsion with stripped canola oil in order to evaluate their effect on lipid oxidation in emulsions. For comparison, the antioxidative effect of phenolic standards for Sinapic acid and Sinapine (as Sinapine thiocyanate) were also evaluated in the emulsions, and BHT was used as a positive control. Emulsions were stored at 3°C and sample was taken at different time point. Evaluation of the antioxidative effect was based on Peroxide Value (PV) and secondary volatile oxidation products by headspace GC supported by evaluation of the properties of the extracts and corresponding phenolic standards in 3 different in vitro antioxidant assays.

**Impact of Endogenous Phenolics in Canola Oil on the Oxidative Stability of Oil-in-Water Emulsions**

Canola oil is low in saturated fat, high in monounsaturated fat and has a favourable omega-6:omega-3 ratio. Therefore, canola oil has a healthier fatty acid profile compared to other plant oils such as soy oil. Therefore, canola oil is also an ingredient in many food products. However, the content of unsaturated lipid makes canola oil susceptible towards lipid oxidation. Many food products are lipid containing emulsions and a lot of efforts have been put into developing methods to protect the lipids against oxidation. Since lipid oxidation has a negative influence on the shelf life of the foods, efficient antioxidants will result in increased shelf life and thereby increased quality of the food products. Besides tocopherols, canola oil contains different compounds with antioxidative properties. These compounds are Sinapic acid, Sinapine and Canolol; all belonging to the group of phenolic compounds. However, the effect of these endogenous antioxidants on lipid oxidation in o/w emulsion is yet unknown. Hence, the aim of this study was to evaluate the effect of the endogenous phenolics in canola oil on lipid oxidation in o/w emulsion.

For this purpose individual phenolics were extracted from defatted ground canola seeds. Fractionated extracts of Sinapic acid, Sinapine and Canolol was used as well as a non fractionated extract. These extracts was added (100 and 350 μM) to 10% o/w emulsion with stripped canola oil in order to evaluate their effect on lipid oxidation in emulsions. For comparison, the antioxidative effect of phenolic standards for Sinapic acid and Sinapine (as Sinapine thiocyanate) were also evaluated in the emulsions, and BHT was used as a positive control. Emulsions were stored at 3°C and sample was taken at different time point. Evaluation of the antioxidative effect was based on Peroxide Value (PV) and secondary volatile oxidation products by headspace GC supported by evaluation of the properties of the extracts and corresponding phenolic standards in 3 different in vitro antioxidant assays.
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.

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.

The efficacy of compounds with different polarities as antioxidant in emulsions with omega-3 lipids

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Scopus rating (2017): CiteScore 1.72 SJR 0.641 SNIP 1.004
Web of Science (2017): Impact factor 1.601
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.64 SJR 0.706 SNIP 0.916
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BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.678 SNIP 0.991 CiteScore 1.66
Web of Science (2015): Impact factor 1.505
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.768 SNIP 1.053 CiteScore 1.68
Web of Science (2014): Impact factor 1.541
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.812 SNIP 1.069 CiteScore 1.71
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Scopus rating (2012): SJR 0.852 SNIP 1.233 CiteScore 1.81
Web of Science (2012): Impact factor 1.592
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.851 SNIP 1.31 CiteScore 1.98
Web of Science (2011): Impact factor 1.773
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
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Scopus rating (2010): SJR 0.765 SNIP 1.08
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BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.879 SNIP 1.192
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.661 SNIP 1.032
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.687 SNIP 0.891
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.67 SNIP 0.887
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.719 SNIP 1
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.763 SNIP 1.021
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.762 SNIP 1.137
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 0.817 SNIP 1.155
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 0.894 SNIP 1.235
Web of Science (2001): Indexed yes
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 (PUFAs) 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.

General information
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Organisations: National Food Institute, University of Burgos, Technical University of Denmark, Aarhus University
Authors: Sørensen, A. M. (Intern), de Diego, S. (Ekstern), Petersen, L. K. (Ekstern), Nielsen, N. S. (Intern), Yang, Z. (Ekstern), Xu, X. (Ekstern), Jacobsen, C. (Intern)
Publication date: 2010
Event: Abstract from 8th Euro Fed Lipid, Munich, Germany.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 272417
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2010
Human milk fat substitute from butterfat: production by enzymatic interesterification and evaluation of oxidative stability

Recent data have suggested that the fatty acid composition and molecular structure of fats in infant formulas should be as similar to human milk fat as possible to obtain optimal fat and calcium absorption from the infant formula. This work investigated the possibilities of using enzyme technology and butterfat as a material to produce a fat similar to human milk fat with respect to the above parameters. Moreover, the oxidative stability of the enzyme modified human milk fat substitute (HMFS) was compared to the fat blend used for the production of HMFS. Using a combination of enzyme technology, fractionation and batch deodorization and with butterfat in combination with soybean oil and rapeseed oil as raw materials it was possible to produce HMFS with a molecular structure and fatty acid composition that was very similar to that of human milk fat. The oxidative stability of the HMFS oil was lower than that of the reference oil with the same fatty acid composition. However, oxidation did not lead to a severe increase in rancidity scores during storage. Rather, the panel gave high intensity scores for other off-flavors such as burnt and bitter. Further optimization of the deodorization process is therefore necessary to remove these off-flavors.

General information
State: Published
Organisations: Division of Seafood Research, National Institute of Aquatic Resources, Center for BioProcess Engineering, Department of Chemical and Biochemical Engineering, National Food Institute, Aarhus University, Novozymes A/S
Authors: Sørensen, A. M. (Intern), Xu, X. (Ekstern), Zhang, L. (Intern), Kristensen, J. B. (Ekstern), Jacobsen, C. (Intern)
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Scopus rating (2016): CiteScore 1.64 SJR 0.706 SNIP 0.916
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BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.678 SNIP 0.991 CiteScore 1.66
Web of Science (2015): Impact factor 1.505
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.768 SNIP 1.053 CiteScore 1.68
Web of Science (2014): Impact factor 1.541
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.812 SNIP 1.069 CiteScore 1.71
Web of Science (2013): Impact factor 1.62
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.852 SNIP 1.233 CiteScore 1.81
Web of Science (2012): Impact factor 1.592
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.851 SNIP 1.31 CiteScore 1.98
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 posses 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.

General information
State: Published
Organisations: Division of Seafood Research, National Food Institute
Authors: Sørensen, A. M. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
Publication date: 2010
Event: Abstract from 101st AOCS Annual Meeting, Phoenix, AZ, United States.
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).

General information
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Organisations: Division of Seafood Research, National Food Institute
Authors: Sørensen, A. M. (Intern), Nielsen, N. S. (Intern), Jacobsen, C. (Intern)
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Main Research Area: Technical/natural sciences
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)
Pages: 1012-1023
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Main Research Area: Technical/natural sciences
Antioxidant strategies to prevent lipid oxidation in omega-3 enriched food emulsions

General information
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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)
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Main Research Area: Technical/natural sciences
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Publication: Research › Conference abstract for conference – Annual report year: 2009

Effect of fish oil concentration and emulsifier on lipid oxidation in fish oil enriched mayonnaise

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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
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Publication: Research › Conference abstract for conference – Annual report year: 2009

The efficacy of compounds with different polarities as antioxidant in fish oil enriched emulsions

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)
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Event: Abstract from 25th LipidForum Symposium. Elsinore, Denmark, June 15-17, Elsinore, Denmark, .
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Applications of natural antioxidants in omega-3-enriched foods

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Jacobsen, C. (Intern), Bruni Let, M. (Intern), Sørensen, A. M. (Intern), Horn, A. F. (Intern), Timm Heinrich, M. (Intern), Nielsen, N. S. (Intern)
Interactions between iron, phenolic compounds, emulsifiers, and pH in omega-3-enriched oil-in-water emulsions

The behavior of antioxidants in emulsions is influenced by several factors such as pH and emulsifier type. This study aimed to evaluate the interaction between selected food emulsifiers, phenolic compounds, iron, and pH and their effect on the oxidative stability of n-3 polyunsaturated lipids in a 10% oil-in-water emulsion. The emulsifiers tested were Tween 80 and Citrem, and the phenolic compounds were naringenin, rutin, caffeic acid, and coumaric acid. Lipid oxidation was evaluated at all levels, that is, formation of radicals (ESR), hydroperoxides (PV), and secondary volatile oxidation products. When iron was present, the pH was crucial for the formation of lipid oxidation products. At pH 3 some phenolic compounds, especially caffeic acid, reduced Fe3+ to Fe2+, and Fe2+ increased lipid oxidation at this pH compared to pH 6. Among the evaluated phenols, caffeic acid had the most significant effects, as caffeic acid was found to be prooxidative irrespective of pH, emulsifier type, and presence of iron, although the degrees of lipid oxidation were different at the different experimental conditions. The other evaluated phenols were prooxidative at pH 3 in Citrem-stabilized emulsions and had no significant effect at pH 6 in Citrem- or Tween-stabilized emulsions on the basis of the formation of volatiles. The results indicated that phenol-iron complexes/nanoparticles were formed at pH 6.
Web of Science (2017): Impact factor 3.412
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.45 SJR 1.305 SNIP 1.343
Web of Science (2016): Impact factor 3.154
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.224 SNIP 1.245 CiteScore 3.23
Web of Science (2015): Impact factor 2.857
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.267 SNIP 1.413 CiteScore 3.25
Web of Science (2014): Impact factor 2.912
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.43 SNIP 1.47 CiteScore 3.44
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ISI indexed (2013): ISI indexed yes
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BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.408 SNIP 1.464 CiteScore 3.2
Web of Science (2012): Impact factor 2.906
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.389 SNIP 1.441 CiteScore 3.1
Web of Science (2011): Impact factor 2.823
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.42 SNIP 1.391
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Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.33 SNIP 1.306
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.327 SNIP 1.338
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.252 SNIP 1.44
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Scopus rating (2006): SJR 1.367 SNIP 1.418
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.298 SNIP 1.517
Web of Science (2005): Indexed yes
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Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 1.152 SNIP 1.469
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 1.219 SNIP 1.532
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Interactions between phenolic compounds, emulsifiers and Ph in Omega-3 enriched emulsions

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Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources
Authors: Jacobsen, C. (Intern), Sørensen, A. M. (Intern), Becker, E. (Ekstern), Skibsted, L. (Ekstern), Bergenståhl, B. (Ekstern)
Publication date: 2008
Event: Poster session presented at 99th AOCS Annual Meeting & Expo, Seattle, WA, United States.
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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

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Homogenization conditions affect the oxidative stability of fish oil enriched milk emulsions: Lipid oxidation

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Aquatic Lipids and Oxidation, Center for BioProcess Engineering, Department of Chemical and Biochemical Engineering
Authors: Bruni Let, M. (Intern), Jacobsen, C. (Intern), Sørensen, A. M. (Intern), Meyer, A. S. (Intern)
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Publication date: 2007
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Web of Science (2017): Impact factor 3.412
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.45 SJR 1.305 SNIP 1.343
Web of Science (2016): Impact factor 3.154
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.224 SNIP 1.245 CiteScore 3.23
Web of Science (2015): Impact factor 2.857
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BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.267 SNIP 1.413 CiteScore 3.25
Web of Science (2014): Impact factor 2.912
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.43 SNIP 1.47 CiteScore 3.44
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ISI indexed (2013): ISI indexed yes
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BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.408 SNIP 1.464 CiteScore 3.2
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ISI indexed (2012): ISI indexed yes
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ISI indexed (2011): ISI indexed yes
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BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.42 SNIP 1.391
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Scopus rating (2009): SJR 1.33 SNIP 1.306
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.327 SNIP 1.338
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.252 SNIP 1.44
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.367 SNIP 1.418
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.298 SNIP 1.517
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.353 SNIP 1.489
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 1.152 SNIP 1.469
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 1.219 SNIP 1.532
Web of Science (2002): Indexed yes
Homogenization conditions affect the oxidative stability of fish oil enriched milk emulsions: Oxidation linked to changes in protein composition at the oil-water interface

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Department of Systems Biology
Authors: Sørensen, A. M. (Intern), Baron, C. (Intern), Bruni Let, M. (Intern), Brüggemann, D. A. (Intern), Pedersen, L. (Ekstern), Jacobsen, C. (Intern)
Pages: 1781-1789
Publication date: 2007
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Agricultural and Food Chemistry
Volume: 55
Issue number: 5
ISSN (Print): 0021-8561
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.64 SJR 1.269 SNIP 1.343
Web of Science (2017): Impact factor 3.412
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.45 SJR 1.305 SNIP 1.343
Web of Science (2016): Impact factor 3.154
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.224 SNIP 1.245 CiteScore 3.23
Web of Science (2015): Impact factor 2.857
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.267 SNIP 1.413 CiteScore 3.25
Web of Science (2014): Impact factor 2.912
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.43 SNIP 1.47 CiteScore 3.44
Web of Science (2013): Impact factor 3.107
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.408 SNIP 1.464 CiteScore 3.2
Web of Science (2012): Impact factor 2.906
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
Phenolipids as antioxidants in omega-3 model and real food systems - Effect of alkyl chain length and concentration

Fish oil contain omega-3 PUFAdue to the content of unsaturated lipids, thefish oil is easily oxidized. Theoxidation and development of rancidity in fishoil can be inhibited or delayedby the addition of antioxidants. Phenolics are compoundspresent in plants and are known to have goodantioxidative properties. However,phenolics are primary water solubleantioxidants, and will in many food products(emulsions) be located in the water phase and not close to the interface wherethe oxidation isinitiated.

The lipophilicity of thephenolics can be modified by attaching a fattyacid to the phenolic compound(Phenolipids). This modification will change thelocation of the new phenolipid in emulsions, which may increase theirantioxidant activity due to the location.

The aim of the project are toevaluate the optimale chain lenght of thefatty acid attached to differentphenol in order to give optimale antioxidantactivity in different foodemulsion systems. Second aim of the project is todevolpe mathematicallymodels, there can be use by the industry to predict theefficacy of the newsynthesized phenolipids.

Activities
Research stay at UMR IATE, CIRAD, Montpellier, France - Producing Phenolipids, September 2011 – March 2012
103rd AOCS Annual Meeting & Expo, Long Beach, California, USA, April 29 – May 2, 2012 - Phenolipids as antioxidants in emulsified systems and the effect of alkyl chain length (Ann-Dorit Moltke Sørensen, Christelle Bayrasy, Mickaël Laguerre, Jérôme Lecomte, Pierre Villeneuve and Charlotte Jacobsen)
See AOCS 2012 abstract ADMS in the right column
Research stay at SINTEF, Trondheim, Norway - Introduction to Oxygraph, June 2012
10th Euro Fed Lipid Congress, Cracow, Poland, September 23 -26, 2012 - Phenolipids as antioxidants in emulsified systems (Ann-Dorit Moltke Sørensen, Christelle Bayrasy, Mickaël Laguerre, Jérôme Lecomte, Pierre Villeneuve and Charlotte Jacobsen)

Phenolipids as antioxidants in omega-3 model and real food systems - Effect of alkyl chain length and concentration

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Activities
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See AOCS 2012 abstract ADMS in the right column
Research stay at SINTEF, Trondheim, Norway - Introduction to Oxygraph, June 2012
10th Euro Fed Lipid Congress, Cracow, Poland, September 23 -26, 2012 - Phenolipids as antioxidants in emulsified systems (Ann-Dorit Moltke Sørensen, Christelle Bayrasy, Mickaël Laguerre, Jérôme Lecomte, Pierre Villeneuve and Charlotte Jacobsen)
See EFL 2012 abstract ADMS in the right column

104th AOCS Annual Meeting & Expo, Montreal, Quebec, Canada, April 28 – May 1, 2013.

See AOCS 2013 abstract ADMS in the right column

Phenolipids as antioxidant in omega-3 enriched food products (Ann-Dorit Moltke Sørensen, Mercedes Alemán, Erwann Durand, Pierre Villeneuve, Ricard Bou, Francesc Guardiola & Charlotte Jacobsen)

Presentation: Delivery of antioxidants in bulk oil, food and emulsions (Ann-Dorit Moltke Sørensen & Charlotte Jacobsen)


See ACS 2013 abstract ADMS in the right column


See EFL 2013 abstract ADMS in the right column


See AOCS 2014 abstract ADMS in the right column

Publications


National Food Institute

Division of Industrial Food Research
Period: 01/07/2011 → 30/06/2014
Number of participants: 4
Project participant:
Jacobsen, Charlotte (Intern)
Villeneuve, Pierre (Ekstern)
Storø, Ivar (Ekstern)
Project Manager, academic:
Sørensen, Ann-Dorit Moltke (Intern)

Financing sources
Source: Public research council
Name of research programme: Danish Agency for Science Technology and Innovation Danish Council of Independent Research (DFF), Technology and Production
Amount: 3,479,916.00 Danish Kroner
Documents:
ACS 2013 Abstract ADMS
AOCS 2012 Abstract ADMS
AOCS 2013 Abstract ADMS
AOCS 2014 Abstract ADMS
EFL 2012 Abstract ADMS
EFL 2013 Abstract ADMS
Project
Phenolipids as antioxidants in omega-3 model and real food systems - Effect of alkyl chain length and concentration

Fish oil contain omega-3 PUFA due to the content of unsaturated lipids, the fish oil is easily oxidized. The oxidation and development of rancidity in fish oil can be inhibited or delayed by the addition of antioxidants. Phenolics are compounds present in plants and are known to have good antioxidative properties. However, phenolics are primary water soluble antioxidants, and will in many food products (emulsions) be located in the water phase and not close to the interface where the oxidation is initiated. The lipophilicity of the phenolics can be modified by attaching a fatty acid to the phenolic compound (Phenolipids). This modification will change the location of the new phenolipid in emulsions, which may increase their antioxidant activity due to the location. The aim of the project are to evaluate the optimale chain length of the fatty acid attached to different phenolic in order to give optimale antioxidant activity in different food emulsion systems. Second aim of the project is to develope mathematically models, there can be use by the industry to predict the efficacy of the new synthesized phenolipids.

Activities Research stay at UMR IATE, CIRAD, Montpellier, France - Producing Phenolipids, September 2011 – March 2012 103rd AOCS Annual Meeting & Expo, Long Beach, California, USA April 29 – May 2, 2012 - Phenolipids as antioxidants in emulsified systems and the effect of alkyl chain length (Ann-Dorit Moltke Sørensen, Christelle Bayrasy, Mickael Laguerre, Jerome Lecomte, Pierre Villeneuve and Charlotte Jacobsen); Conference abstractResearch stay at SINTEF, Trondheim, Norway - Intoduction to Oxygraph, June 2012 0th Euro Fed Lipid Congress, Cracow, Poland, September 23 -26, 2012 - Phenolipids as antioxidants in emulsified systems (Ann-Dorit Moltke Sørensen, Christelle Bayrasy, Mickael Laguerre, Jerome Lecomte, Pierre Villeneuve and Charlotte Jacobsen).

National Food Institute
Division of Industrial Food Research
Period: 01/07/2011 → 01/06/2014
Number of participants: 4
Acronym: Phenolipids as antioxidants
Contact person:
Jacobsen, Charlotte (Intern)
Project participant:
Villeneuve, Pierre (Ekstern)
Storø, Ivar (Ekstern)
Project Manager, organisational:
Sørensen, Ann-Dorit Moltke (Intern)
Project

Improvement of Oxidative Stability of Fish Oil Enriched Foods - Ingredients Interactions and Antioxidant Effects

National Food Institute
Period: 01/08/2006 → 23/06/2010
Number of participants: 6
Phd Student:
Sørensen, Ann-Dorit Moltke (Intern)
Supervisor:
Nielsen, Nina Skall (Intern)
Main Supervisor:
Jacobsen, Charlotte (Intern)
Examiner:
Hellgren, Lars (Intern)
Olsen, Karsten (Ekstern)
Villeneuve, Pierre (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Ansat eksternt
Project: PhD

Activities:

Antioxidant composition and activity of seaweed Saccharina latissima: a seasonal perspective
Period: 19 Jun 2017
Goncalo Silva Marinho (Speaker)
Ann-Dorit Moltke Sørensen (Speaker)
Description
Safety concerns regarding reported toxicity of artificial antioxidants lead the search for novel natural antioxidants. In this context, seaweeds have been receiving increasing attention as a promising source of antioxidants such as phenolic compounds (e.g., phenolic acids and flavonoids), carotenoids (e.g., fucoxanthin and β-carotene), and phycobiliproteins. Nevertheless, seaweed composition generally presents marked seasonal variations. The present study aimed at evaluating seasonal variations in the antioxidant composition and activity of sugar kelp, Saccharina latissima, cultivated at two different sites; in close proximity to a blue mussel and rainbow trout farm (IMTA), and at a reference/control site (REF), outside Horsens fjord, Denmark.

Degree of recognition: International
Documents:
Abstract_ISAP 2017-Marinho et al_FINAL

Related external organisation
University of Nantes
France
Activity: Talks and presentations › Conference presentations

OBTENTION OF FUNCTIONAL COMPOUNDS FROM FISH OIL AND PROTEIN (External organisation)
Ann-Dorit Moltke Sørensen (External examiner)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
Written evaluation of the PhD thesis before defence
Degree of recognition: International
Activity: Examinations and supervision › External examination

DEVELOPMENT OF MEAT PRODUCTS FORTIFIED WITH OMEGA-3 RICH OIL OBTAINED FROM FISH BY-PRODUCTS BY SUPERCritical CARBON DIOXIDE EXTRACTION (External organisation)
Period: 2 Jan 2016 → 11 Jan 2016
Ann-Dorit Moltke Sørensen (External examiner)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
DEVELOPMENT OF MEAT PRODUCTS FORTIFIED WITH OMEGA-3 RICH OIL OBTAINED FROM FISH BY-PRODUCTS BY SUPERCritical CARBON DIOXIDE EXTRACTION (External organisation)

Written evaluation of the PhD thesis before PhD defence

Degree of recognition: International
Activity: Examinations and supervision › External examination

Delivery of antioxidants in bulk oil, food and emulsions
Period: 12 Jul 2013
Ann-Dorit Moltke Sørensen (Speaker)
National Food Institute
Related event

Antioxidants: Fundamentals, Applications, and Health Effects
12/07/2013 → 13/07/2013
Chicago, United States
Activity: Talks and presentations › Conference presentations