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Report
Proteins with neutral taste from salmon backbones

Development of industrial processes for production of marine proteins with neutral taste

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ABSTRACT
The main goal in this project is to find an economic and profitable technology for production of "tasteless" fish proteins from salmon backbones. Two possible sources/technologies for the isolation of the proteins are evaluated in the project: the solid phase from salmon oil production and a process with cooking of salmon backbones before bone separation. The process where the salmon backbones were cooked before separation (the continuous cooker process) gave the highest product yield. In order to be able to produce tasteless fish proteins with a low amount of lipids, the applied shear forces should be reduced to a minimum throughout the process, as this will make the removal of lipid more efficient.

Preliminary sensory analyses show that the produced fish proteins powders taste intensity is in the same range as that of soya isolates, a common commercial product, sold in large volumes. However, taste panellists usually recognize fish proteins to be fish. Therefore, the use of masking taste compounds could be evaluated. Preliminary sensory results also indicated that taste of the protein powders was not affected by the amount of lipids in the studied samples. This is an important finding, since it opens the door for a simpler, more cost effective process.The type of meat, red or whole meat, used for isolation of proteins could not be distinguished by sensory panellists. Further work should clarify the importance of the lipid content and the stability of these protein powders.

A preliminary economic analysis of the two processes shows that the band cooking process has the highest potential to succeed due to higher yield of protein from the back bones. Based on a raw material price on 2 NOK/kg, crude marine oil NOK 4/kg and on 80 NOK/kg for produced protein powder ethanol extracted protein powder give a net cash flow of 0.78 mill NOK for a process based on roughly 2000 tons/year of salmon backbones. If ethanol extraction can be omitted the net cash flow is 12 mill NOK.
A further stability test on the produced protein powders with accompanying sensory tests are recommended, such study could indicate the potential marked segments for these products.

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APPENDICES

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1 Aim of the project and background

The main goal of this project was to design a technology for production of "tasteless" fish proteins for human consumption from salmon backbones as a more profitable utilisation than for feed.
The work is also a result of recommendations in the project "Development of a profitable processing of odour- and tasteless fish protein ingredients from marine by products" funded by RUBIN report no.204 link; Smakløst and SINTEF report nr F19825 June 2011. This pre-study showed that initial heat denaturation of proteins, followed by several washing steps with hot water and ethanol give a protein powder with a yield of 70% of dry weight from salmon backbone meat. Sensory tests indicated that this protein powder is in the same line as other commercially available protein powders. Markets for "tasteless" and stable marine proteins include sports nutrition, ingredients for meal replacement, fish pates, fish soups, sauces and gratins.

The meat from backbones was in the previous study (SINTEF report nr F19825 June 2011) removed manually. Cooking of the backbones before removal of meat could ease the removal of meat from backbones, in addition initially cooking also could help to remove more lipids from the meat. Homogenisation of meat should theoretically help to disrupt cell structures and thereby facilitate easier lipid removal. On the other hand heavy homogenisation could cause lipid emulsification and hamper lipid removal. Therefore it is important to understand the influence of emulsification of lipids caused by shear forces during the processing.

This project had the following aims:

1. Test of initial separation of salmon backbone meat from cooked salmon backbones with industrial bone separator.

2. Investigate the effect of shear forces during the separation and washing steps, on emulsification of lipids in the salmon meat, and to what extent this influence fat removal from the protein fraction.

3. Investigate if the physical structure of rest fat in the protein fraction affects the stability of the product, mainly lipid oxidation?

4. Clarify whether the solid phase from the salmon oil production by conventional technology could be used for production of tasteless proteins.

5. Economic analysis of the chosen processes.

The project is funded by the Norwegian Seafood Research Fund (NSRF) with 950.000 NOK. The funds from NSRF shall be used for industrial R&D work for the benefit of all or part of the industry. The project was guided by a steering committee with following external members; Sigrun Bekkevold (RUBIN), Robert Wahren (Core Competence AB), Tore Remman (Nutrimar) and Stein Ove Østvik (NSRF) as an observer. During the project period there has been 6 meetings in the steering committee were the on going work has been presented and advised. In the third meeting the steering committee decided to not focus on point 3. Regarding lipid stability, but focus on the other aims.

2 Materials and methods

2.1 Material

Salmon backbones from the filleting line in (SalMar ASA, Kverva-Norway) and/or from the fishmonger (Ravnkloa, manually filleted) were use in the tests.

2.2 Chemical analyses

The moisture in the samples (raw material and the solid fractions) was determined gravimetrically by drying at 104^{o}C for 24 h. Ash content was estimated by charring in a crucible at 550^{o}C until the ash had a white appearance (AOAC, 1990). The measurements were performed in triplicate.
The analyses of total lipid content in raw material and sediments were performed according to the method of Bligh and Dyer (Bligh and Dyer, 1959). The total fat content was determined and expressed as gram lipid pr. gram sample material. The measurements were performed in duplicate.
Total nitrogen (N), determined by CHN-S/N elemental analyser 1106 (Costech Instruments ECS 4010 CHNSO Analysator) and crude protein was estimated by multiplying total N by a factor of 6.25. The measurements were performed in four parallels.

2.3 Sensory analyses

The aim of the analyses was to evaluate the taste intensity of the produced protein powders in comparison with reference powders. For this purpose "ranking" test was performed. The following references were used: Soy protein isolates (WDF-930M, from Norfoods Sweden AB) and milk protein isolates MPI90 (from Milk Specialties Global, USA). The reference samples were kindly provided by Core Competence, Sweden.
Semi-trained sensory evaluators were asked to arrange six coded protein solutions (1% concentration) according to their intensity of taste using the scale from 0 (least intense) to 5 (most intense). The samples that were evaluated were following: four different salmon proteins isolated in the project and two control samples: soya protein isolate and milk protein isolate.

2.4 Colour measurement

Colour measurements were made using a Minolta Chroma Meter CR-200/CR231. L (lightness), a (redness) and b (yellowness) of the dry powders were recorded. Measurements were performed in triplicate.

3 Process optimisation in the lab

3.1 Separation of bones

In the pre-project the meat from salmon backbones were manually removed and heated up till 90°C. One of the aims in this project was to find if cooking of backbones before meat separation could ease the de-boning process and reduce lipid amount in the isolated protein powders. Backbones were divided into 4 pieces and put into boiling water (ratio 1:2). Backbones were cooked for 10 min. Fat that released from backbones during cooking was skimmed by removal of 300 ml of fat/water surface. After skimming, cooked backbones were taken out from the water and red meat or all meat (red plus white meat) was removed by a spoon from the back bone. The yields are given in Table 3.1.1.

Table 3.1.1. Cooking of backbones

Producer	Salmar*		Salmar		Ravnkloa	
fractions	g	yield, %	g	yield, %	g	yield, %
2 backbones	1250	100	1250	100	1200	100
after cooking	1100	88	1050	84	1100	92
scraped cooked meat	600	48				
scraped cooked red meat			400	32	350	29
bones	400	32	600	48	700	58
fat (skimmed)	90	7	90	7	50	4
water phace increase	50	4	50	4		
Sum	1140	91	1140	91	1100	92

*- average of two experiments

Several tests for separating meat from un-cooked back bones have been performed (Rubin reports 4507/131 and 4510/176). The yield from these tests was from manual scraping 36 % read meat, and in this work we report 29 and 32 % read meat. By scraping of both white meat and read meat, a yield of 48 % was achieved. All values based on wet weight. Cooking of the backbones led to easier removal of meat from backbones. The cooking also removed some lipids from the backbones. The de-boned salmon meat from cooked backboned were sent to a de-fatting process.

3.2 The de-fatting process and effect of applied shear forces

3.2.1 The de-fatting process

De-fatting was performed in two steps. The first step (Figure 3.2.1.1) is based on the removal of lipids with hot water.

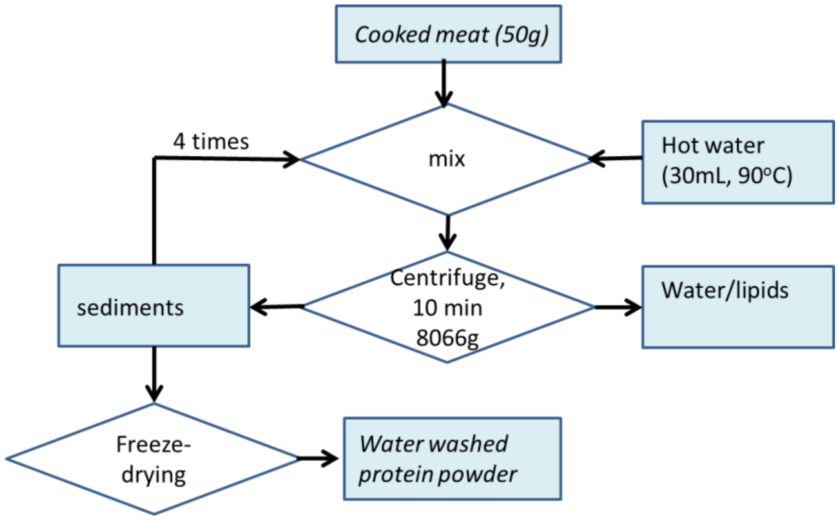

Figure 3.2.1.1. The first the de-fatting step, wash with hot water.

The water washed protein powder goes to the second de-fatting step, extraction of lipids by ethanol (Figure 3.2.1.2.).

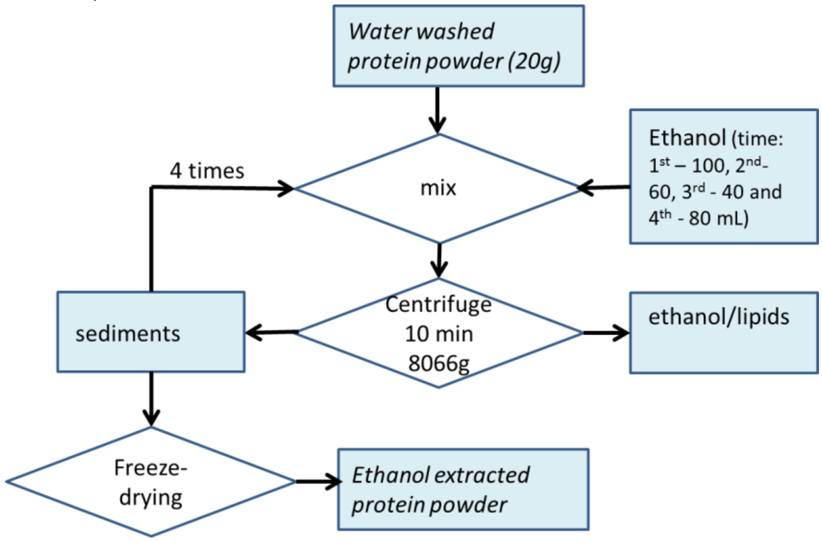

Figure 3.2.1.2. The second de-fatting step, extraction of lipids by ethanol.

3.2.2 Effect of applied shear forces on fat removal

In order to find the effect of applied shear forces on the following de-fatting process, manually deboned cooked meat (red and whole meat) from backbones was homogenised by a food processor with the shear forces; 0: no homogenisation, "low": homogenisation for 1 min at the lowest speed and "high": homogenisation for 2 min at the highest speed.

The same amount of lipids (40% on dry weight basis) in the red and in whole meat deboned manually was obtained. Increased shear forces lead to less lipids removal in the first de-fatting step, wash with hot water (Table 3.2.2.1.). The extraction with ethanol was also not so effective when shear forces was applied on the meat and gave a removal of approx. 10 g of lipids from 100g water washed protein powder (Table 3.2.2.1.).

Table 3.2.2.1 Lipid amount % on dry weight basis as function of various shear forces applied.

Lipid amount % in dry matter	Shear force					
	Whole meat			Red meat		
	0	low	high	0	low	high
De-boned	40	40	40	40	40	40
Water washed	16,2	17,4	27,1	13,2	16,9	26,7
Ethanol extracted	6,7		17,2	5		18,5

Amount of lipids is an essential quality parameter in protein powders. Low lipid concentration is assumed to increase the stability (reduced rancidity) and thereby increasing the quality and price for the protein product. Therefore, in order to obtain protein powder with lowest amount of lipid, minimum shear force should be applied on the raw material.
The fat binding ability seems to be the same in red meat and total meat from salmon back bones. The ethanol extraction reduced the lipid concentration by roughly 10 % points, independent of the lipid content in the meat before extraction

3.2.3 Sensory test

A sensory test was performed on this manually scraped meat. The sensory panellists were asked to evaluate the taste intensity, giving grades from 1 to 5; 1 expressing the weakest taste, and 5 the strongest (Figure 3.2.3.1.).

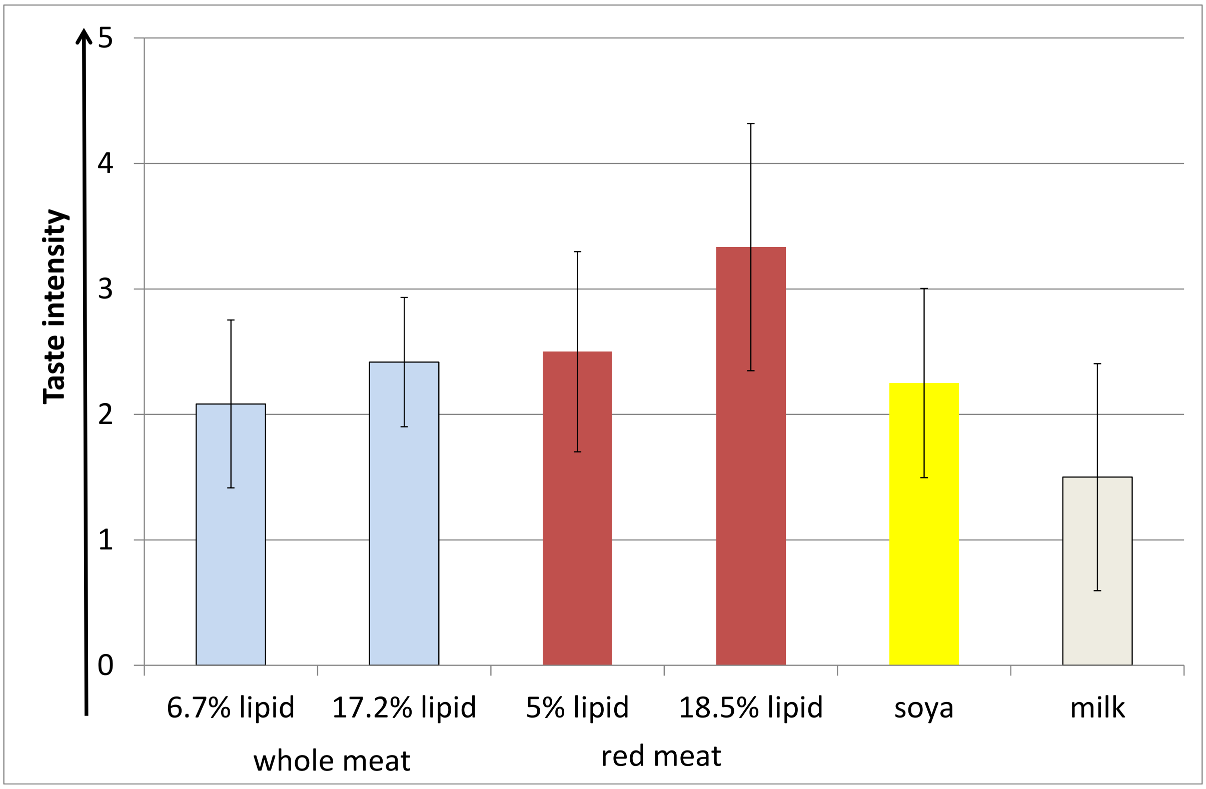

Figure 3.2.3.1 Sensory test of the ethanol extracted protein powders. The test was run evaluating taste intensity from 1 to 5; 1 weakest- and 5 strongest taste.

The taste intensity of fish proteins were evaluated in the same range as soy proteins (as also the previous study, RUBIN report 204). Interestingly the sensory panel recognized no significant taste intensity differences in powders with different lipid content and type of backbone meat (red or whole) (Figure 3.2.3.1.).

4 Pilot scale experiments

The project verified two possible sources/processes for production of fish protein powder: the solid phase (sludge or grakse) from salmon oil production based on back bones and a process with separating meat from cooked salmon backbones. In the first process based on technology for production of salmon oil, the oil is removed first and secondly the bone and the meat are separated. In the cooking process the bones are separated from the meat and the oil and as a second step the oil is removed. The cooking could be industrialized with a continuous band cooker.

4.1 Separating meat from cooked salmon backbones

The principle technological steps in the process with a continuous cooker are:

- Steam cooking of backbones (industrially this can be performed with continuous band cooker Mag 417, GEA).
- Removal of bones. E.g. with Baader bone separator 300.
- De-fatting in two steps;
    1. Hot water wash
    2. Ethanol extraction.

The steam cooking of backbones was performed in the lab by using a conventional oven (SelfCooking Center, Rational, Germany). The 100% and 120°C steam for 10 min was used in order to cook the backbones. The bone removal from steam-cooked backbones was performed by a band separator (Baader 300). A yield of 80% (wet weight) of deboned cooked meat could be gained by using the Baader bone separator. This yield is almost double of yield obtained by manual scraping. The yields of dried protein powders (from wet salmon backbones) after hot water wash and ethanol extraction were 16% and 13%, respectively.

Table 4.1.1. The yields and composition of the backbones, deboned backbone meat, and protein powders (water washed and ethanol extracted) from the cooking process.

Products	Composition, g/100g dry weight					
	yield, g	protein	lipid	ash	color a	taste
wet backbones	1000	42,5	53,3	3,7		
deboned backbone meat Baader	800	42,7	58,0	2	9	
oil yield	160		100			
dried-sediments after water wash	160	83	18	2	7	4
dried-sediments after ethanol wash	138	91,6	8,8	1,4	-1,7	3

4.2 Production and use of solid phase from salmon oil production

4.2.1 Production of salmon oil and solid phase in the pilot plant.

Salmon backbones were transferred to a heavy mincer and further through an industrial meat mincer (with disk hole diameter of 10 mm). The meat mincer was connected directly to a pump which at constant rate fed the minced material into a closed continuous process. The minced material was heated in a scraped surface heat exchanger (Votator, Waukesha Cherry-Burrell) to 90°C. The heated material was directly delivered to a three-phase separator (Flottweg), where the oil, the stick water (water phase) and the solid phase was separated. The solid phase from this process was used for the isolation of tasteless proteins in the lab.

4.2.2 Isolation of tasteless protein from the solid phase.

4.2.2.1 Removing of bones by sieving

The protein powders were produced by using the modified de-fatting procedure described in chapter 3.2.1. The solid phase (300g) was placed on a sieve and 1000ml of water was added (Figure 4.2.2.1.1). The solid phase was stirred manually in order to get the meat through the sieve. Then, the bones in the sieve were removed. Proteins with water were centrifuged in 10 min at 8066g. The sediments (50g) were placed in centrifuge bottles and the water washing steps as described in Figure 3.2.1.1. was followed.

The water washed powders were again sent through the sieve in order to remove remaining parts of bones. The de-boned and water washed powder was extracted with ethanol as described in Figure 3.2.1.2.

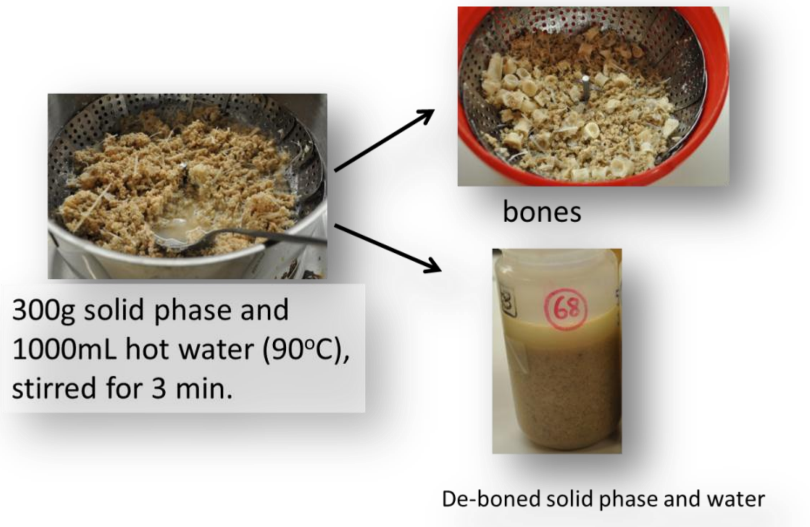

Figure 4.2.2.1.1. The first washing step of the solid phase with hot water and removal of the biggest bones by sieving.

The yield of the isolated protein powders (from wet backbones) was low: 6 % for water washed and 5 % for ethanol extracted dry powders. In addition, the powders contained a high amount of ash (11-12 %).

Table 4.2.2.1.1 Yields and composition of products during the isolation of protein powders from the solid phase.

Products	Composition, g/100g dry weight					
	yield, g	protein	lipid	ash	color a	taste
wet backbones	1000	42,5	53,3	3,7		
wet solid phase	500	52,6	35,5	7,1		
oil yield	160		100			
dried-sediments after water wash	83,3	72	10	15		
dried-sediments after bone removal	60,3	78	14	11	1,1	3,1
dried-sediments after ethanol wash	51,3	88	5	12	-2,8	2,1

4.2.2.2 Removing bones from the solid phase by Baader separator

Baader bone separator was tested for the removal of bones from the solid phase. The yield of de-boned sediment was approx. 78%. The deboned sediment was water washed and ethanol extracted as described in chapter 3.2.1. The yield and composition of proteins from the de-boned solid phase is given in Table 4.2.2.2.1. The yields of proteins were higher from deboned solid phase by using bone separator (8,6 and 7.3%) than using sieving technology (6 and 5 %). However, the ash content in the protein powders still remained high (12 and 14 %) compared to 11 and 12 % in the manual sieving process.

Table 4.2.2.2.1. Yields and composition of products during the isolation of protein powders from the solid phase. From 1000g salmon back bones we obtained 500g of solid phase with bones.

Products	Composition, g/100g dry weight					
	yield, g	protein	lipid	ash	color a	taste
wet backbones	1000	42,5	53,3	3,7		
de-boned solid phase Baader	390	52	46,0	7	5	
oil yield	55					
dried-sediments after water wash	86	76	15	12	2,8	3
dried-sediments after ethanol wash	73	87	6	14	-2,2	2

4.3 Mass balances for the two processes

To be able to perform economic analysis of chemical processes, the mass balance for all compounds must be determined. Preliminary mass balances are presented in table 4.3.1 for the solid phase process and 4.3.2. for the cooking process.

Table 4.3.1: Preliminary mass balance for the solid phase process

		Wet-weight								Flow (kg/h)				
		Total	Water	Ethanol	Drymatter	Lipid	Ash	Sum		Water	Ethanol	Drymatter	Lipid	Ash
		kg/h	%	%	%	%	%							
Input:	Back bones, Salmon	1080	57		18	23	3,7	101,7		615,6		194,4	248,4	39,96
Oilsep.	Oil	170	0		0	100	0	100		0		0	170	0
	Stickwater	370	97		3			100		358,9		11,1	0	0
	Sludge	540	60		24	15	7,5	106,5		324		129,6	81	40,5
Oilsep.										682,9		140,7	251	40,5
	Recovery									1,109324		0,723765	1,010467	1,013514
Bonesep	Bone	120	50		29	5	19	103		60		34,8	6	22,8
	Boneless	420	60		21	19	2,8	102,8		252		88,2	79,8	11,76
Bonesep.										312		123	85,8	34,56
	Recovery									0,962963		0,949074	1,059259	0,853333
Wash	Water in	1000	100		0	0	0	100		1000		0	0	0
	Water out	1010	92		2	5,9	0	99,9		929		20	60	0
	Washed meat	400	75		19	3,75	3	100,75		300		76	15	12
Wash										1229		96	75	12
	Recovery									0,981789		1,090703	0,934712	1,020408
				Ethanol							Ethanol			
Extraction	Ethanol in	1344	5	95	0	0	0	100		67,2	1276,8	0	0	0
	Ethanol out	1344	26	74	1	0	0	101		349,44	994,56	13,44	0	0
	Oil	10				100		100					10	0
	Extracted	400	12,5	70	15,225	1,05	2,45	101,225		50	280	60,9	4,2	9,8
Ekstraksjon										399,44	1274,56	74,34	14,2	9,8
	Recovery									1,0878	0,998246	0,978158	0,946667	0,816667

Table 4.3.2.: Preliminary mass balance for the cooking process.

		Wet-weight								Flow (kg/h)				
		Total	Water	Ethanol	Dry matte	Lipid	Ash	Sum		Water	Ethanol	Dry matte	Lipid	Ash
		kg/h	%	%	%	%	%							
Input:	Back bone, Salmon	1080	57		18	23	3,7	101,7		615,6		194,4	248,4	39,96
Bonesep.	Bones	216	50		29	5	19	103		108		62,64	10,8	41,04
	Boneless	884	56		18,8	25,5	0,9	101,2		495		166	225	7,95582
Bonesep.										603,03		228,83	236,21	49,00
	Recovery									0,98		1,18	0,95	1,23
Wash	Water in	2070	100		0	0	0	100		2070		0	0	0
	Water out	2070	92		2	8,2	0,2	102,4		1904		41	170	4
	Washed meat	800	79		17,43	3,78	0,42	100,63		632		139,44	30,24	3,36
Wash										2536		181	200	8
	Recovery									0,99		1,09	0,89	0,94
				Ethanol							Ethanol			
Extraction	Ethanol in	2380	5	95	0	0	0	100		119	2261	0	0	0
	Ethanol out	2380	26	74	0,67	0	0	100,67		619	1761	15,946	0	0
	Oil	18				100		100					18	0
	Extracted	800	12,5	70	16,03	1,54	0,245	100,315		100	560	128,24	12,32	1,96
Extraction										719	2321	144	30,32	1,96
	Recovery									0,96	1,03	1,03	1,00	0,58

4.4 Stability of the produced protein powders.

To get some preliminary information on the stability (shelf life) of the produced powders, powders produced by the cooking process, both water washed and ethanol extracted were subjected to accelerated storage test. The powders were stored at constant temperature at 70 °C with free access to air, and the weight increase due to oxidation was recorded (Figure 4.4.1). To our great surprise the two powders showed the same stability, independent of ethanol extraction. This indicates that the ethanol extraction that was introduced to lower the lipid concentration and thereby increase the shelf life of the protein powder, might not be necessary for increasing the stability.

The stability is measured as time before the weight starts to increase. To estimate the stability time at room temperature and 4 °C, a rule of thumb can be used, if no other data is available. This rule says that for each 10 °C the temperature is lowered, the shelf life is doubled. So a stability that will last for 100 h at 70 °C can be estimated to 4.4 month at 20 °C and 1year by 4 °C.

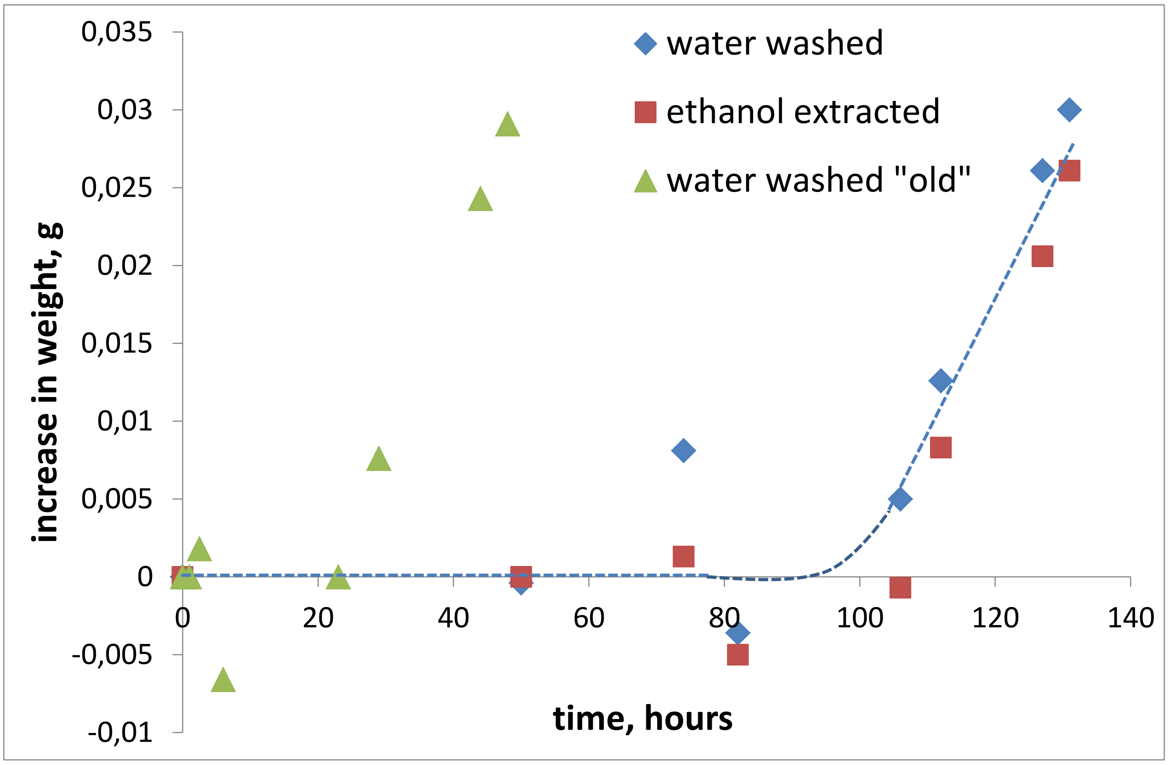

Figure 4.4.1: Weight increase for protein powders stored at 70 °C with free access to air. Blue diamonds: only water washed, red squares water washed and ethanol extracted. Green triangles are water washed sample from an old preparation that was stored 7 month in refrigerator before analysed.

5 Economical evaluation of the processes

To evaluate the financial and economic aspects of the new processes, a “Greenfield ”model borrowed from chemical process industry has been used; the process is built up from scratch with no existing infrastructure. To assess the production cost of taste neutral marine protein products in the two described production processes, flowcharts of the processes have to be constructed, including a list of equipment and its size.

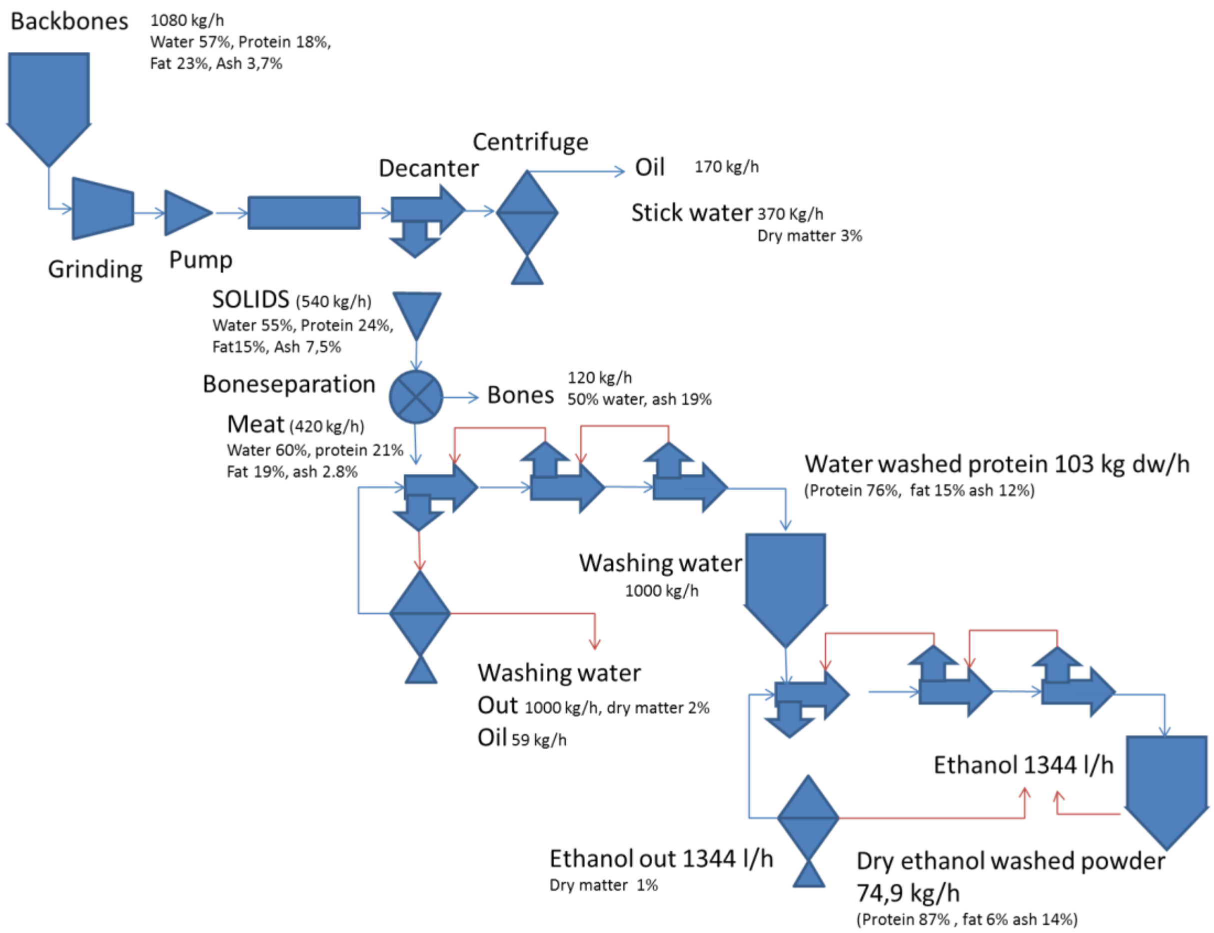

Figure 5.1. Flow chart of the solid phase process.

The solid phase process is based on equipment usually found in fish meal and oil production plants, where the solid phase (protein and bones) are separated from oil and water. The rest of the process contains a bone separator and a washing step consisting of three decanters and a polisher of the wash water to reduce the loss of proteins. The washed protein is extracted with ethanol in a three stage process with decanters as separators and the extracted protein is dried in a dryer. Ethanol is recovered through a distillation plant and returned to the process (equipment not shown in the figure).

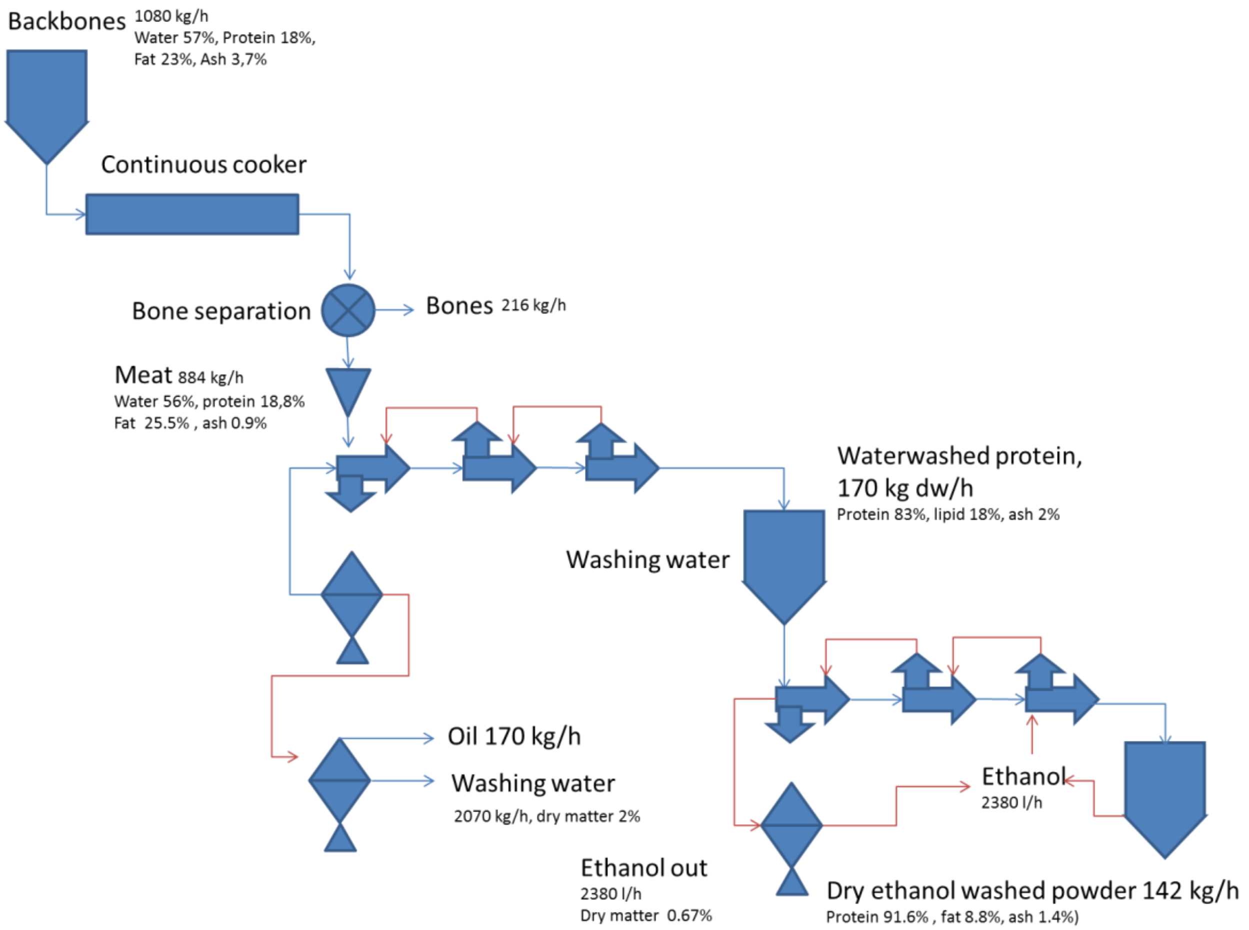

Figure 5.2. Flowchart of the cooking process

The cooking process starts with cooking of the backbones in a continuous band cooker, thereafter the bones are removed and the proteins are washed with hot water. The washing water removes the oil and the oil is separated from the wash water after the wash water polishing centrifuge. The washing process and the ethanol extraction process are similar to the sludge process. The equipment lists are assembled from the shown flow diagram. The prices are gathered as budget prices for equipment of the given size. Most prices are collected from equipment suppliers.

Table 5.1. Major equipment costs for the cooking process.

Item	Item description	Size	Size	Delivered costs (k€)	Delivered costs (kNOK)	No of iten	Total cost kNOK	% Of MEC
1	Buffertank, rawmaterial	10	m^3		200	1	200	1,0 %
2	Continuous cooker	1000	kg/h	380	2850	1	2850	14,8 %
3	Bone separator	3	m^3/h	100	750	1	750	3,9 %
4	Pump	3	m^3/h		80	1	80	0,4 %
7	Oil tank		m^3		200	1	200	1,0 %
8	Washing dekanter	2	m^3/h		800	3	2400	12,4 %
9	Wash water polishing	2	m3/h		700	1	700	3,6 %
10	Oilseparator	2	m3/h		700	1	700	3,6 %
11	Ethanol dekanter	2	m3/h		800	3	2400	12,4 %
12	Etanol recovery	2,5	m3/h		5000	1	5000	25,9 %
13	Produkt dryer	0,8	m3/h		4000	1	4000	20,7 %
	Total MEC (kNOK)						19280	

Ethanol recovery plant and dryer are turnkey equipment and costs in the table are given as 50 % of the delivered cost, because this equipment needs lower installation costs than the other processing items.

Table 5.2. Major equipment costs for the solid phase process.

Item	Item description	Size	Size	Delivered costs (k€)	Delivered costs (kNOK)	No of iten	Total cost kNOK	% Of MEC
1	Buffertank, råstoff.	10	m^3		200	1	200	1,1 %
2	Kvern	2,4	m^3/h	30	225	1	225	1,2 %
3	Pumpe	3	m^3/h		80	1	80	0,4 %
4	Skrapevarmeveksler	3	m^3/h		500	1	500	2,7 %
5	Dekanter		m^3		800	1	800	4,3 %
6	Limvannspumpe	1	m^3		45	1	45	0,2 %
7	Oljeseparator		m^3/h		700	1	700	3,7 %
8	Oljetank		m^3/h		200	1	200	1,1 %
11	Beinseparator			100	750	1	750	4,0 %
12	Vaskedekanter	2	m^3/h		800	3	2400	12,8 %
13	Vaskevannspolering	2	m^3/h		700	1	700	3,7 %
10	Oilseparator	2	m3/h		700	1	700	3,7 %
11	Ethanol dekanter	2	m3/h		800	3	2400	12,8 %
12	Etanol recovery	2,5	m3/h		5000	1	5000	26,7 %
13	Produkt dryer	0,8	m3/h		4000	1	4000	21,4 %
	Total MEC (kNOK)						18700	

Ethanol recovery plant and dryer are turnkey equipment and costs in the table are given as 50 % of the delivered cost, because this equipment needs lower installation costs than the other processing items.

To determine the total fixed capital investment several expenditures have to be added to the major equipment costs. These expenditures are calculated as percentage of the major equipment cost based on several decades experience from chemical industries. Only the table for the cooking process is presented in the report.

Table 5.3. Calculation on total fixed capital based on total equipment costs for the cooking process.

Item	Item description	% of MEC	Costs (kNOK)	%of TFCI
1	Major purchased equipment (MEC)	100	19280	30 %
2	Installetion costs	30	5784	9 %
3	Instrumentation and control	10	1928	3 %
4	Piping	30	5784	9 %
5	Electrical	10	1928	3 %
6	Buildings	30	5784	9 %
7	Yard improvements	10	1928	3 %
8	Service facilities	20	3856	6 %
9	Land	6	1157	2 %
10	Engineering and supervision	25	4820	8 %
11	Construction expensis (Sum 1-9)	10	4743	7 %
12	Contractors fee (Sum 1-9)	5	2371	4 %
13	Contingency	7	4155	7 %
		293		
	Total fixed capital investment		63519	

From the total fixed capital, total fixed capital cost per year can be determined. The depreciation is set to 10 years. Only the cooking process is shown as an example.

Table 5.4. Total fixed capital costs per year for the cooking process.

Item	Item descrption		Costs (kNOK)	% of TFC/Y
1	Depreciation (item 1-8 + 10-13)	10 y	6236	86 %
2	Property tax (of Depreciation)	0,01	62	1 %
3	Insurance (of Depreciation)	0,006	37	1 %
4	Dept service (none, 100% equipt capital)	0	0	0 %
5	Purchase tax (item1-12/10)	0,16	950	13 %
	Total fixed capital per year		7286	

The valuable costs are divided into raw materials, utilities and labour and others.

Table 5.5. Raw material costs for the cooking process.

Item	**Raw materials**			Prod h/year		
	Item	Unit costs	Unit		Total quantity	Costs (kNOK)
1	Backbones	2	NOK/kg	2000	1080	4320
2	Ethanol in process	15	NOK/kg	0	2380	36
3	Ethanol loss	15	NOK/kg	2000	59,5	1785
	Total raw material costs (TRMC)					6141

The price for the backbones has been estimated to NOK 2/kg after discussion with Nutrimar. The loss of ethanol in the process is calculated to 2,5 % per hour.

Table 5.6. Utilities for the cooking process.

Item	Utilities						
				Prod h/year			
7	Power	1	NOK/kWh	2000	694	1388	
8	Water cost	0,5	NOK/m3	2000	1,5	1500	
	Utilities					2888	

Table 5.7. Labors and other expenditures for the cooking process

	Labour and others						
Item		kNOK/ma	Persons	Shifts	fraction	cost	
9	Labor	500	2,0	1		1000	
10	Supervision			of Labor	0,2	200	
11	Payroll charges			of Labor+Sup	0,25	300	
12	Maintenance			of MEC	0,04	771	
13	Operating supplies			of TRMC	0,004	25	
14	General plant overhead			Item	0,55	1084	
15	Tax			Item	0,16	1572	
16	Contingency			Item	0,05	451	
17	Marketing (not included)					0	
	Total labours and othersothers					5403	

The income is calculated from a yield given in a separate table for the cooking process (Table 5.8.) and for the solid phase process (Table 5.9.). If the factory already is producing fish meal they will have a loss in ordinary fish meal production of 720 tons at a unit price of 2,5 NOK/kg

Table 5.8. Calculation of net cash flow for the cooking process with ethanol extraction.

Expensens		kNOK	kNOK		
Total fixed capital per year		7286			
Total raw material costs (TRMC)		6141			
Utilities		2888			
Labour, overhead Tax		5403			
Prod cost per year		21718		Kr/kg	ton/year
Loss in ordinary meal prod		1800		2,5	720
Total production expenditure			23518		
Income					
Protein		22800		80	285
Oil		1504		4	376
Total,income			24304		
Net cash flow			**786**		

The price for the new marine protein has been set to NOK 80/kg after a comparison with world market prices of soya and whey protein isolates. For crude marine oil, NOK 4/kg is an average price, on the low side and the raw material price is set to 2 NOK/kg.Operating revenue for the band cooking process with ethanol extraction is 0,7 mill NOK.

As the shelf life from non-ethanol extracted protein was comparable to the only washed protein, it is interesting to look at operating revenues from a production of only water washed protein. The economy in such a process is given in table 5.9. This process has operating revenue of 12 mill NOK.

Table 5.9. Production revenues in a process where ethanol extraction is omitted.

Expensens		kNOK	kNOK		
Total fixed capital per year		4489			
Total raw material costs (TRMC)		4320			
Utilities		2088			
Labour, overhead Tax		4338			
Prod cost per year		15236		Kr/kg	ton/year
Loss in ordinary meal prod		1800		2,5	720
Total production expenditure			17036		
Income					
Protein		27680		80	346
Oil		1504		4	376
Total,income			29184		
Net cash flow			**12148**		

In the solid phase process the layout of the process is somewhat different from the cooking process. The total operating revenues for the solid phase process with ethanol extraction and without ethanol extraction is shown in tables 5.10. and 5.11.

Table 5.10. Operating revenues for the solid phase process with ethanol extraction.

Expensens		kNOK	kNOK		
Total fixed capital per year		7067			
Total raw material costs (TRMC)		6141			
Utilities		3355			
Labour, overhead Tax		6542			
Prod cost per year		23104		Kr/kg	ton/year
Loss in ordinary meal prod		1800		2,5	720
Total production expenditure			24904		
Income					
Protein		9760		80	122
Oil		1920		4	480
Total,income			11680		
Net cash flow			-13224		

Compared to the cooking process there is not much difference in Total fixed capital per year, total raw material cost and Utilities. Labour are a bit higher because of three workers in this process compared to two in the cooking process. Total production expenditures are 23 mills in the cooking process compared to 25 mills in the solid phase process. The Total income by these two processes is quite different due to lower protein yield in the solid phase process. In the solid phase process the yield is measured to approximately 6 % compared to the cooking process where the yield was 13 %. The operating revenue for the solid phase process with ethanol extraction is minus 13 mill NOK.

Table 5.11. Operating revenues for the solid phase process without ethanol extraction.

Expensens	kNOK	kNOK		
Total fixed capital per year	4270			
Total raw material costs (TRMC)	4320			
Utilities	2555			
Labour, overhead Tax	5477			
Prod cost per year	16622		Kr/kg	ton/year
Loss in ordinary meal prod	1800		2,5	720
Total production expenditure		18422		
Income				
Protein	16480		80	206
Oil	1920		4	480
Total,income		18400		
Net cash flow		-22		

If ethanol extraction is taken out of the process the operating revenue is slightly negative by 0,02 mill NOK.

6 Conclusions

In order to be able to produce tasteless fish proteins from salmon backbones, the amount of lipids should be reduced to a minimum by reducing the shear forces in the processing. An industrial cooking of salmon backbones, by e.g. a band cooker with a conveyor belt, before backbone meat separation and applying a minimum of shear forces on the deboned meat enable to produce ethanol extracted protein powder containing 6.7 % lipids. While applying high shear forces on the deboned cooked meat led to production of an ethanol extracted protein powder with a lipid concentration of 17.2%.

Two possible sources/technologies for isolation proteins are evaluated in the project: the solid phase from salmon oil production and a process with cooking of salmon backbones before separation. The biggest challenge when using the solid phase from salmon oil production is the removal of bones and the high ash content in the dried product. The use of sieves could be possible, however together with the bones, proteins are also lost. Therefore, lab tests shows only 5% yield of dried ethanol extracted powders based on wet backbone weight basis. The use of a bone separator for the removal of bones from the solid phase was also tested and gave a yield of 7.3% of ethanol extracted protein powders (on backbone wet weight basis). Cooking of salmon backbones before separation gave the highest yield of the ethanol extracted protein powders 13.8% based on wet weight basis of backbones or 17.3% based on wet deboned meat basis.

Preliminary sensory analyses show that the produced fish proteins powders taste intensity is in the same range as soya isolates. However, taste panellists usually recognize fish proteins to be fish. Therefore, the use of masking taste compounds could be evaluated. Preliminary sensory results also showed that taste of the produced protein powders was not affected by the amount of lipids. The type of meat, red or whole meat, extracted from the backbone and used for isolation of proteins was not distinguished by sensory panellists. Therefore, the further investigation on the importance of the lipid amount and the stability in these protein powders should be investigated.

Interestingly the stability of the produced protein powders seem not to be influenced by reduction of lipid concentration by ethanol extraction.

A further stability test on the produced protein powders with accompanying sensory tests are recommended, such a study will indicate the preferred potential market segments for these products.

A preliminary economic analysis of the two processes shows that the band cooking process has the highest potential to succeed due to higher yield of protein from the back bones. Based on a raw material price on 2 NOK/kg, crude marine oil NOK 4/kg and on 80 NOK/kg for produced protein powder ethanol extracted protein powder give an operating revenue of 0.78 mill NOK for a process based on roughly 2000 tons/year of salmon backbones. If ethanol extraction can be omitted the operating revenue is 12 mill NOK.

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