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THE POTENTIAL OF USING CAPELIN OIL FOR HUMAN CONSUMPTION

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Skýrsluágrip Rannsóknastofnunar fiskiðnaðarins

Icelandic Fisheries Laboratories Report Summary

Titill / Title	**The potential of using capelin oil for human consumption**		
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Ágrip á íslensku:	The objective of this project was increase the value of capelin oil by incorporating this fish oil into food products. Water-in-oil emulsion with fish oil enrichment was selected for this purpose. Egg-free mayonnaise, consisting of commercial emulsifier mixture with whey proteins, was made with 20% fish oil, with and without antioxidant (tocopherol mixture-200 mg/kg), in addition to a control sample without fish oil. The quality and shelf life during storage at 10 °C was evaluated by the development of conjugated dienes/ trienes (CD/CT) and sensory analysis, along with stability tests at 60 °C. Lipid oxidation of the mayonnaise was not increased by fish oil addition although sensory scores for rancidity were higher for fish oil enriched mayonnaise that contained tocopherol as antioxidant. Tocopherol was ineffective as antioxidant in the fish oil enriched mayonnaise and tended to increase oxidative degradation in this study. Optimisation of processing parameters by studies on the effect of raw material qualities and refinement techniques are necessary in order to conclude if capelin oil can be used in functional foods with acceptable sensory qualities. Potential possibilities are however in sight for capelin oil, as this study indicated that accepted stability regarding lipid oxidation could be obtained.		
Lykilorð á íslensku:	*Capelin oil, mayonnaise, lipid oxidation, sensory evaluation*		
Summary in English:	Tilgangur þessarar rannsóknar var stuðla að auknum verðmætum loðnulýsis með því að kanna möguleika á því að nota hágæða loðnulýsi til manneldis. Í þeim tilgangi var majónes valin sem efnileg afurð varðandi notkunarmöguleika og geymsluþol. Notuð var tilbúin ýrublanda sem innihélt mysuprótein til þess að framleiða eggjalaust majónes með 20% loðnulýsi með og án þráavarnarefnis (tókóferólblanda-200 mg/kg), auk viðmiðunarsýnis án lýsis. Gæði og geymsluþol við 10 °C var metið með mælingum á CD/CT (conjugated dienes/conjugated trienes) og skynmati, auk stöðugleikaprófs við 60 °C. Þránun í majónesinu jókst ekki með viðbót loðnulýsis, þó svo skynmatsniðurstöður fyrir þránun væru hærri fyrir lýsisbætt majónes sem var þráavarið með tókóferóli. Tókóferól reyndist áhrifalaust sem þráavarnarefni í lýsisbættu majónesi, en hafið tilhneigingu til þess að örva þránun í þessari rannsókn. Þessi rannsókn gaf vísbendingar um að hægt væri að tryggja stöðugleika loðnulýsis gagnvart þránun í eggjalausu majónesi og þar með möguleika á notkun loðnulýsis til manneldis. Niðurstöður þessarar rannsóknar er tillaga að afurð úr loðnulýsi í formi majóness sem gæti hentað í bragðmikla salatsósu t.d. með fiskréttum, þar sem fiskibragðið fær notið sín. Rannsaka þarf nánar áhrif hráefnisgæða og vinnsluaðferða til þess að unnt sé að álykta um hvort almennt er hægt að nota loðnulýsi í markfæði með viðunandi bragðgæðum.		
English keywords:	Loðnulýsi, majónes, þránun, skynmat		

CONTENTS

1. INTRODUCTION

The significance of fish oils as an important dietary source of A- and D-vitamins, as well as the valuable fatty acids of long chained omega-3 type has been confirmed by research. The diverse beneficial health effects of a diet high in long chain n-3 polyunsaturated fatty acids has been demonstrated by epidemiological studies and reviewed extensively (Schmidt and others 2004; Uauy and Valenzuela 2000). Furthermore, scientific evidence for omega-3 and the need to increase the ratio of omega-3 fatty acids on account of omega-6 fatty acids has recently been reviewed (Simopoulos & Cleland 2003). In order to increase the consumption of marine fatty acids several attempts have been made to incorporate fish oil into different foods (Medina and others 2003, Young 1990, Kolanowski and others 1999). Incorporation of fish oil into food products might also be an effective way to increase the value of fish oils, as they are rarely used for human consumption. The incorporation of omega-3 fatty acids and fish oils into functional food is limited by their high susceptibility to oxidative degradation which leads to rancidity. Nevertheless, several sources indicate that oil-in-water emulsions may be an effective method to deliver omega-3 fatty acids into foods and many studies in this field emphases on oxidation in oil-in-water emulsions rather than bulk lipids because emulsions are more frequently found in actual food products (Coupland & McClements 1996, McClements & Decker 2000). An emulsion consists of thee regions: the interior of a droplet, the continuous phase and the interfacial region, where systems consisting of oil droplets dispersed in an aqueous phase are known as an oil-in water emulsion (Coupland & McClements 1996). Emulsifiers are situated at the oil-water interface because they contain both hydrophilic and hydrophobic groups, and their function is to prevent emulsions to separate into oil and water phases. Mayonnaise is an example of oil-in-water emulsion that is traditionally made of egg yolk as the emulsifying agent. Other ingredients in mayonnaise are oil, water, vinegar, salt, sugar and mustard. Potassium sorbate and sodium benzoate are often added to mayonnaise to inhibit microbial growth, along with vinegar. Furthermore, vinegar, salt, sugar and mustard are added to mayonnaise as flavouring ingredients, but all of these ingredients also seem to play an important role for the physical stability of emulsions (McClements & Decker 2000). Besides egg yolk, many emulsifying agents are applied in oil-in-water emulsions. Whey proteins have gained much attention as emulsifying agents, as they have been found to increase oxidative stability of emulsions, including those containing omega-3 fatty acids (Djordjevic and others 2004b). Whey proteins are believed to inhibit oxidation by chelating prooxidant metals, inactivate free radicals or by forming physical barriers between water-soluble prooxidants and lipids at the lipid-water interface (Donnely and others 1998). Lipid oxidation in oil-in-water emulsions has been extensively studied and is believed to be mainly caused by interaction between lipid hydroperoxides located at the droplet surface and transition metals originating in the aqueous phase. The most successful type of antioxidant in oil-in-water emulsions are therefore those that chelates transition metal ions (McClements & Decker, 2000).

The fish oil consumption in Iceland has to date almost entirely been in the form of a daily spoon of cod liver oil as a health remedy. Other sources of fish oils derive from fish meal production of small, whole fish, such as capelin (*Mallotus villosus*), which is the major part of the Icelandic fish oil production. To date little effort has been made in order to exploit the capelin oil for human consumption. The capelin oil produced in Iceland is mainly exported as an ingredient for use in aquaculture and animal feeds, and is sold for less than half the price of fish oil for human consumption (e.g. cod-liver oil). Consequently, the possibilities to increase the value of capelin oil by incorporating it into food products are encouraging. The capelin is considered to be of prime quality for human consumption just prior to its spawning during late winter months, when part of the catch is frozen as whole fish and exported to Japan where it is considered a delicacy. The oil content in capelin can vary from 2 - 20%, depending on season, and the quality of the crude oil can vary as well, as reflected in the content of free fatty acids, the content of natural antioxidants like tocopherol and astaxanthin, as well as in fatty acid profile (Bragadóttir and others 2002). The fatty acid profile of capelin is unusual, with extraordinary high concentration of monounsaturated fatty acids (MUFA´s), ranging from 46-57% and omega-3 fatty acids (C20:5 + C22:5 + C22:6) ranging from 12.5 to 18% of total fatty acids (Bragadóttir and others 2002). The omega-3 fatty acids of commercial capelin oil can however reach as high as 24%; comprising of approximately 10% for C20:5 (eicosapentaenoic fatty acid - EPA), 13% for C22:6 (docosahexaenoic fatty acid – DHA) and 1.5% for C22:5 (Pálmadóttir 2005).

Long-chained (MUFA´s) are believed to inhibit fatty acid elongation activity and thereby prevent accumulation of very long chain fatty acids (VLFA) as seen in patients with adrenoleukodystrophy (ALD) and Zellweger syndrome (Koike and others 1991). Hexacosanoate (C20:0) is a saturated VLFA and a minor fatty acid component in human tissues, but has been used as a diagnostic marker for peroxisomal disorders including ALD (Koike and others 1991). Elevated levels of erythrocyte membrane C26:0 have been found to be highly correlated with the same risk factors as seen for atherosclerosis (Antoku and others 2000). These noteworthy findings indicate that capelin oil with its high content of long-chained MUFA´s might be of special interest for human health, in addition to the omega-3 fatty acids.

The present investigation was undertaken to evaluate the possibilities to produce food products containing capelin oil and thereby increase its value, with emphasis on the best suitable means to prevent lipid oxidation. Capelin oil was included in egg-free mayonnaise, containing commercial emulsifier mixture with milk proteins. Mayonnaise was selected as a food product for capelin oil incorporation, as oil-in-water emulsions have been extensively studied for the past years, and found to be promising to prevent lipid oxidation and deliver omega-3 fatty acids into foods.

2. MATERIALS & METHODS

Materials

The crude fish oil from capelin (*Mallotus villosus*) was provided by Síldarvinnslan hf., a fish meal factory in Siglufjördur, during the winter season. The fish oil was distilled in a bench top molecular distiller, type: KDL (UIC GmbH, Alzenau-Hörstein, Germany) at 185 ± 2 °C. The oil was packed under nitrogen gas into 1 L brown flasks and kept at -24 °C until used. Soybeen oil was obtained from Kjarnavörur hf, Garðabær, Iceland, the importer of Victoria -refined and deodorized soya oil (produced in Holland by Vereenigde Oil Fabrieken). Coviox T-70, natural 70% tocopherol mixture was purchased from Cognis GmbH (Düsseldorf, Germany). The vinegar, mustard, salt (NaCl) and sugar were purchased from a local supermarket. Sodium benzoate was purchased from Merck

(Darmstadt, Germany). The Grindsted™ FF1110 stabiliser system was provided by Danisco A/S (Langebrogade, Copenhagen), containing; milk protein (whey protein isolate), acetylated distarch adipate (E1422), guar gum (E412) and sodium alginate (E401).

Preparation of mayonnaise

The mayonnaise was made by a recipe from Danisco, Culinary Manual (Langebrogade, Copenhagen), on 70% egg free mayonnaise, by a cold batch process in a mixer (Braun Electronic, type 4265, Germany). Each batch contained by weight; distilled water (18.15%), salt (1.00%), sugar (2.00%) and sodium benzoate (0.10%) that were mixed together. Grindsted™ FF1110 (1.40%) was pre-mixed with oil in a ratio of 1:2 and added to the mixture. The oil (70.00%) was continuously emulsified into the water phase for 25 min. Finally, 10% vinegar (3.50%) and mustard (1.50%) were blended together and added to the emulsion. Three samples were prepared; one with soya oil and two with soya oil mixed with fish oil, with and without addition of tocopherol as antioxidant (**Table 1**). For shelf life testing, the mayonnaise samples were vacuum packed into glass jars (100 mL) for storage in the dark at 10-12 °C.

Table 1. Combinations of oils for the mayonnaise samples.

Code name	Soya oil (%)	Fish oil (%)	Tocopherol (mg/kg oil)
S	100	-	-
F	80	20	-
T	80	20	200

Free fatty acids

Free fatty acids (FFA) were determined in the lipid extracts after evaporation (37 °C, vacuum), solubilized in alcohol/diethyl ether (1:1) and titrated with diluted NaOH (AOCS, 1998).

Peroxide value

Peroxide value of oils was measured by iodometric titration according to AOAC official method 965.33 (AOAC 1990).

Anisidine value

Anisidine value of oils was determined by the reaction of aldehydic compounds in oil and *p*-anisidine, and absorbance measured at 350 nm, according to standard methods (IUPAC 1987).

Conjugated dienes (CD) and conjugated trienes (CT)

The determination of the absorbance in the UV spectrum of the samples was measured at 232 nm as conjugated dienes and at 268 nm as conjugated trienes according to standard methods (IUPAC 1987), with minor modifications. Mayonnaise emulsions (0.150 g) were dissolved in methanol (20-25 mL) and mixed for 20 s with Ultra-Turrax homogenizer (type T25, IKA Werke, Staufen, Germany). The samples were centrifuged at 6500*g* for 5 min and the absorbance of the supernants measured. Two measurements were performed on duplicate samples and the results expressed according to the following formula: CD or CT = A_{232} or A_{268} / c x d; where A is the absorbance reading at 232 or 268 nm, c denotes the concentration of the solution in g per 100 mL and d is the length of the cell, in cm.

pH

The pH was measured using a puncture, combination electrode (SE 104, Mettler Toledo, Greifensee, Switzerland) connected to a pH meter (Knick-Portamess 913 pH, Berlin, Germany).

Sensory analysis

Samples were evaluated by Quantitative Descriptive Analysis (QDA) method (Stone and Sidel 1985). The method assumes detailed description of a product, such as odour, flavour, appearance and texture. List of attributes are defined and used with unstructured scale. The Icelandic Fisheries Laboratories (IFL) sensory panel was trained in two sessions. Panel members have several years of experience in evaluating rancidity of fish, fish oils and vegetable oils and have been trained according to international standards (ISO 1993). Freshly made mayonnaise with pure soya oil, soya and fish oil (70:30) as well as soya and rancid fish oil (70:30) was used for training the panel. The panel compiled 16 descriptive attributes for mayonnaise, ranging from not present to strong; each for both odour and taste: acetic acid, oily, musty, painty, fish oil, rancid, acidic, and for texture and appearance; creamy, clammy and colour (white/yellow).
Sensory assessments were carried out by seven to eight assessors (age range 30 - 60). Six samples were evaluated (three different samples each in duplicate) in two sessions, three at each. Sensory analysis, data collection and data analysis were done in the sensory program Fizz version 1.3 (Biosystemes, France). The order of presentation of samples to the panelists was balanced to minimize possible carry-over effects between samples. All observations of samples were conducted under standardized conditions, with as little interruption as possible, at room temperature, and under white fluorescent light. The mayonnaise was presented to the panelists in small, transparent, disposable plastic cups covered with an aluminium foil, along with water and crackers for oral rinsing between samples.

Oxidative stability

The oxidative stability of the mayonnaise was measured electronically under oxygen pressure (5 bars) in an Oxipres apparatus (Mikrolab Aarhus A/S, Højbjerg, Denmark). Samples (7 g) were weighed into reaction flasks (125 mL) and the pressure signal was recorded at 60 °C. Each sample was measured in duplicate and the results presented as mean values.

Data Analysis

Statistical analysis was done on the data by analysis of variance (ANOVA) on Number Cruncher Statistical Software (NCSS 2000 and Pass Trial, Kaysville, Utah). Duncan comparison test used to determine differences between samples ($P < 0.05$).

3. RESULTS

Measurements on oils as raw materials in mayonnaise

Efforts were made to ensure that the oils used as raw materials for the mayonnaise were of high quality. The peroxide value (PV) of the soya oil was 1.0 meq/kg, whereas the PV of the distilled fish oil was not detected. The anisidine value (AV) of the fish oil was therefore also measured to verify its quality, and was found to be low, with AV of 2.5. For comparison, the range of AV in commercial capelin oil (58 samples) measured at our lab were approximately 2 to 17, with an average of roughly 6. These samples were mostly made up of crude capelin oil that usually has lower AV than a more processed oil. Our prior results with capelin oil, showed that the AV increased from 7.4 in crude oil to 8.5 in alkali refined oil, increasing further to 16.2 after bleaching of the oil, and the AV ended in 21.2 for the same oil after deodorization (Bragadóttir and others 1992). In order to minimize negative effects of advanced processing, the fish oil used in this study was only refined by molecular distillation. The distillation decreased the content of fatty acids (FFA) from 2.04% in the crude oil to 0.3%, and the AV decreased from 4.6 to 2.5.

CD and CT

Absorbance around 232 nm is a measure of conjugated dienes (CD) which may result from decomposition of linoleic hydroperoxides (IUPAC 1987), an initial product of oxidation and this measurement has shown high correlation with other measurements of primary oxidation like peroxide value in olive oil triacylglycerols (Gómez-Alonso and others 2004), as well as with headspace oxygen in soybean oil (Chung and others 2004). Secondary products of autoxidation and, particularly ethylenic diketones, show an absorption band at approximately 268 nm together with conjugated trienes (CT) (IUPAC 1987). This measurement has shown good correlation with other measures of oxidation products as dimers and polymers of triacylglycerols from olive oil (Gómes-Alonso and others 2004). CT-values (presented as A_{268}) were also found to increase with oxidation during frozen storage of herring (Undeland and others 1998).

The CD values of mayonnaise in this study increased fast during the first week of storage from approximately 0.4 to 1.3-1.6 (**Figure 1**). Little difference was observed in CD-values between samples, although the control sample S (mayonnaise without fish oil) ended in higher value of approximately 2, compared to 1.8 in the F sample, consisting of fish oil enriched mayonnaise without antioxidant addition ($P < 0.05$).

The CT values showed similar behaviour, with an incensement in the first week of storage, a lag phase between 1 and 3 weeks and a subsequent incensement (**Figure 2**). The values increased from approximately 0.15 to 0.6-0.8, and the control sample (S) had in fact higher CT values than the F sample after 1 and 6 weeks storage ($P < 0.05$). While the tocopherol addition (sample T) did not improve the stability of the fish oil mayonnaise as measured by CD or CT.

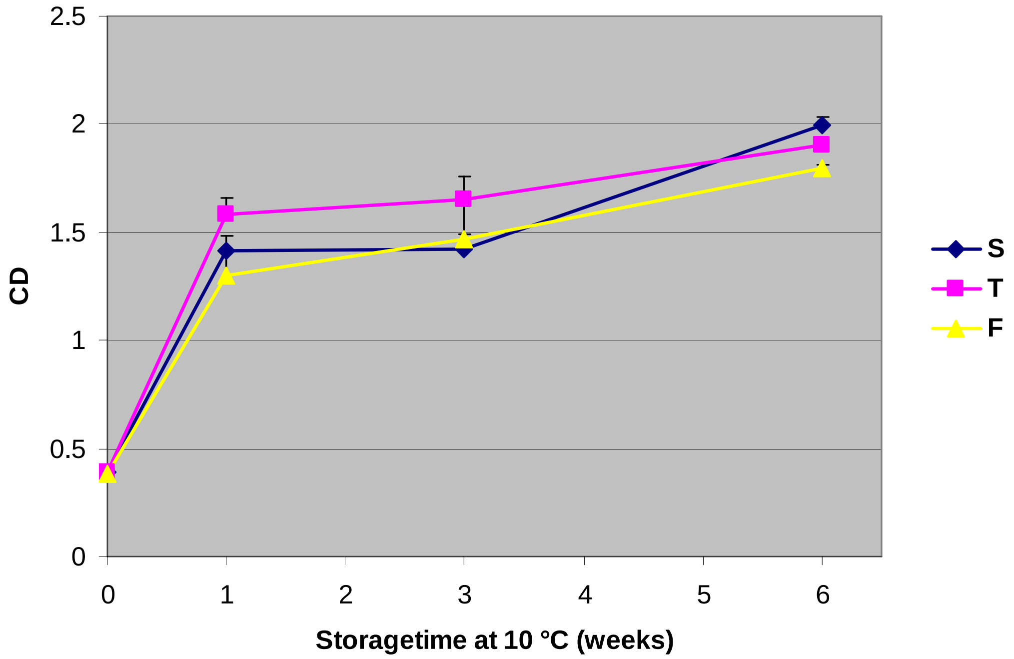

Figure 1. Changes in conjugated dienes (CD) during storage of mayonnaise (*n* = 2). S: mayonnaise with 100 % soya oil, F: mayonnaise with soya and fish oil (80:20), T: same as F with tocopherol as antioxidant (200 mg/kg).

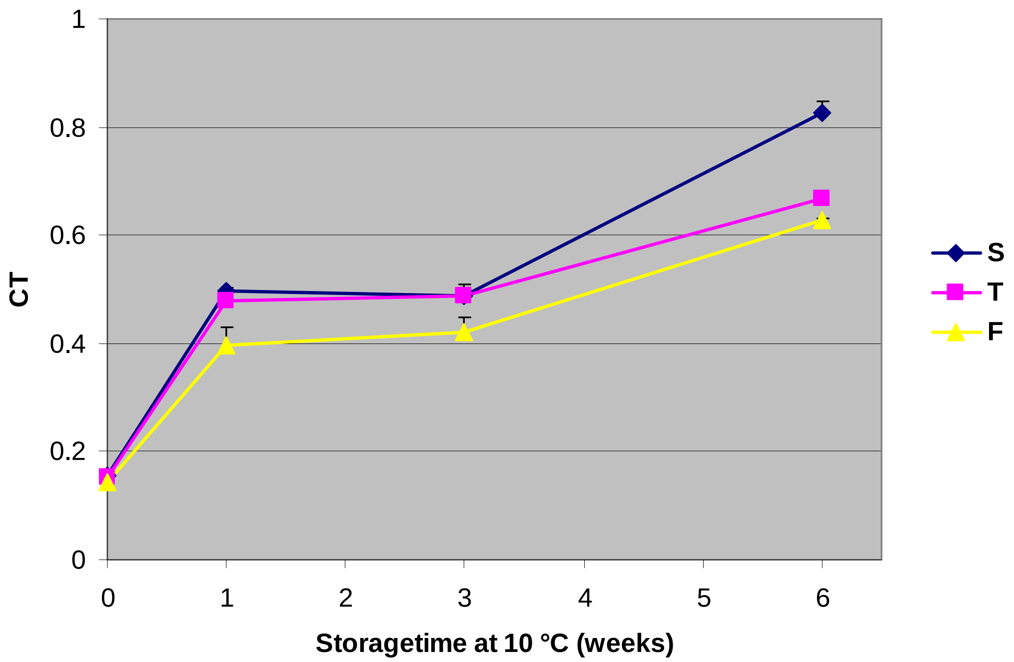

Figure 2. Changes in conjugated trienes (CT) during storage of mayonnaise (*n* = 2). For abbreviations, see Figure 1.

Sensory analyses

The “home made”, egg-free mayonnaise prepared with diverse ingredients according to producers recipe, contained 3.5% vinegar of 10% concentration, resulted in rather sour mayonnaise with pH of approximately 3.8. The vinegar odour and taste were also the most dominant sensory attributes for all samples, along with a thick and creamy texture (**Table 2**). Furthermore, the colour of fish oil added mayonnaise (both F and T) was more yellow than soya oil mayonnaise (S) ($P < 0.05$). This colour difference between the two oils was obvious, soya oil being very pale yellow and the fish oil more orange in colour, that resulted in a yellow mayonnaise in combination with soya oil, which alone produced almost white mayonnaise (**Figure 3**).

Odour attributes of mayonnaise revealed little differences between samples except for fish oil odour, where the S sample showed tendencies to be lower than the other samples, although only significantly lower than sample T after 6 weeks storage ($P < 0.05$). The S sample had values for fish oil odour ranging from 1 to 6, where as the F sample had values ranging from 11-22 and the T sample had values from 11 and reaching 27 at the end of the storage time (**Table 2**). The score for fish oil taste was higher for both F and T samples than the S sample throughout the storage time ($P < 0.05$). The fish oil taste did however not increase in these samples during the storage, ranging from 0 to 9 in the S sample, but around 30 for the F and T samples throughout the storage time (**Figure 4**).

Figure 3. Mayonnaise in plastic cups. From left; mayonnaise with soya and fish oil (80:20) (F) and mayonnaise only with soya oil (S).

Table 2. Sensory scores (n = 7-8, mean ± SD) for descriptive attributes of mayonnaise during storage on scale from 0-100 (not present to strong).

			Weeks at 10 °C											
		Sample	0			1			3			6		
Odour	vinegar	S	60	±	18	57	±	14	61	±	11	53	±	16
		T	57	±	12	56	±	17	57	±	12	55	±	16
		F	57	±	12	52	±	16	59	±	16	58	±	16
	oily	S	9	±	10	20	±	20	26	±	26	22	±	24
		T	16	±	14	18	±	16	18	±	16	16	±	13
		F	16	±	14	17	±	15	21	±	14	20	±	14
	musty	S	4	±	7	2	±	3	3	±	5	4	±	6
		T	5	±	8	2	±	4	10	±	13	6	±	10
		F	5	±	8	3	±	6	4	±	7	6	±	10
	painty	S	8	±	13	4	±	9	8	±	15	9	±	14
		T	7	±	12	10	±	14	13	±	16	11	±	14
		F	7	±	12	12	±	12	9	±	11	13	±	14
	fish oil	S	1	±	1	4	±	11	6	±	11	2	±	5
		T	11	±	19	15	±	14	13	±	18	27	±	25
		F	11	±	19	22	±	17	10	±	8	14	±	25
	rancid	S	1	±	2	0	±	0	2	±	6	1	±	2
		T	4	±	6	3	±	7	5	±	13	8	±	15
		F	4	±	6	3	±	6	2	±	4	2	±	12
Taste	vinegar	S	55	±	11	60	±	11	58	±	13	56	±	14
		T	57	±	14	57	±	12	60	±	10	58	±	17
		F	57	±	14	51	±	21	58	±	17	56	±	16
	oily	S	17	±	12	29	±	18	30	±	22	28	±	24
		T	17	±	14	21	±	20	23	±	14	22	±	11
		F	17	±	14	22	±	19	22	±	14	22	±	14
	musty	S	10	±	16	2	±	3	9	±	15	9	±	10
		T	11	±	11	6	±	9	9	±	15	12	±	18
		F	11	±	11	6	±	9	6	±	12	11	±	18
	painty	S	9	±	14	5	±	9	13	±	18	16	±	15
		T	8	±	12	11	±	12	19	±	17	13	±	14
		F	8	±	12	12	±	14	6	±	13	17	±	16
	fish oil	S	0	±	1	4	±	11	9	±	17	2	±	4
		T	27	±	30	30	±	24	28	±	24	33	±	24
		F	27	±	30	31	±	16	28	±	20	30	±	27
	rancid	S	4	±	11	0	±	1	2	±	5	5	±	7
		T	8	±	9	6	±	7	11	±	21	16	±	23
		F	8	±	9	7	±	9	3	±	4	6	±	18
Texture	thick	S	64	±	13	66	±	11	65	±	10	63	±	19
		T	57	±	13	64	±	10	67	±	8	65	±	13
		F	57	±	13	60	±	12	53	±	16	56	±	14
	creamy	S	66	±	10	68	±	13	63	±	10	66	±	14
		T	57	±	11	58	±	12	66	±	9	65	±	10
		F	57	±	11	59	±	9	57	±	14	58	±	14
	clammy	S	19	±	18	19	±	19	22	±	19	25	±	26
		T	18	±	18	20	±	18	28	±	24	24	±	27
		F	18	±	18	19	±	15	22	±	24	23	±	25
	colour	S	13	±	7	12	±	8	12	±	6	9	±	6
		T	56	±	15	59	±	19	53	±	16	57	±	18
		F	56	±	15	64	±	15	61	±	14	54	±	17

[a] S: mayonnaise with soya oil, F: mayonnaise with soya and fish oil (80:20), T: same as F with tocopherol as antioxidant (200 mg/kg).

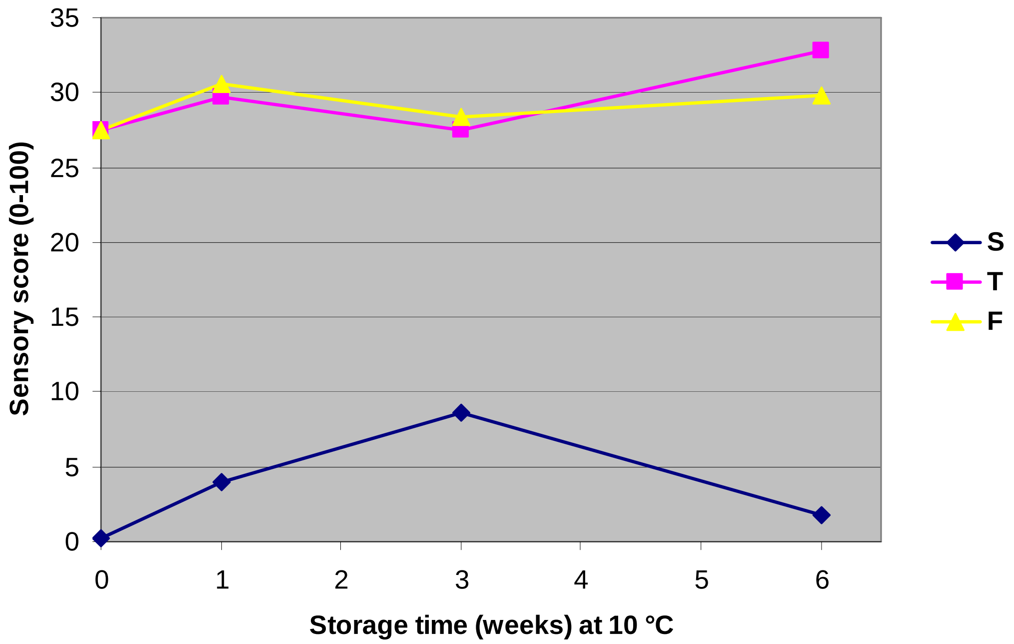

Figure 4. Evaluation of fish oil taste by sensory panel (n = 7-8). For abbreviations, see Figure 1.

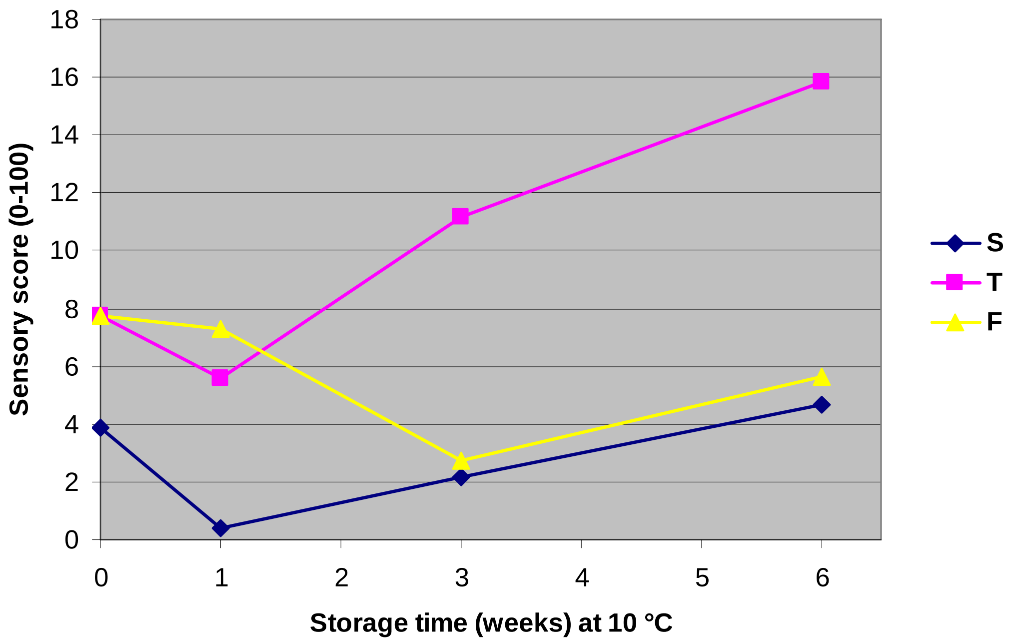

Figure 5. Evaluation of rancid taste by sensory panel (n = 7-8). For abbreviations, see Figure 1.

As for the rancidity taste, there was a more rancid tendency during storage of the T sample than in the S sample ($P = 0.07$), ending in rancidity score of 16 for T but 5 for the S sample (**Figure 5**). The F sample was surprisingly more in range with the S sample, with rancidity scores from 3 to 8.

Stability test with Oxipres

Stability test of mayonnaise samples revealed very little difference between samples, as the pressure drop occurred at almost the same time in all samples (**Figure 6**). Surprisingly, the F sample of fish oil added mayonnaise with no antioxidant was neither less stable than the control sample (S) nor the T sample with tocopherol (200 mg/kg) as antioxidant, but seemed to oxidize somewhat slower in the end of the test than the other samples.

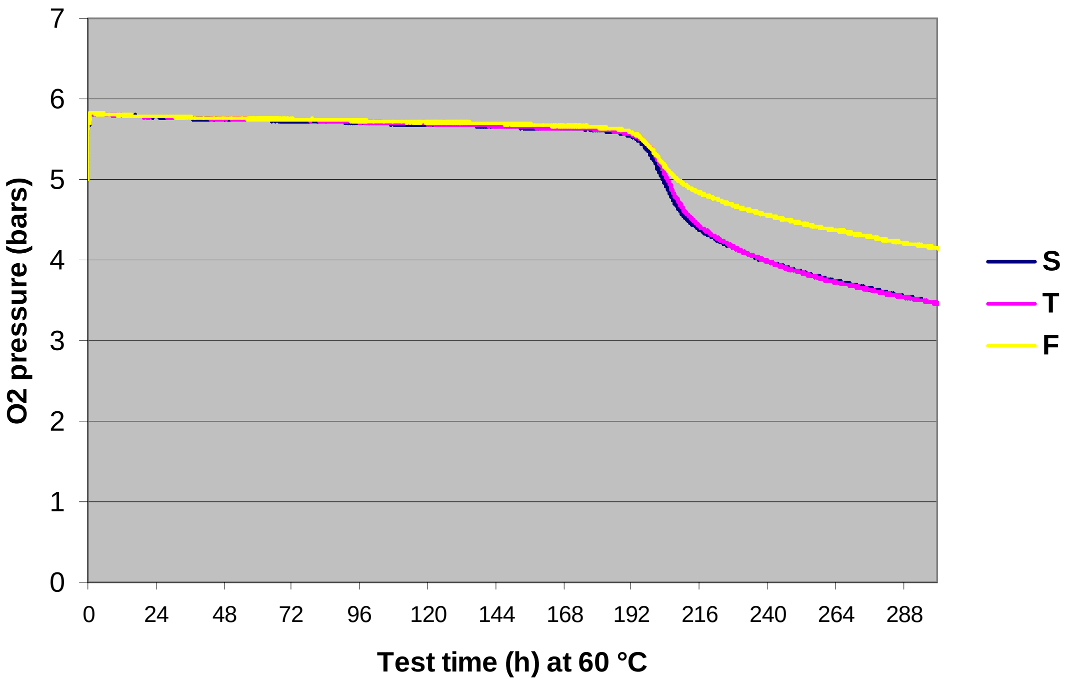

Figure 6. Oxipres results from mayonnaise ($n = 2$). For abbreviations, see Figure 1.

4. DISCUSSION

The results from the chemical measurements (CD and CT), as well as the Oxipres stability test, indicated that there was little difference in the oxidative stability of the control soya oil mayonnaise and the fish oil enriched mayonnaise. In fact these results give the impression that the fish oil enriched mayonnaise was doing slightly better during storage. The sensory analysis, on the other hand, gave a clear message; the enrichment of fish oil into mayonnaise could be detected by fish oil taste (and odour) with sensory scores around 4 for the control mayonnaise and 30 (on a scale from 0 – 100) for fish oil enriched mayonnaise, and the rancid taste was also more pronounced in the fish oil enriched mayonnaise

Comparable observations have been reported from studies with conventional egg yolk mayonnaise, where mayonnaise containing 16% fish oil did not oxidise faster than mayonnaise without fish oil, judged from chemical parameters such as peroxide value and volatile oxidation products by dynamic headspace GC-MS (Jacobsen and others 1999). The same mayonnaise did however develop unpleasant off-odours and off-flavours much faster than the mayonnaise without fish oil. The authors proposed that the fishy off-flavour compounds, in fish oil enriched mayonnaise might be caused by volatile compounds in trace amounts, with low sensory threshold, present in the water phase of the mayonnaise. That might explain why the oxidation was not higher in fish oil enriched mayonnaise, because the measurements were done on the lipid fraction and not in the water phase. Moreover, the measurement on volatile compounds may not be as sensitive to small amounts of off-flavour compounds as the sensory panel.

The antioxidant addition of mixed tocopherols in the fish oil enriched mayonnaise did not improve the oxidative stability or the sensory quality of the mayonnaise tested in this study, but showed tendencies to induce rancidity during storage according to sensory evaluation. These results were in fair agreement with the work of Jacobsen and co-workers (2000) that found no difference in the development of volatile off-flavour as evaluated by GC-MS, but the peroxide values were slightly increased in tocopherol (200 mg/kg) added mayonnaise. The sensory perception of the fish oil enriched mayonnaise was on the other hand not affected by the tocopherol addition in their study. Likewise, tocopherol did not appear to be an efficient antioxidant in another study with both waterdispersible tocopherols and oil-soluble tocopherols in 20-280 mg/kg concentrations added to 16% fish oil enriched mayonnaise (Jacobsen and others 2001).

The pH of the mayonnaise in this study was around 3.8 in all samples, resulting in rather sour mayonnaise, as described by the sensory panel. The pH of emulsions has been found to play an important role for the stability of emulsions as the activity of proteins, such as whey proteins, has been found to be greatest at pH values below the p*I* of the proteins (Hu and others 2003). This effect has been attributed to the ability of the proteins to generate a positive electrical charge on the oil droplets, thereby repelling positively charged transition metal ions (McClements & Decker, 2000). The same research team working with whey protein isolate at pH 3, found that it can be used effectively to protect polyunsaturated lipids from oxidation (Djordjevic and others 2004a, 2004b).

The capelin oil used in this study was only refined by molecular distillation on lab-scale to use as few intervenient processing steps as possible in order to maintain endogenous antioxidants and minimise oxidation. As a result, the fish oil taste might have been more pronounced than by conventional fish oil production involving alkali refinement, bleaching and deodorisation. However, processes like bleaching and deodorisation cause major loss of retinols, tocopherols and other constituents with antioxidant activity as well as health beneficial effects (Scott & Latshaw 1991, Dunford 2001). The emulsion stabiliser system and the recipe from its manufacturer, might have given optimal results in a commercial emulgator but had to be run on lab-scale, that eventually turned out fine after some trials with machinery and processing conditions. More optimal conditions regarding refinement of the capelin oil, concentration of the capelin oil as well as incorporation of the mayonnaise into some tasteful foods, like aromatic salad dressings that could mask the flavour of fish oil are only to mention few of the factors that could be investigated in order to verify if capelin oil could be generously applied for human consumption.

5. CONCLUSIONS

The focus in this preliminary study was to investigate the use of capelin oil in mayonnaise, with emphasis on sensory acceptance. The lab-scale refinement of capelin oil and production of mayonnaise replacing 20% of soya oil with capelin oil, resulted in a mayonnaise with a significant fish oil taste. Lipid oxidation of the mayonnaise was not increased by fish oil addition although sensory scores for rancidity were higher for the fish oil enriched mayonnaise that contained tocopherol as antioxidant. Tocopherol was therefore ineffective as antioxidant in the fish oil enriched mayonnaise using 200 mg/kg of mixed tocopherols, but tended to increase oxidative degradation in this study. Optimisation of processing parameters by studies on the effect of raw material qualities and refinement techniques are necessary in order to conclude if capelin oil can be used in functional foods with adequate sensory acceptance. Potential possibilities are however in sight for capelin oil, as this study indicated that accepted stability regarding lipid oxidation could be obtained.

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