PEER-REVIEWED PAPERS AND BOOKS

ANIMAL FEED PRODUCTS / FISH MEAL

Aksnes A, Hope B, Hostmark O, Albreksten S. 2006. Inclusion of size fractionated fish hydrolysate in high plant protein diets for Atlantic cod, *Gadus morhua*. Aquaculture 261(3):1102-1110.

Abstract: Fish hydrolysate was evaluated as feed ingredient in high plant protein diets in an 89 days feed experiment with Atlantic cod (*Gadus morhua*). The fish hydrolysate was size fractionated by ultra- and nano-filtration and the various fractions were tested specifically as feed ingredients to trace any effect observed with the hydrolysate. All diets contained 68% of total protein as plant protein, added as a mixture of corn gluten, full-fat soy bean meal, soy protein concentrate and extracted soy bean meal. The diets were equal in protein, lipid and energy. The control diet contained 21.8% fish meal. Fish hydrolysate was tested in another diet where one third of the fish meal protein was exchanged with the fish hydrolysate. Retentate after ultra-filtration of fish hydrolysate and retentate and permeate after nano-filtration were used in three separate diets at dietary inclusion levels corresponding to the absolute dry matter level of the fractions in the hydrolysate. The cod tripled in weight during the experimental period. No significant differences were observed for growth or feed intake for any groups. The diets containing retentate from ultra- and nano-filtration showed lower feed efficiency than the control diet with fish meal or the diet containing fish hydrolysate or permeate after nano-filtration. In conclusion the results show that fish hydrolysate may successfully be used as a protein source in high plant protein diets for Atlantic cod in exchange of fish meal. Removal of small molecules from the fish hydrolysate by filtration reveals poorer feed utilization indicating that this marine fraction of small compounds is important for optimal growth of Atlantic cod. This may be important in the discussion of increased dietary utilization of plant protein sources in feed for fish.

Das HK, Hattula MT, Myllymaki OM, Malkki Y. 2006. Effects of formulation and processing variables on dry fish feed pellets containing fish waste. J Sci Food Ag 61(2):181-187.

Abstract: A low-cost preparation process starting from fish waste, pregelatinised wheat flour and soya flour was optimised with regard to the physical properties of the pellets, by using response surface modelling. Independent variables were the ratio of wheat flour to soya flour, quantity of added water, temperature of added water, and mixing time. Pellet quality attributes measured for each set of variables were bulk density, water absorption index, sinking velocity, residual moisture, and structural integrity in water. Mixing time played the most important role among the input variables in defining pellet quality. The results suggest that a dry fish feed pellet of good quality can be manufactured by a simple pressing method using a mixture of 50% fish waste, 30-35% pregelatinised wheat flour, and 15-20% soya meal mixed with water (30-35% of the sum of other ingredients) of 60-65°C for 4-5 min. A method for determining structural integrity of pellets in turbulent water is presented.

Drakeford B, Pascoe S. 2008. Substitutability of fishmeal and fish oil in diets for salmon and trout: A meta-analysis. Aquacult Econ Manage 12(3):155-175.

Abstract: Historically, the world's oceans were considered limitless, and thought to harbour enough fish to feed an ever-increasing population. Today, however, the FAO (2002) estimate that 69% of world stocks are fished to capacity, overfished or recovering. In contrast, aquaculture has seen a rapid expansion (over 10% per annum) over the past twenty years or so as a result of new and intensive farming techniques. These developments have led to the production of valuable species such as salmon and trout.

Intensive aquaculture, especially the production of carnivorous species, requires artificial feeding. Fishmeal and oil are preferred to vegetable proteins, since marine proteins provide the essential nutrients required by farmed fish. Currently, aquaculture demands 34% of total fishmeal and 54% of total fish oil. Assuming current production growth rates and feed utilisation rates, this is expected to increase to 56% and 97% by 2010. Globally, the production of fishmeal and oil has remained stable over the past decade at 6million tonnes and 1.2 million tonnes (Pike and Barlow, 1999). This suggests that fishmeal and oil has reached a production limit in the main producing and exporting countries (Peru, Chile, Denmark and Norway). Therefore, with most industrial fisheries fully or overexploited, this increase in demand can only be met through either diversion of inputs from other sources, or through substitution with a suitable replacement.

Given the stagnant production of reduction species and the rapid increase in aquaculture production, fishmeal availability can pose a biological constraint on aquaculture contribution to world fish supplies in the future. In this paper, the technical substitutability between fish and vegetable based feeds are assessed through the estimation of Morishima elasticities of substitution. These are derived from a meta-analysis production function.

Espe M, Lemme A, Petri A, El-Mowafi A. 2006. Can Atlantic salmon (*Salmo salar*) grow on diets devoid of fish meal? Aquaculture 255(1-4):255-262.

Abstract: Abstract: The present experiment tested whether Atlantic salmon accept, grow and utilise diets devoid of fish meal. Four diets were prepared, one reference diet in which 49% of the diet was fish meal and three diets not containing any fish meal. The amino acid composition in the test diets not containing fish meal was made similar to the reference diet by balancing with crystalline amino acids. All plant protein diets also contained 5% fish protein hydrolysate and, additionally, two diets were added with either stick water or squid hydrolysate in order to improve the palatability and thus feed acceptance. The experimental diets were fed to Atlantic salmon of 300 g body weight for a period of 3 months during which period no fish died. Fish fed the plant protein diets showed reduced feed intake as compared to fish fed the reference fish meal diet resulting in lower growth in the former. Feed conversion did not differ between treatments. Although the fish fed the fish meal diet showed higher growth than those fed the alternative three diets, protein accretion was not significantly different. In contrast, fat retention was significantly higher in the fishmeal treatment suggesting both a higher retention of dietary fat which was higher

in the fish meal diet and a better utilisation of the dietary energy by salmon fed the vegetable diets due to a highly balanced dietary amino acid profile. The use of up to 10% crystalline amino acids in the diet increased the amino acid digestibility in the plant protein diets but utilisation of the dietary protein was not affected. The latter indicate that crystalline amino acids are utilised as well as protein bound amino acids at the level of 10% addition. Taking all together, particularly the diet containing squid hydrolysate might be an alternative to the fish meal diet in order to produce salmon.

Finstadt G, Wicklund E, Long K, Rincker P, Oliveira AC, Bechtel PJ. 2007. Feeding soy or fish meal to Alaskan reindeer (Rangifer tarandus tarandus) - effects on animal performance and meat quality. Rangifer 27(1):59-75.

Abstract**:** Fourteen reindeer were used to compare the effects of two different reindeer diets containing soybean meal (SBM) or fishmeal (WFM) as protein source) on animal growth performance, feed efficiency and ultimate meat quality. No significant difference was observed in overall weight gain between the WFM and SBM animals; however, the feed efficiency was higher for the reindeer fed the WFM mix. No differences were found in live weight, carcass characteristics, meat pH, temperature decline, shear force, meat color or cooking loss when comparing the treatment groups. The meat samples (M. longissimus) from the free-range group had the highest amount of omega-3 fatty acids and also the highest amount of polyunsaturated fatty acids (PUFA). No significant differences were found when the trained panel compared the sensory attributes of the meat. Off-flavor attributes related to “wild” or “gamey” flavor was reported by consumers for samples from the WFM and free-range reindeer. No “fish-related” flavor was reported.

Folador JF, Karr-Lilienthal LK, Parsons CM, Bauer LL, Utterback PL, Schasteen CS, Bechtel PJ, Fahey GC Jr. 2006. Fish meals, fish components, and fish protein hydrolysates as potential ingredients in pet foods. J Anim Sci 84(10):2752-2765.

Abstract: An experiment to determine the chemical composition and protein quality of 13 fish substrates (pollock by-products, n = 5; fish protein hydrolysates, n = 5; and fish meals, n = 3) was conducted. Two of these substrates, salmon protein hydrolysate (SPH) and salmon meal with crushed bones (SMB), were used to determine their palatability as components of dog diets. Pollock by-products differed in concentrations of CP, crude fat, and total AA by 71, 79, and 71%, respectively, and GE by 4.1 kcal/g. Fish protein hydrolysates and fish meals were less variable (approximately 18, 14, and 17%, and 1.4 kcal/g, respectively). Biogenic amine concentrations were much higher in fish protein hydrolysates as compared with pollock by-products and fish meals. Pollock liver and viscera had the highest total fatty acid concentrations; however, red salmon hydrolysate and SMB had the highest total PUFA concentrations (49.63 and 48.60 mg/g, respectively). Salmon protein hydrolysate had the highest protein solubility in 0.2% KOH. Based on calculations using immobilized digestive enzyme assay values, lysine digestibility of fish meal substrates was comparable to in vivo cecectomized rooster assay values and averaged approximately 90.3%. Also, pollock milt, pollock viscera, red salmon hydrolysate, and sole hydrolysate had comparable values as assessed by immobilized digestive enzyme assay and rooster assays. A chick protein efficiency ratio (PER) assay compared SMB and SPH to a whole egg meal control and showed that SMB had high

protein quality (PER = 3.5), whereas SPH had poor protein quality (PER value less than 1.5). However, using whole egg meal as the reference protein, both fish substrates were found to be good protein sources with an essential AA index of 1.0 and 0.9 for SMB and SPH, respectively. In the dog palatability experiments, a chicken-based control diet and 2 diets containing 10% of either SPH or SMB were tested. Dogs consumed more of the SPH diet compared with the control, and similar amounts of the SMB and control diets. The intake ratios for each were 0.73 and 0.52, respectively. Salmon protein hydrolysate was especially palatable to dogs. These data suggest that chemical composition and nutritional quality of fish substrates differ greatly and are affected by the specific part of the fish used to prepare fish meals and fish protein hydrolysates.

Forster I, Babbitt J, Smiley S. 2004. Nutritional quality of fish meals made from by-products of the Alaska fishing industry in diets for Pacific white shrimp (*Litopenaeus vannamei*). J Aquat Food Prod Technol 13(2):115-123.

Abstract: The nutritional quality of ten commercially available white fish meals made from by-products of the Alaska fish processing industry (primarily pollock) was determined. Pelleted feeds were manufactured containing these meals in complete replacement of a low-temperature processed Norwegian fish meal (control). These feeds were fed to triplicate tanks of Pacific white shrimp at the facilities of the Oceanic Institute for a period of ten weeks. At the end of the trial, the growth, feed conversion ratio and survival data were subjected to analysis of variance procedures. The final weight of the shrimp was more than ten times the initial and mean survival was 97%. There were no significant differences in performance parameters among the treatments. It is concluded that the nutritional quality of Alaska white fish meals is equivalent to the highest standard in the industry and are of suitable quality for inclusion in commercial shrimp feeds.

Forster I, Babbitt J, Smiley S. 2005. Comparison of the nutritional quality of fish meals made from byproducts of the Alaska fishing industry in diets for Pacific threadfin (*Polydactylus sexfilis*). J World Aquacult Soc 36(4):530-537.

Abstract: The nutritional quality of 13 commercial fish meals (10 from pollock, two from salmon, and one from cod) made from by-products of the Alaska fish processing industry was determined in diets for the marine fish Pacific threadfin (*Polydactylus sexfilis)*. Pelleted feeds were manufactured containing these meals as complete replacement of a low-temperature processed Norwegian fish meal (control). These feeds were fed to triplicate tanks of fish at the facilities of the Oceanic Institute, Hawaii for a period of 9 wk. At the end of the trial, the final weight, feed efficiency, protein efficiency ratio and survival data were subjected to ANOVA procedures. The performance parameters of the fish fed the white fish meals (pollock and cod) were not significantly different from the control. Of the two salmon meals, one promoted good growth and efficiency and one did not. It is concluded that the nutritional quality of Alaska white (pollock and cod) fish meals is equivalent to that of the low-temperature Norwegian fish meal and are of suitable quality for inclusion in commercial feeds for Pacific threadfin.

Gottlob RO, DeRouchey JM, Tokach MD, Goodband RD, Dritz SS, Nelssen JL, Hastad CW, Knabe DA. 2007. Amino acid and energy digestibility of protein sources for growing pigs. J Anim Sci 84(6):396-402.

Abstract: Two experiments were conducted to determine the apparent ileal digestibility (AID) and standardized ileal digestibility (SID) of AA and DE, and to estimate ME and NE of rice protein concentrate, salmon protein hydrolysate, whey protein concentrate, and spray-dried plasma protein. In Exp. 1, 6 barrows (initially 29.5 +/- 2.5 kg of BW) were fitted with ileal T-cannulas and fed each of 5 cornstarch-based diets in a balanced crossover design over 35 d. During a given week, there were either 1 or 2 replications of each treatment, resulting in 6 total replications over 5 wk. The 4 test diets (fed from d 0 to 28) were formulated to contain 12.5% CP by using analyzed nutrient compositions of rice protein concentrate, salmon protein hydrolysate, whey protein concentrate, or spray-dried plasma protein. The fifth (N-free) diet was fed from d 28 to 35 to estimate basal endogenous losses of CP and AA, which were used to calculate SID. Ileal digesta were collected and analyzed, and AID and SID values were calculated. Apparent ileal digestible Lys, Met, and Thr values were 80.0 +/- 3.3, 65.6 +/- 3.1, and 68.4 +/- 4.5% for rice protein concentrate; 85.6 +/- 4.8, 85.5 +/- 4.3, and 69.8 +/- 8.5% for salmon protein hydrolysate; 93.3 +/- 1.4, 89.9 +/- 5.8, and 83.6 +/- 5.3% for whey protein concentrate; and 92.8 +/- 0.9, 85.7 +/- 2.1, 86.5 +/- 2.3% for spray-dried plasma protein, respectively. In Exp. 2, 6 barrows (initially 37.6 +/- 1.7 kg of BW) were fed each of 5 corn-based diets in a balanced crossover design over 35 d. During a given week, there were either 1 or 2 replications of each treatment, resulting in 6 total replications over 5 wk. The 4 diets containing the test ingredients were formulated to contain approximately 20% CP by using their analyzed nutrient compositions. The fifth (corn control) diet containing 8.2% CP was also used to calculate energy values by difference. Feces were collected to determine DE. The ME and NE contents were estimated using published regression equations. The DE, ME, and NE (as-fed) values were 4,724 +/- 461, 4,226 +/- 437, and 3,235 +/- 380 kcal/kg for rice protein concentrate; 4,173 +/- 1,052, 3,523 +/- 1,002, and 2,623 +/- 872 kcal/kg for salmon protein hydrolysate; 4,949 +/- 1,002, 4,352 +/- 955, and 3,344 +/- 831 kcal/kg for whey protein concentrate; and 4,546 +/- 673, 3,979 +/- 652, and 3,020 +/- 567 kcal/kg for spray-dried plasma protein, respectively. The excellent AA digestibility and relatively high DE, ME, and NE values indicate that these protein sources warrant further investigation as ingredients for growing pig diets.

Hardy RW, Sealey WM, Gatlin DM III. 2005. Fisheries by-catch and by-product meals as protein sources for rainbow trout (*Oncorhynchus mykiss*). J World Aquacult Soc 36(3):393-400.

Abstract: Fisheries by-catch and by-product meals are portrayed as ingredients having a great potential as ingredients in aquaculture feeds. The present study was designed to evaluate the nutritional value of shrimp by-catch meal, shrimp processing waste meal, and two fish meals made from Pacific whiting (meal with and without solubles) for rainbow trout by determining apparent digestibilityof these ingredients and conducting a 12-wk feeding trial with juvenile fish (average initial weight 20 g/fish). Apparent digestibility coefficients (ADCs) for protein in diets containing by-catch

and processing by-products were 76% for shrimp by-catch meal, 79% for shrimp processing waste meal, 88% for Pacific whiting meal without solubles, and 92% for Pacific whiting meal with solubles. ADCs for lipid were higher than 94% for all the diets. ADCs for energy were 57% for shrimp by-catch meal, 73% for shrimp processing waste meal, 70% for Pacific whiting meal without solubles, and 73% for Pacific whiting meal with solubles. Growth performance was significantly affected by dietary protein source. Fish fed the shrimp by-catch meal diet had weight gain and feed conversion ratios similar to that of fish fed the control diet with anchovy fish meal. Fish fed diets containing shrimp processing waste and Pacific whiting meal with solubles had significantly lower weight gain and higher feed conversion ratios than the control diet. Growth was significantly lower in fish fed the Pacific whiting meal diet compared to fish fed the anchovy fish meal. The lower growth of fish fed diets containing Pacific whiting meal appeared to be a result of lower feed intake, indicating perhaps a lower palatability of this ingredient. Additional research addressing processing methods, nutritional manipulations, and palatability enhancement is needed to improve potential of some fisheries byproduct meals as ingredients in the diets of rainbow trout.

Li P, Wang X, Hardy RW, Gatlin DM III. 2004. Nutritional value of fisheries by-catch and by-product meals in the diet of red drum (*Sciaenops ocellatus*). Aquaculture 236(1-4):485-496.

Abstract: Discarding of by-catch and generation of by-products from capture fisheries has long been recognized as wasteful, but greater effort is needed to make use of these resources in aquaculture as its growth throughout the world requires increased production of feeds to support the cultured organisms. Protein resources, primarily fish meal, will probably be a constraint to further development of the aquaculture industry. Fisheries by-catch or by-product meals theoretically have good potential to reduce dependence on fish meal, although research in this subject is limited. A digestibility study with sub-adult red drum and a feeding trial were conducted with juveniles to evaluate the use of various by-product ingredients in aquafeeds. A shrimp by-catch meal (SBM) from shrimp trawling in the Gulf of Mexico, a shrimp processing waste meal (SWM) from aquacultured *Litopenaeus vannamei*, two underutilized fish meals [Pacific whiting meal without soluble (PW) and Pacific whiting meal with soluble (PWS)], and a fish-processing waste [red salmon head meal (RSHM)] from Alaska were included in the diets. The digestibility study employed chromic oxide as a marker and stripping for fecal collection. No differences ($P>0.05$) in organic matter, crude protein, energy and total phosphorus digestibility were observed among fish fed Special Select menhaden fish meal, SBM, PW or PWS, while digestibility of these nutrients and energy from RSHM was significantly lower. During the 6-week feeding trial, no significant differences were observed among fish fed diets in which 25% of the protein from menhaden fish meal was replaced with RSHM or 50% was replaced by SBM in 40% crude protein diets. Fish fed diets in which 50% or 100% of protein from menhaden fish meal was replaced with PWS, PW and SWM showed significantly ($P<0.05$) reduced growth and feed efficiency, although there was no significant difference in survival of fish fed the different diets. More research is needed to optimize the use of these

ingredients and to eliminate limiting factors by improving processing techniques, amino acid availability and palatability.

Murray AL, Pascho RJ, Alcom SW, Fairgrieve WT, Shearer KD, Roley D. 2003. Effects of various feed supplements containing fish protein hydrolysate or fish processing by-products on the innate immune functions of juvenile coho salmon (*Oncorhynchus kisutch*). Aquaculture 220(1-4):643-653.

Abstract: Immunomodulators administered to fish in the diet have been shown in some cases to enhance innate immune defense mechanisms. Recent studies have suggested that polypeptide fractions found in fish protein hydrolysates may stimulate factors in fish important for disease resistance. For the current study, groups of coho salmon were reared on practical feeds that contained either fish meal (Control diet), fish meal supplemented with cooked fish by-products, or fish meal supplemented with hydrolyzed fish protein alone, or with hydrolyzed fish protein and processed fish bones. For each diet group, three replicate tanks of fish were fed the experimental diets for 6 weeks. Morphometric measurements, and serologic and cellular assays were used to evaluate the general health and immunocompetence of fish in the various feed groups. Whereas the experimental diets had no effect on the morphometric and cellular measurements, fish fed cooked by-products had increased leucocrit levels and lower hematocrit levels than fish from the other feed groups. Innate cellular responses were increased in all feed groups after feeding the four experimental diets compared with pre-feed results. Subgroups of fish from each diet group were also challenged with Vibrio anguillarum (ca. 7.71x10(5) bacteria ml-1) at 15 °C by immersion. No differences were found in survival among the various feed groups.

Oliveira ACM, Stone DAJ, Plante S, Smiley S, Bechtel PJ, Hardy RW. 2008. Fish oils from Alaskan seafood processing by-products: an un-exploited sustainable resource for aquaculture. World Aquacult 39(2):50-51, 69.

Abstract: Oils from marine fish have several unique chemical properties, including high levels of the nutritionally important omega-3 highly unsaturated fatty acids (HUFA), primarily eicosapentaenoic (EPA C20:5'3) and docosahexaenoic acids (DHA; C22:6'3). The fatty acids found in oils derived from Alaskan seafood by-products are nutritionally well suited for inclusion into aquaculture feeds and are similar in many respects to those found in menhaden oil. Alaskan fish oils also have three desirable characteristics that make them suitable to fill valuable niches in two increasingly important areas of fish production: 1. High levels of omega-3 fatty acids, particularly EPA and DHA; 2. Very low levels of organic contaminants; 3. The oils are currently underutilized and could be made available with changing economic circumstances. These characteristics also make Alaska fish oils suitable for incorporation into aquaculture finishing diets that may also contain substantial amounts of plant oils.

Pasquini A, Luchetti E, Cardini G. 2008. Plasma lipoprotein concentrations in the dog: the effects of gender, age, breed, and diet. J Anim Physiol Anim Nutri 92(6):718-722.

Abstract: Earlier studies of canine lipoprotein metabolism have frequently not taken into account such variables as age, gender, lifestyle or feeding status. In the last years,

many changes to lifestyle and feeding of dogs have occurred. In this study, C-tot, C-HDL, C-LDL, triglycerides and lipoprotein fractions were determined in 251 healthy dogs by means of enzymatic methods and through the electrophoretic technique. All data were analysed by multifactor anova test to determine which factors (age, gender, breed and diet) have a statistically significant effect ($p < 0.05$) on the determined parameter and subsequently Bonferroni's test was applied where necessary. Gender, age, breed and diet can significantly affect lipid metabolism, in particular lipoproteins involved in cholesterol plasma transport; on the contrary, triglycerides are not influenced by the same factors. The most important observation about age is the high level of C-LDL in puppies under 1 year of age. The highest cholesterol concentrations are found in Rottweiler but high values of plasma cholesterol are found also in Pyrenees Mountain dog and a great level of C-LDL in Labrador. Diet has shown a great influence on lipidic metabolism: dogs fed with different high-quality dry foods had significant differences in plasma cholesterol values (C-tot, C-HDL, C-LDL,), in particular, dogs fed with a diet rich in fish and fish-by-products have shown the lowest levels of C-tot, C-HDL and C-LDL.

Pelletier N, Tyedmers P. 2007. Feeding farmed salmon: Is organic better? Aquaculture. 272(1-4):399-416.

Abstract: Feed provision accounts for the majority of material and energetic inputs and emissions associated with net-pen salmon farming. Understanding and reducing the environmental impacts of feed production is therefore central to improving the biophysical sustainability of salmon farming as a whole. We used life cycle assessment (with co-product allocation by gross energy content) to compare the cradle-to-mill gate life cycle energy use, biotic resource use, and global warming, acidifying, eutrophying and aquatic ecotoxiticy impacts associated with producing ingredients for four hypothetical feeds for conventional and organic salmon aquaculture in order to assess the benefits, if any, associated with a transition to organic feed use. Fish and poultry-derived ingredients generated substantially greater impacts than crop-derived ingredients. Despite the fact that organic crop ingredients had markedly lower life cycle impacts compared to equivalent conventional ingredients, substituting organic for conventional crop ingredients therefore resulted in only minor reductions to the total impacts of feed production because the benefits of this substitution were effectively overwhelmed by the much larger impacts associated with animal-derived ingredients. Replacing fish meals/oils from dedicated reduction fisheries with fisheries by-product meals/oils markedly increased the environmental impacts of feed production, largely due to the higher energy intensity of fisheries for human consumption, and low meal/oil yield rates of fisheries by-products. Environmental impacts were considerably lower when feeds contained reduced proportions of fish and poultry-derived ingredients. These results indicate that current standards for organic salmon aquaculture, which stipulate the use of organic crop ingredients and fisheries by-product meals and oils, fail to reduce the environmental impacts of feed production for the suite of impact categories considered in this study. This information should be of interest to feed producers and aquaculturists concerned with improving the biophysical sustainability of their products, and bodies responsible for aquaculture certification, eco-labeling, and consumer awareness programs.

Plante S, Smiley S, Oliveira, ACM, Stone DAJ, Hardy RW, Bechtel PJ. 2008. Chemical characterization of testes meals made from Alaska's seafood processing byproducts. J Aquat Food Prod Technol 17(2): 195-211.

Abstract: Our objective was to produce a unique feed ingredient from underutilized walleye pollock (*Theragra chalcogramma*) and pink salmon (*Oncorhynchus gorbuscha*) testes. Protein content in meals from both species (72% and 80%, respectively) were above the values found in high quality herring meals (~70%), but both were poor in some essential amino acids, e.g., methionine. Additionally, both were good sources of the amino acid taurine (1.7 and 2.2% of meal, respectively). Pollock meal was very rich in phospholipids (82% of total lipids) and in DHA (28 mg/g meal) and EPA (18 mg/g meal), indicating potential as an ingredient in larval starter diets. The purine contents in both pollock and salmon testes meals were more than 10 times the concentrations found in other fish byproducts or commercial fishmeals. The high concentrations of purines found in these testes, especially in the salmon meal, make it an ideal candidate for an immune system stimulant when added to dietary formulations.

Refstie S, Olli JJ, Standal H. 2004. Feed intake, growth, and protein utilisation by post-smolt Atlantic salmon (*Salmo salar*) in response to graded levels of fish protein hydrolysate in the diet. Aquaculture 239(1-4):331-349.

Abstract: This study investigated how partial dietary replacement of fish meal (FM) by a novel fish protein hydrolysate (FPH) affected feed intake, growth, feed efficiency, nutrient retention, and nutrient digestibility by Atlantic salmon in the early seawater stage. FM was replaced by FPH in increments, producing four extruded diets containing 0%, 5%, 10%, and 15% FPH. Each diet was fed to quadruplicate groups of 163-g salmon maintained in 8.3 degrees C seawater. The experiment lasted 68 days, divided into three periods. The feed consumption was higher in groups fed 10% and 15% FPH than in those fed 0% FPH, with intermediate intake in groups fed 5% FPH. This was mirrored by the growth, and the groups fed 0%, 5%, 10%, and 15% FPH reached respective individual weights of 323, 350, 362, and 377 g. The retention of protein, which ranged from 48% to 53%, was higher in groups fed 5% and 15% FPH than in those fed 0% FPH. The protein retention was lowest in the groups fed 10% FPH. The retentions of individual amino acids largely mirrored the overall protein retention. The differences in apparent digestibility of protein and individual amino acids were slight, but generally highest when feeding 5% and 15% FPH, lowest when feeding 0% FPH, and intermediate when feeding 10% FPH. In conclusion, the tested FPH proved an efficient feeding stimulant in Atlantic salmon and was highly digestible and well utilised for growth.

Sathivel S, Bechtel, PJ, Babbitt J, Prinyawiwatkul W, Negulescu, II. 2005. Functional, thermal, and rheological properties of Alaska white fish meal made from processing byproducts. J Aquat Food Prod Tech 14(4):5-22.

Abstract: Functional, nutritional, thermal, and rheological properties of Alaska white fish meals were evaluated. Five fish meal samples were made from pollock: cod (95%:5%) processing byproducts collected on five separate days. Results showed that functional and nutritional properties of the fish meals were relatively consistent

among the five different runs. Fish meals contained 66.1- 69% protein and 6.2-8.1% fat. No differences were observed among fish meal samples for emulsification capacity and stability, and fat and water adsorption. All fish meals had similar amino acid and mineral contents. The denaturation peak, Tmax, values ranged from 46.8 to 48.6 oC and the enthalpy values ranged from 1.3 to 1.6 j/g. Doughs made from the white fish meals had viscoelasticity properties with G'>G" and the delta values below 20.

St-Hiliare S, Cranfill K, McGuire M, Mosley E, Tomberlin JK, Newton L, Sealey W, Sheppard C, Irving S. Fish offal recycling by the black soldier fly produces a foodstuff high in Omega-3 fatty acids. 2007. J World Aquacult Soc 38(2):309-313.

Abstract: The black soldier fly, *Hermetia illucens*, has the potential to reduce animal waste on livestock facilities and produce an animal-grade feedstuff high in protein and fat. The lipid content of insects is largely dependent on their diet. Data from this study suggest that black soldier fly prepupae incorporate linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) when fish offal is included in their diet. Fly larvae were fed three different proportions of fish offal and cow manure diets over a 21-d trial. An additional group of larvae were fed 22% fish offal diet within 24h of their pupation. Larvae fed fish offal were, on average, 30% lipid, which was 43% more than the controls fed cow manure only, and approximately 3% of this lipid was omega-3 fatty acids (EPA, DHA, and ALA). Furthermore, this concentration of omega-3 fatty acids was achieved within 24h of feeding fish offal. These omega-3 fatty-acid-enhanced prepupae may be a suitable fish meal and fish oil replacement for carnivorous fish and other animal diets. In addition, they may provide a method of reducing and recycling fish offal from processing plants.

Tacon AGJ. 2004. Use of fish meal and fish oil in aquaculture: a global perspective. Aquat Resour, Cult Dev 1(1): 3-14.

Abstract: Although aquaculture's contribution towards total world fisheries landings has increased 6-fold over the past three decades, increasing from 3.58 mmt (million metric tons) or 5.3% of total fisheries landings in 1970 to 51.39 mmt or 35.2% of total fisheries landings in 2002, the aquaculture sector is still highly dependent on marine capture fisheries for sourcing key dietary nutrient inputs, including fish meal, fish oil and 'trash fish'. In fact, when viewed in wet fish weight equivalents, although only about 20.0 mmt or 40.9% of total global aquaculture production in 2002 was in the form of aquafeed-dependent finfish and crustacean species, this production was realized through the consumption of an equivalent weight of 21–22 mmt of marine pelagics on a wet weight basis. This paper reviews the current and predicted global use and demand for fish meal and fish oil with compound aquafeeds for farmed finfish and crustaceans; aquafeeds including commercially compounded diets, farm-made aquafeeds, and/or whole marine food/feed organisms as well as fresh/frozen fish, molluscs and crustaceans. Particular emphasis is placed on the urgent need for the aquafeed-fed finfish and crustacean aquaculture sector to reduce its current dependence on potentially food-grade marine capture fishery resources for sourcing its major dietary protein and lipid nutrient inputs, and to seek alternative more sustainable feed resources.

Whiteman KW, Gatlin DM III. 2005. Evaluation of fisheries by-catch and by-product meals in diets for red drum Sciaenops ocellatus L. Aquac Res 36(16):1572-1580.

Abstract: This study evaluated various by-catch and by-product meals of marine origin with red drum (Sciaenops ocellatus L.). Four different kinds of by-catch or by-product meals [shrimp by-catch meal from shrimp trawling, Pacific white shrimp (Litopenaeus vannamei (Boone)) processing waste meal, red salmon (Oncorhynchus nerka (Walbaum)) head meal, and Pacific whiting (Merluccius productus (Ayres)) meal] were substituted for Special Select menhaden fish meal at 33% or 67% of crude protein in diets formulated to contain 40% crude protein, 12% lipid, and 14.6 kJ digestible energy g-1. Each of these diets and three additional diets consisting of shrimp processing waste meal formulated on a digestible-protein basis and two Pacific whiting diets containing reduced levels of ash were also evaluated in two 6-week feeding trials with juvenile red drum (initial weight of 4-5 and 1-2 g fish1 in trials 1 and 2). Red drum fed by-catch meal at either level of substitution performed as well as fish fed the control diet; whereas, fish fed shrimp processing waste meal diets had significantly (P less than or equal to 0.05) reduced weight gain and feed efficiency ratio values compared with the controls, even when fed on a digestible-protein basis. The diets containing Pacific whiting at either levels of substitution and regardless of ash level supported similar performance of red drum as those fed the control diet. Fish fed the red salmon head meal diet fared poorly, probably owing to an excessive amount of lipid in the diet that became rancid. Overall, by-catch meal associated with shrimp trawling and Pacific whiting appear to be suitable protein feedstuffs for red drum.

Zinn K, Hernot D, Fastinger N, Karr-Lilienthal L, Bechtel PJ, Swanson K, Fahey G. 2008. Fish protein substrates can substitute effectively for poultry by-product meal when incorporated in high quality senior dog diets. J Anim Physiol An N [Internet]. [Cited 2008 November 7]. Available from: http://www3.interscience.wiley.com/journal/120123373/abstract.

Abstract: An experiment was conducted to analytically define several novel fish substrates and determine the effects of feeding diets containing these substrates on total tract nutrient digestibility and on immune status of senior dogs. The control diet contained poultry by-product meal while test diets contained 20% milt meal (MM), pink salmon hydrolysate (PSH) and white fish meal (WFM) added at the expense of poultry by-product meal. Concentrations of lymphocytes positive for CD3, CD4, CD8alpha, and CD21, cell surface markers and immunoglobulin concentrations were measured. Gene expression of cytokines TNF-alpha, IL-6, IFN-gamma, IL-10, and TGF-beta was determined by qRT-PCR. Major compositional differences were noted among fish substrates but apparent nutrient digestibility coefficients and immune indices were not affected by treatment. Fish protein substrates substituted effectively for poultry by-product meal to provide diets of high nutritive value for senior dogs.

BYPRODUCTS / WASTE – GENERAL

Arason S, Kristbergsson K. 2007. Utilization of by-products in the fish industry. In: Oreopoulou V, Russ W, editors. Utilization of by-products and treatment of waste in the food industry. 1st edition. New York: Springer. p. 233-258.

Description: Utilization of By-products and Treatment of Waste in the Food Industry, the third volume of the ISEKI-Food book series, deals with the main features of utilization of the food industry waste, defined thereby as by-product, and the treatments necessary to discard waste to environmental acceptors. Topics range from an overview about ways of utilization, the necessity of food waste utilization, treatment according to established standards and directives, methods and applications of treatments for wastewater, the use of anaerobic fermentation technology, and ideas for the range of possible useable wastes.

Arvanitoyannis IS, Kassaveti A. 2008. Fish industry waste: treatments, environmental impacts, current and potential uses. Int J Food Sci Technol 43(4): 726-745.

Abstract: Fish waste management has been one of the problems having the greatest impact on the environment. Fish farming detrimental effects on the marine environment in particular have become an issue of public concern. In European Union, numerous Directives, Decisions and Regulations were voted in an attempt to minimise the environmental impact of fisheries within the frame of Integrated Coastal Management. Treated fish waste has found many applications among which the most important are animal feed, biodiesel/biogas, dietic products (chitosan), natural pigments (after extraction), food-packaging applications (chitosan), cosmetics (collagen), enzyme isolation, Cr immobilisation, soil fertiliser and moisture maintenance in foods (hydrolysates). In this review, an update of both environmental impact (inputs and outputs) and treated fish waste uses is provided by means of six comprehensive tables and seven figures.

Bechtel PJ. 2003. Properties of different fish processing by-products from pollock, cod and salmon. J Food Process Preserv 27(2):101-116.

Abstract: Individual fish processing waste stream components can be used to make feed ingredients or other products. Waste stream components obtained from commercial fish processing plants included heads, viscera, frames, and skins from Alaska pollock (*Theragra chalcogramma*) and Pacific cod (*Gadus macrocephalus*); and heads, and viscera from pink salmon (*Oncorhynchus gorbuscha*). The protein content of heads from all three species ranged from 13.9 to 16.4%; and the fat content ranged from 0.9 to 10.9%. Viscera protein content ranged from 13.0 to 15.3%, and the fat content from 2.0 to 19.1%. After heating to 85C the percent soluble protein in salmon heads was different ($P < 0.05$) from pollock or cod heads. Percent soluble protein of pollock and cod skin increased 8 fold ($P < 0.05$) after the 85C heat treatment. Connective tissue content was calculated from chemical determination of hydroxyproline content, and large differences in percent connective tissue content were found (1 % for pollock viscera to 46% for skin). Estimated rat PER values ranged from a low of 2.1 for skin to a high of 3.1 for viscera and fillet samples ($P < 0.05$).

Bechtel PJ, Johnson RB. 2004. Nutritional properties of pollock, cod and salmon processing by-products. J Aquat Food Prod Technol 13(2):125-142.

Abstract: It is possible to make feed ingredients of different byproducts and this paper evaluates some of the important nutritional properties of Alaska Pollock (Theragra chalcogramma) and Pacific cod (Gadus macrocephalus). Heads, viscera, frames, and

skins were obtained from processing plants, and heads and viscera from plants processing pink salmon (*Oncorhynchus gorbuscha*). Essential amino acid concentrations were used for calculating rat protein efficiency ratio (PER) and resulted in high values for fillet, followed by whole fish, frames and viscera, heads and skin. All byproducts except salmon viscera had greater than 90% pepsin digestibility. Differences in mineral content were detected between species within a byproduct and between byproducts within species. Percent soluble protein of pollock and salmon byproducts increased as pH increased from 5.4 to 7.1.

Bower C, Hietala K. 2008. Acidification Methods for Stabilization and Storage of Salmon By-Products. Accepted for publication in J Aquat Food Prod Technol July 2008. Publication pending.

Abstract: Alaska's fishing industry generates over one million metric tons of fish by-products each year, much of which is discarded during processing unless fishmeal plants are located nearby. Preservation methods, such as acidification, are less commonly used to inhibit spoilage. In this study, individual salmon by-products (heads, viscera, and a mixture) were stabilized through fermentation by lactic acid bacteria and through ensilage by direct acidification. Viscera and heads preserved separately for 120 days maintained a lower, more desirable pH than when mixed together. This finding has major implications for how fish processing waste should be collected and stored if maximum nutritional quality is to be preserved.

McGinnis L, Wood M. 2007. Finding new uses for fish byproducts. Ag Res 55(4):18-19.

Introduction: Alaska's fish-processing industry produces more than 2.2 billion pounds of fish byproducts every year—the weight equivalent of nearly 10,000 blue whales.

Large processors often convert these byproducts into fishmeal or fish oil, which are generally sold for meager profit. There is little economic incentive for smaller or at-sea processors to do the same, so they generally return byproducts to the ocean, where they are consumed by marine creatures. But is this the best use of these products? Could fish processors be throwing money into the sea?

Shahidi F, editor. 2006. Maximising the Value of Marine By-Products. Cambridge (England): Woodhead Publishing Ltd.

Book summary: A complete review of the characterization, recovery, processing, and applications of marine by-products, *Maximising the Value of Marine By-Products* begins with a summary of the physical and chemical properties of marine proteins and lipids and assesses methods for their extraction and recovery. The book goes on to examine the various applications of by-products in the food industry, including health-promoting ingredients such as marine oils and calcium, as well as enzymes, antioxidants, flavorings, and pigments. The book concludes with discussions of the utilization of marine by-products in diverse areas such as agriculture, medicine, and energy production.

Wright I. 2004. Salmon Byproducts. Aqua Feeds 1(1):10-12.

Abstract: Processing waste from aquaculture products is largely an untapped ingredient resource for the aqua feed industry. Oils and proteins recovered from the offal would partially offset the future gap in demand and supply of marine oils and

proteins. This article reviews the opportunities for oil and hydrolysate manufactured from the processing waste of farmed salmon. Nearly 250,000 MT of waste is available for conversion into useful products such as salmon hydrolysate and oil. Since salmon is processed entirely for human consumption, very high standards of freshness and hygienic quality are followed. This can be used to advantage by the byproducts manufacturer to produce high quality byproducts. The processing wastes are stabilized within 4 hours of slaughter. The typical process of manufacturing salmon byproducts involves maceration of viscera or bony by-products and then enzymatically digesting the protein into a liquid soup. During the next stage bones are removed and the fish oil is separated by centrifugation. The final stage is concentration of the hydrolysate by either spray drying to produce a powder, or low temperature vacuum evaporation to produce a thick liquid. Yields of hydrolysate and oil vary with the type of fish processed. In Atlantic salmon, every metric ton of the byproduct yields about 200 kg each of orange coloured salmon oil and condensed salmon hydrolysate.

Wu TH, Bechtel PJ. 2008. Salmon by-product storage and oil extraction. Food Chem 111(4):868-871.

Abstract: Oils extracted from wild salmon by-products are excellent sources of long chain omega-3 polyunsaturated fatty acids including eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). However, quality loss is expected if time delays are encountered before oil extraction. The free fatty acid levels (FFA), fatty acid profile and total fat soluble antioxidant activity in extracted oil from aging pink salmon heads and viscera stored at two temperatures (6 and 15°C) for four days were determined. The FFA values in raw salmon heads and viscera increased with storage time and temperature. A significant difference ($p < 0.05$) from the starting material was noted at day 1 at both temperatures for FFA. Fatty acid composition data indicated no changes in the levels of long-chain omega-3 fatty acids with the respective temperature. The concentration of long-chain omega-3 fatty acids EPA ranged from 9.3 to 11.3g/100g of crude oil and DHA ranged from 12.3 to 13.1g/100g of crude oil. The antioxidant activity of the pink salmon oils at day 0 was 0.89±0.15□mole Trolox equivalent/g of crude oil. Significant decreases ($p < 0.05$) from the starting material were noted on day 2 for 15°C samples and day 3 for 6°C samples. After four days of storage antioxidant levels (Trolox equivalent/g of crude oil) were approximately 25% of initial values. Oil extracted from raw salmon heads and viscera remained a good source of long chain omega-3 fatty acids even after 4 days of raw material storage at 15°C; however, fat soluble antioxidant activity was reduced and free fatty acid levels increased with increased raw material storage temperature and time.

FERTILIZERS

Ashcroft WJ, Surapaneni A, Milner AD. 2006. Response of processing tomatoes to an alternative phosphate fertiliser incorporating composted fish waste. Acta hort 724:203-206.

Abstract: Phosphorus (P) is an essential nutrient for plant growth and is applied extensively to crops, particularly in P deficient soils such as those commonly found in

Australia. A new phosphorus fertiliser, derived from activated rock phosphate composted with fish waste from the seafood industry, has been proposed for agricultural use in Australia. Such a product has the dual advantages of providing nutrients to agricultural crops as well as utilising waste materials that are otherwise economically and environmentally costly to dispose of. It also meets requirements for use in organic production systems in New Zealand, and is likely to be accepted for similar applications in Australia and other countries. Field experiments were conducted over two seasons (2002-04) on a low-P loam soil at Tatura in south-eastern Australia, to examine the effectiveness of this material in comparison with a traditional P fertiliser (Superphosphate) on processing tomatoes ('Heinz 9035'). The application rate for P was determined from commercial recommendations based on pre-season soil tests, and fruit yields above the industry average were achieved in both seasons. Results in both seasons also showed that plant growth and yields were similar between the two P treatments, but that treated plots were significantly more productive than the unfertilised control. Indices of fruit quality for processing (fresh weight per fruit, soluble solids, colour and pH) were largely unaffected by the treatments.

Swanson L. 2004. Firm turns fish waste into fertilizer and feed. BioCycle 45(3): 62.

Abstract: The life cycle of the salmon is intricately linked with products of a company called Bio-Oregon based in Warrenton, Oregon, at the mouth of the Columbia River. The firm recycles nearly 50 million pounds of fish residuals from coastal processing plants and manufactures feeds for hatchery programs as well as organic fertilizers. These products mimic the salmon's life. From its aquaculture feeds that nurture fingerlings throughout the Pacific Northwest, to processing marine by-products into all-natural fish fertilizers, Bio-Oregon completes the cycle. Its complicated manufacturing process keeps tons of waste from going to landfills.

Teuber N, Alfaro MA, Salazar FJ, Bustos C. 2005. Sea salmon sludge as fertilizer: effects on a volcanic soil and annual ryegrass yield and quality. Soil Use Manage 21(4):432-434.

Abstract: To evaluate the effect of sea salmon sludge on soil and ryegrass yield and quality, five treatments were tested (30, 60 and 90 t ha-1 of sludge, inorganic fertilizer and control). The sludge contained 16% dry matter (DM), 0.13% total N and 1.6% P. The sludge increased ryegrass DM yield, P and Na content, but decreased K concentrations in soil and plants. Sludge can be applied successfully on to land, but its addition should be complemented with inorganic nutrients (N, K). The high Na content of the sludge may limit repeated application, but the main benefit is its P content.

Zhang M, Sparrow S, Bechtel PJ, Pantoja A. 2007. Characteristics of nitrogen and phosphorus release from fish meals and fish hydrolysates in subarctic soils. J Environ Monitor Restor 3:262-275.

Abstract: Fish harvested in Alaska waters contributes about 60% of total fish harvest for human consumption in USA. The annual seafood harvest is over two million metric tons and after processing, there are approximately one million metric tons of fish byproducts. These fish byproducts, depending on the fish species and components, vary in nutrition concentration. Laboratory incubation experiment is an

approach to determine the amount of N released from organic nutrient sources in soil. Some Alaska farmers are ready to go to organic for two simple reasons, 1) the farm scale in Alaska is relative small, a few acres to several hundred acres, and as such, farmers can't compete with the imported conventional farm products from the western United States; 2) the organically and locally produced farm products can give the farmer a higher premium than the conventional farm products. Because of short growing season, using legume as a rotational crop to increase soil fertility is limited. The organic producers heavily rely on domestic compost from plant residues, and fish by-products. The objectives of this research was: 1) to compare N and P release from three fish by-products in two major soils in Alaska; and 2) to determine a kinetic model/models that can be used to predict N release of fish by-products in Alaska soils.

FOOD PRODUCTS – HUMAN CONSUMPTION

Han BW, Kim H-S, Jee SJ, Lee JH, Kim HJ, Park SH, Ji SG, Heu MS, Kim J-S.2007. Characteristics of hot-water extracts from salmon frame as basic ingredients for gomtang-like products. J Korean Soc Food Sci Nutri 36(10):1326-1333.

Abstract: Conditions for extracting components from salmon frame for use in production of gomtang-like (soup) products was investigated and characteristics of the extracts were compared with commercial gomtang. Based on crude protein, extractive-N and sensory properties the optimal extraction procedure was found to be extracting pre-treated salmon frame in 12× (v/w) of water for 12 h, filtering with cheese cloth to yield 3× the vol. of the raw material. Heavy metals in salmon frame extracts were below safety limits suggested by the Korean FDA. The major free amino acids were glutamic acid and asparatic acid and the major total amino acids were glycine, proline and glutamic acid. Ca and P contents were 18.0 mg/100 ml and 33.1 mg/100 ml, respectively and they accounted for 20 and 18%, respectively, of the recommended daily allowance for mineral intake. Angiotensin I converting enzyme inhibitory activity was improved by incubation with Flavourzyme for 4 h; its IC50 was 2 mg/ml. The results suggest that enzymic hydrolysates from extracts of salmon frame could be used as a basic ingredient for preparing gomtang-like products.

Han BW, Ji S-G, Kwon J-S, Good J-G, Kang KT, Jee SJ, Park SH, Heu MS, Kim J-S. 2008. Food component characteristics of fish frames as basic ingredients of fish gomtang. J Korean Soc Food Sci Nutri 36(11):1417-1424.

Abstract: The composition of fish (skipjack tuna, yellowfin tuna, bluefin tuna, conger eel, salmon, Spanish mackerel, armored weasel-fish) frames and their hot-water extracts were investigated to explore the possibility for their use for fish gomtang. Volatile basic N and heavy metal contents of bluefin tuna and salmon frames were found to be below the safety limits suggested by the Codex Code and could be used as basic ingredients for fish gomtang. Nitrogenous compounds were the major components of all hot-water extracts from fish frames. Results of N extraction and sensory evaluation of hot-water extracts from fish frames indicated that the salmon frame was a good raw material as a basic ingredient of fish gomtang. Ca and P contents of hot-water extracts from salmon frame were 18.0 mg/100 ml and 33.1 mg/100 ml, respectively.

Heu MS, Kim JS. 2008. Preparation and characterization of seasoned salmon powder. J Kor Soc Food Sci Nutr 37(10):1323-1329.

Abstract: A seasoned salmon powder was developed and its characteristics were studied to enable production of new products utilizing salmon. The proximate composition of the seasoned salmon powder (P) was 42.1% moisture, 30.3% protein, 18.9% lipid and 6.2% ash and the Hunter colour values were 68.14 for lightness, 7.86 for redness, 19.13 for yellowness and 35.12 for colour difference. Trichloroacetic acid-soluble N content of product P was 360 mg/100 g, which is higher than that of a commercial product (234 mg/100 g). Total taste value was 2.2× higher in product P than in the commercial product, and the major free amino acid was glutamic acid. In both product P and the commercial product, the major fatty acids were 16:0, 18:1n-9, 18:2n-6 and 22:6n-3. Total amino acid content was higher in product P (29.05 g/100 g) than in the commercial product (20.79 g/100 g) and the major amino acids were aspartic acid, glutamic acid, leucine, and lysine. The results of sensory evaluation for taste, colour and flavour showed that product P was superior to the commercial product.

Heu MS, Park SH, Kim H-S, Jee SJ, Kim HJ, Han BW, Ha J-H, Kim JG, Kim J-S. 2008. Preparation of snack using residues of fish gomtang. J Korean Soc Food Sci Nutr 37(1):97-102.

Abstract: Preparation of a snack using salmon frame residues from salmon gomtang production was investigated. The optimal residues content of the snack was found to be 15% based on volatile basic N content, aw and sensory evaluation. Total amino acid content was higher in the snack (14.8 g/100 g) with 15% residues than in a snack (9.8 g/100 g) without residues. The major amino acids of the snack with added residues were aspartic acid (9.9%), glutamic acid (14.7%) and proline (9.5%). The Ca, P and polyunsaturated fatty acid (20:5n-3 and 22:6n-3) of the snack with 15% residues were higher compared to those of the snack without residues.

Heu MS, Park SH, Kim H-S, Jee SJ, Lee JH, Kim HJ, Han BW, Kim JS. 2008. Improvement on the functional properties of gomtang-like product from salmon frame using commercial enzymes. J Korean Soc Food Sci Nutri 36(12):1596-1603.

Abstract: This study was conducted to improve the properties of salmon frame extracts for use in gomtang-like (Korean soup) products using various commercial enzymes (Alkalase 2.4 L FG, Flavourzyme 500 MG, Neutrase 08 L and Protamex 1.5 MG). ACE (angiotensin I converting enzyme) inhibitory activity was the highest (IC50 =0.67 mg/ml) in the product incubated with Neutrase for 4 h (N4-treated hydrolysates). However, antioxidative activity of all salmon frame extracts were <15%. There were no significant differences in proximate composition and sensory properties for fish odour and taste. However, the N4-treated hydrolysate was higher in extractive N content and optical transmission compared to the other hydrolysates. When compared to commercial gomtang products, the N4-treated hydrolysate was high in protein, extractive N, total amino acids and Ca contents but low in taste sensory score. There were no differences in optical transmission and sensory score for fish odour between N4-treated hydrolysates and commercial gomtang.

Heu MS, Park SH, Kim H-S, Kim H-J, Han BW, Ji SG, Kim J-G, Yoon M S, Kim J-S. 2008. Improvement on fish odor of extracts from salmon frame soaked in soybean milk. J Korean Soc Food Sci Nutr 37(2):223-230.

Abstract: Use of extracts from salmon frame as a basic material for production of gomtang-like (a Korean soup) products was studied. Various methods (soaking in soymilk, adding anchovies and adding spices) for masking fish odour in salmon frame extracts were examined. Sensory properties, proximate composition, mineral content and amino acid content were compared with commercial gomtang. Volatile basic N content, light transmission at 660 nm and sensory evaluation of extracts showed that soaking salmon frame in soybean milk was the most efficient method for masking fish odour in extracts from salmon frame. There was no difference in proximate composition between extracts from salmon frame soaked (FS) and unsoaked (C) in soymilk. Heavy metals (including Cr, Pb and Cd) were not detected in FS. The flavour of FS was preferred to that of C and the major amino acids were glutamic acid and aspartic acid. Total amino acid content of FS (3.08 g/100 ml) was higher than that of C (2.95 g/100 ml) and commercial gomtang (1.70 g/100 ml), the major amino acids were glycine, proline, glutamic acid and arginine. The Ca and P contents of FS/500 ml accounted for 21.7% and 18.5%, respectively, of the recommended daily allowance of these minerals for adults.

Kim KY, Ustadi, Kim SM. 2006. Characteristics of the protease inhibitor purified from chum salmon (*Oncorhynchus keta*) eggs. Food Sci Biotechnol 15(1):28-32.

Abstract: Proteinase inhibitors (PI) can be used to prevent quality deterioration in surimi products. A PI was isolated from chum salmon (*Oncorhynchus keta*) eggs, purified and characterized. The PI had a mol. wt. of 72.6 kDa, consisting of 2 subunits (54.0 and 18.6 kDa), was stable at 20–40°C and pH 6, and inhibited papain, cathepsin and cysteine proteinases, but not chymotrypsin. Inhibition of cathepsin by PI was more effective than by its counterpart from egg white, whereas the reverse was true for papain inhibition. Results suggest that PI should be classified as a cysteine proteinase inhibitor.

Kong J, Dougherty MP, Perkins LB, Camire ME. 2008. Composition and consumer acceptability of a novel extrusion-cooked salmon snack. J Food Sci 73(3):S118-S123.

Abstract: The objectives of this study were to develop a value-added jerky-style snack from salmon flesh and to minimize loss of healthful lipids during processing. Three formulations were extruded in a laboratory-scale twin-screw extruder. The base formulation included Atlantic salmon (82%, w/w), sucrose (4%), pregelatinized starch (3%), modified tapioca starch (3%), salt (2%), and teriyaki flavoring (2%). Three oil binding agents (tapioca starch, high-amylose cornstarch, oat fiber) were each studied at the 4% level. Barrel temperature, from feed to die, was 65, 155, 155, and 80 °C. Screw speed was 250 rpm. Feed rate was 220 g/min. Extrudates were convection-dried at 93 °C for 40 min. A texture analyzer was used to evaluate textural properties. Sixty-three consumers evaluated the hedonic attributes of the snacks. Extrusion cooking did not adversely affect content of omega-3 fatty acids docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) in Atlantic salmon. The oat fiber formulation had the highest lipid (17.49%) content. The other

formulations had higher moisture content. A serving (28 g) of the oat formulation provides 0.6 g EPA + DHA. Snacks containing oat fiber had the highest CIE L* and b* values. Snacks containing oat fiber required greater force to bend, cut, and puncture. The oat fiber formulation had the lowest overall acceptability. This portable snack could appeal to consumers who are interested in the health benefits of fish and omega-3 fatty acids and provide salmon processors with a value-added solution for processing by-products.

Luten JB, Jacobsen C, Bekaert K, Saebø A, Oehlenschälger J, editors. 2006. Seafood research from fish to dish: quality, safety and processing of wild and farmed fish. Wageningen, The Netherlands: Wageningen Academic Publishers.

Book Summary: In this book, scientists from various disciplines address the advances in seafood research with respect to quality, safety, consumer's demands and processing of wild and farmed fish. The nutritional properties of marine lipids and lipid oxidation from model systems to seafood are presented. Several contributions on the effects of natural anti-oxidants to prevent oxidation are also included. Effects of dietary factors on muscle tissue quality, pre-rigor processing and brining of farmed cod are covered. The development of rigor mortis and the quality of muscle in relation to commercial and experimental slaughter techniques are also discussed. Consumer's knowledge, perception and need for information about seafood are discussed. Topics such as shelf life and microbial quality of seafood are covered in a range of contributions. Inactivation of micro organisms or biopreservation of seafood are included. Attention is paid to the development of the Quality Index Method for the evaluation of the quality of fresh fish and products. The characterisation and the quality of processed by-products are also presented. The presence of trace elements and organic contaminants in variety of seafood products is highlighted. Finally, several contributions regarding advanced methodologies to determine the quality of seafood are presented. This book will be of interest to anybody concerned with quality and safety of fish throughout the entire chain from catch to consumer.

Manseth E, Skjervold PO, Fjaera SO, Brosstad FR, Odegaard OR, Flengrud R. 2003. Developing a fish meat-binding agent: purification of salmon thrombin. J Food Sci 68(5):1648-1652.

Abstract: Blood from farmed fish could serve as a substitute for mammalian blood as a source for binding agents. In this study, thrombin from Atlantic salmon (Salmo salar) was purified and characterized as a potential new binding agent for the food industry. Purification was performed avoiding inhibitors, using BaSO4 adsorption and heparin-Sepharose affinity chromatography. Prothrombin activation was performed using a mixture of eggs and gills from salmon. Optimized conditions for the adsorption, elution and the activation step are presented. The purified thrombin clotted bovine fibrinogen with a specific activity of 1423 U/mg. Sequence data are presented and compared with other species. It is concluded that this method of non-toxic activation and purification will enable salmon thrombin to be used in the food industry.

Nordvi B, Langsrud O, Egelandsdal B, Slinde E, Vogt G, Gutierrez M, Olsen E. 2007. Characterization of volatile compounds in a fermented and dried fish product during cold storage. J Food Sci 72(6):S373-S380.

Abstract: A N. European production technique for dry-cured meat sausages was applied to the production of a sliceable, fermented and dried fish product rich in □-3 PUFA. The fatty fish Atlantic salmon (*Salmo salar*), the lean fish saithe (*Pollachius virens*; 1:1, w/w), Lactobacillus sakei and 4 different milk protein-based ingredients were used in the recipes. Changes in the volatile compounds during cold storage (+4°C) of vacuum-packed dried sausages were studied by dynamic headspace GC-MS. Of the 117 volatile compounds identified, alcohols, alkanes, esters, aldehydes, ketones and compounds derived from amino acids were the most prevalent groups of volatiles. 30 volatiles decreased and 17 increased significantly ($P < 0.1$) during storage for 15 wk. Despite the high content of PUFA, amino acid catabolism and ester synthesis led to larger changes in the composition of volatiles in the fish product than did lipid oxidation reactions. The milk-protein-based powders that were used to physically stabilize the fish oil did not affect the lipid oxidation compounds.

Palagina MV, Prihod'ko YV, Nabokova AA, Cherkasova SA. 2007. Drinks with fish protein concentrate. Molochnaya Promyshlennost 10:67-68.

Abstract: Development of fermented milk beverages fortified with a mineral-rich fish protein concentrate (FPC) and suitable for use in prevention and treatment of osteroporosis is described. FPC used is derived from salmon or related species and has a Ca:Mg:P ratio of 1:0.6:0.9. A number of formulations, including drinking yoghurt, were made from milk (1.2 or 2.7% fat contents), FPC (added at 1.2%) and optional fruit flavourings. Good results were obtained when the beverages were used in trials in older adults suffering from various forms of osteoporosis.

Suhendan M. 2004. Preparation and the shelf-life assessment of ready-to-eat fish soup. J Eur Food Res Technol 220(3-4):305-308.

Abstract: In this study the waste products of a smoked salmon processing plant were gathered and used for the preparation of a ready-to-eat fish soup. The soup was prepared, filled into a salami cover; chilled and stored at 4±1 °C. This product takes a hard jelly form on chilling and it is possible to consume it as a soup after removing the cover and heating. Sensory, physical, chemical and microbiological analyses were carried out during the storage period and shelf-life was determined. The results showed that this product was in good condition until the 13th week, marketable between the 14th and 17th weeks, and spoiled after the 18th week of cold storage.

GELATINS

Arnesen JA, Gildberg A. 2007. Extraction and characterisation of gelatin from Atlantic salmon (Salmo salar) skin. Bioresource Technol 98(1):53-57.

Abstract: Gelatine was extracted from Atlantic salmon and Atlantic cod skin by the acid extraction process. After filtration and ion exchange treatment the extracts were colourless and free from fishy odour. In three separate experiments the average yields of gelatine from salmon and cod skins were 39.7% (±2.2%) and 44.8% (±0.2%)

respectively, on a dry matter basis. Gelatine from salmon contained slightly more hydroxyproline and proline (16.6%) than cod gelatine (15.4%), whereas the content of serine was lower (4.6% versus 6.3%). Salmon gelatine expressed slightly higher gelling temperature (12°C) than cod gelatine (10°C), and higher initial gel strength. During storage at 10°C, gel strengths were increased and more so with gels made from cod than from salmon gelatine. Hence, gels made from cod and salmon gelatines extracted at 56°C achieved the same gel strength (195g) after 7days of storage. Gelatines extracted at a higher temperature (65°C) gave lower gel strengths.

Avena-Bustillos RJ, Olsen CW, Olson DA, Chiou B, Yee E, Bechtel PJ, McHugh TH. 2006. Water vapor permeability of mammalian and fish gelatin films. J Food Sci 71(4):202-207.

Abstract: Water vapor permeability of cold- and warm-water fish skin gelatins films was evaluated and compared with different types of mammalian gelatins. Alaskan pollock and salmon gelatins were extracted from frozen skins, others were obtained from commercial sources. Water vapor permeability of gelatin films was determined considering differences on percent relative humidity (%RH) at the film underside. Molecular weight distribution, amino acid composition, gel strength, viscoelastic properties, pH, and clarity were also determined for each gelatin. Water vapor permeability of cold-water fish gelatin films (0.93 gmm/m²hkPa) was significantly lower than warm-water fish and mammalian gelatin films (1.31 and 1.88 gmm/m²hkPa, respectively) at 25 °C, 0/80 %RH through 0.05-mm thickness films. This was related to increased hydrophobicity due to reduced amounts of proline and hydroxyproline in cold-water fish gelatins. As expected, gel strength and gel setting temperatures were lower for cold-water fish gelatin than either warm-water fish gelatins or mammalian gelatins. This study demonstrated significant differences in physical, chemical, and rheological properties between mammalian and fish gelatins. Lower water vapor permeability of fish gelatin films can be useful particularly for applications related to reducing water loss from encapsulated drugs and refrigerated or frozen food systems.

Bower CK, Avena Bustillos RD, Olsen CW, McHugh TH, Bechtel PJ. 2006. Characterization of fish skin gelatin gels and films containing the antimicrobial enzyme lysozyme. J Food Sci 71(5):141-145.

Abstract: Fish skins are rich in collagen and can be used to produce food-grade gelatin. Films cast from fish-skin gelatins are stable at room temperature and can act as a barrier when applied to foods. Lysozyme is a food-safe, antimicrobial enzyme that can also produce gels and films. When cold-water, fish-skin gelatin is enhanced with lysozyme, the resulting film has antimicrobial properties. The objective of this study was to characterize the effect on strength and barrier properties of lysozyme-enhanced fish-skin gelatin gels and films, and evaluate their activity against potential spoilage bacteria. Solutions containing 6.67% fish-skin gelatin were formulated to contain varying levels of hen egg white lysozyme. Gels were evaluated for strength, clarity, and viscoelastic properties. Films were evaluated for water activity, water vapor permeability and antimicrobial barrier capabilities. Fish-skin gels containing 0.1% and 0.01% lysozyme had pH (4.8) and gelling-temperatures (2.1°C) similar to lysozyme-free fish-skin gelatin controls. However, gel strength decreased (up to

20%). Turbidities of gels, with or without lysozyme, were comparable at all concentrations. Films cast with gelatin containing lysozyme demonstrated similar water vapor permeabilities, and water activities. Lysozyme was still detectable in most fish gelatin films. More antimicrobial activity was retained in films cast with higher lysozyme concentrations and in films where lysozyme was added after the gelatin had been initially heated. These results suggest that fish-skin gelatin gels and films, when formulated with lysozyme, may provide a unique, functional barrier to increase the shelf-life of food products.

Bower C, Avena Bustillos R, Olsen C, Olson D, McHugh T. 2008. Cost to benefit – fish skin yields unique gelatin products. Glob Aquacult Advocate 11(4):28-29.

Abstract: Gelatin is traditionally produced by hydrolysis of bones and skins from cattle and pigs. This can create problems for people with kosher and halal dietary restrictions, and also carries the potential of health hazards associated with outbreaks of bovine spongiform encephalopathy. The gelatins of coldwater fish skins differ from other gelatins in gel-set and melting temperatures. Skins from coldwater fish produce a gelatin that does not solidify at room temperature, making it difficult to directly substitute for gels prepared from the skins of cattle, pigs, and warmwater fish. This is actually an advantage, since it imparts unique functional properties that are not present in other gelatins. By-products such as fish skins from Alaska's fishing industry represent an underutilized resource often subject to disposal costs rather than economic benefits. Currently, fish processing operations can mechanically separate skins from other fish components during the production of boneless fillets, making the collection of discarded skins economically feasible. These fish skins can be stabilized by various drying techniques without seriously hindering the yield and quality of extracted gelatin. Dried fish skins substantially decrease transportation costs and facilitate storage, perhaps eventually leading to widespread production of high-value fish skin gelatin of acceptable quality for food, aquaculture feeds and pharmaceutical uses.

Chiou BS, Avena-Bustillos RJ, Shey J, Yee E, Bechtel PJ, Imam SH, Glenn GM, Orts WJ. 2006. Rheological and mechanical properties of cross-linked fish gelatins. Polymer 47(18):6379-6386.

Abstract: Gelatin was extracted from the skins of Alaska pollock (*Theragra chalcogramma*) and Alaska pink salmon (*Oncorhynchus gorbuscha*). Amino acid analysis and gel electrophoresis were used to determine their amino acid composition and molecular weight profiles, respectively. Dynamic rheology was also used to characterize the fish gelatins' gelation and melting behavior as well as their cross-linking behavior upon adding genipin and glutaraldehyde. Pollock and salmon gelatin had lower gelation and melting temperatures than that of a commercial porcine gelatin. Both fish gelatins that contained genipin showed faster cross-linking rates for samples with higher pH values. However, salmon samples exhibited greater dependence on pH. Also, pollock gelatin cross-linked faster with glutaraldehyde than with genipin. After five days of cross-linking, all porcine samples had much greater gel strengths than pollock samples. In addition, porcine samples containing genipin had gel strengths several times greater than those containing glutaraldehyde.

Chiou BS, Avena-Bustillos RJ, Bechtel PJ, Jafri H, Narayan R, Imam SH, Glenn GM, Orts WJ. 2008. Cold water fish gelatin films: Effects of cross-linking on thermal, mechanical, barrier, and biodegradation properties. Eur Polym J 44(11):3748-3753.

Abstract: Gelatin was extracted from Alaska pollock (*Theragra chalcogramma*) and Alaska pink salmon (*Oncorhynchus gorbuscha*) skins and cast into films. The fish gelatin films' tensile, thermal, water vapor permeability, oxygen permeability, and biodegradation properties were compared to those of bovine and porcine gelatin films. In addition, fish gelatin films were cross-linked with glutaraldehyde. Pollock and salmon gelatin films had comparable tensile properties, but had lower tensile strength and percent elongation than mammalian gelatin films. The lower strength and elongation might have been due to lower structural gelatin levels present in fish gelatin films. The addition of cross-linkers had little effect on tensile properties and melting temperatures of fish gelatin films. Pollock gelatin films had the lowest water vapor and oxygen permeability values, whereas mammalian gelatin films had the highest permeability values. Cross-linking resulted in lower water vapor permeability for salmon gelatin films and higher oxygen permeability for pollock gelatin films. However, all fish gelatin films had better water vapor and oxygen barrier properties than mammalian gelatin films. Also, fish gelatin films degraded faster than mammalian gelatin films.

Kolodziejska I, Skierka E, Sadowska M, Kolodziejski W, Niecikowska C. 2008. Effect of extracting time and temperature on yield of gelatin from different fish offal. Food Chem 107(2):700-706.

Abstract: The aim of the study was to determine the optimal conditions for preparing gelatin from different kinds of fish offal: heads and backbones of Baltic cod, skins of fresh and cold-smoked salmon, and skins of salted and marinated herrings. The yield of gelatin extraction at 45 °C was 71-75% for fresh salmon skins or cod backbones, and 86%, for smoked salmon skins. When heating marinated herring skins for 15 min or salted herring skins for 45 min, about 100% of collagen was converted to gelatin. For fish skins, 45 °C and 15-60 min extraction time, depending on the kind of skins, were established as optimal conditions for preparing gelatin. The yield of gelatin extraction from the cod heads did not exceed 70%, even when a three stages process was used. In the case of backbones, 100% of collagen in the form of gelatin was isolated using this procedure. SDS-PAGE analysis showed that gelatin from fish skins was much less degraded than gelatin from pigskins.

Lodemel J, Olsen R. 2003. Gelatinases in fish muscle. J Sci Food Agricult 83(10):1031-1036.

Abstract: The gelatinolytic activity in muscle from Atlantic cod (Gadus morhua), spotted wolffish (Anarhichas minor) and Atlantic salmon (Salmo salar) was studied using gelatin SDS-PAGE, gelatin affinity chromatography and enzyme inhibitors. These fish species are known to differ markedly in fillet softening and gaping post mortem. Atlantic cod, which is a promising species for cold water marine aquaculture, often shows such negative properties, particularly after being well fed. Gelatinolytic activity bands were present in all three species. Using gelatin chromatography and enzyme inhibitors, both serine proteinases and

metalloproteinases were detected in wolffish and cod muscle, while only the latter were found in salmon muscle. Activation of the metalloproteinases by p-aminophenylmercuric acetate (APMA) resulted in a shift in activity from higher to lower molecular weight, as is known for mammalian matrix metalloproteinases. In all three species the molecular weight of the metalloproteinases was lowered from approximately 80 to about 70 kDa by activating with APMA.

Nagai N, Kubota R, Okahashi R, Munekata M. 2008. Blood compatibility evaluation of elastic gelatin gel from salmon collagen. J Biosci Bioeng 106(4):412-415.

Abstract: Blood compatibility of a novel elastic gelatin gel (e-gel) from salmon collagen was evaluated. After a 10-min incubation of the e-gel with rat whole blood, there was a macroscopically small thrombus formation on the e-gel. Microscopic observation revealed that few platelets had adhered to the e-gel. Furthermore, the platelet adhesion rate was markedly lower on the e-gel compared to collagen-coated and fibrinogen-coated surfaces. Comparable results were obtained with re-crosslinked e-gel. In conclusion, the e-gel demonstrated good blood compatibility.

Nagatsuka N, Sato K, Harada K, Nagao K. 2007. Radical scavenging activity of 'Nikogori' gelatin gel food made from head, bone, skin, tail and scales of fishes measured using the chemiluminescence method. Int J Mol Med 20(6):843-847.

Abstract: Head, bone, skin and tail mixed parts of yellowtail and bream, scales of bream and head of salmon which have nutritional values and are usually discarded were made into 'Nikogori' gelatin gel. They are not only a good source of protein but are also useful for elderly people with swallowing problems. Soy sauce, a traditional seasoning in Japan, was added to enhance the taste of 'Nikogori'. The rheological properties were examined by a rheometer and the peroxyl radical scavenging activity was measured by the chemiluminescence method. Sensory evaluation was also conducted employing 20 faculty members and students of the Laboratory of Cookery Science, Tokyo Kasei University, Japan to assess its acceptance. It was found that 'Nikogori' has peroxyl radical scavenging activity. Moreover, addition of soy sauce to 'Nikogori' enhanced the peroxyl radical scavenging activity. The rheological properties of 'Nikogori' and of the soy sauce added conformed to the standard set by the Ministry of Health, Labour and Welfare of Japan for elderly people with swallowing problems. From the data of the antioxidative activity and the sensory evaluation, the soy sauce-added 'Nikogori' was preferrable to that of the non-added one.

Wasswa J, Tang J, Gu XH. 2007. Utilization of fish processing by-products in the gelatin industry. Food Rev Int 23(2):159-174.

Abstract: Since the bovine spongiform encephalopathy crisis, there has been a growing interest for finding an alternative source of raw materials for gelatin production. Gelatin produced from fish processing by-products is a potential alternative to mammalian gelatin. Fish processing generates solid wastes that can be as high as 50-80% of the original raw material. These wastes are an excellent raw material for preparation of high protein foods. About 30% of the wastes consists of skin and bone with a high collagen content. Fish gelatin can be obtained by hydrolysis of collagen the principal protein found in skin and bone. Fish skin and

bone gelatin can be prepared with bloom strength similar to that obtained from mammalian sources. Fish gelatin has numerous applications, particularly, in the food, pharmaceutical, and photographic industries due to its unique chemical and physical properties. This review presents how fish processing by-products can be utilized in the manufacture of gelatin.

Yunoki S, Nagai N, Suzuki T, Munekata M. 2004. Novel biomaterial from reinforced salmon collagen gel prepared by fibril formation and cross-linking. J Biosci Bioeng 98(1):40-47.

Abstract: The improvement of the thermal stability of gel prepared from salmon atelocollagen (SC) was studied. The denaturation temperature (Td) of the SC solution was found to be 18.6°C. Neutral buffer including 1-ethyl-3-(3-dimethylaminopropyl)-carbodiimide (EDC) was mixed with acidic SC solution at 4°C, resulting in the introduction of EDC cross-linking during fibril formation. The mechanical strength and thermal stability of the resultant cross-linked SC fibrillar gels reached maximum values at an EDC concentration of 50 mM (f-50 gel). In particular, the melting temperature of the f-50 gel was 47°C, much higher than that of the EDC cross-linked SC gel without fibril formation at the same EDC concentration. The proliferation rate of human periodontal ligament cells on the f-50 gel was higher than that of a porcine atelocollagen fibrillar gel. These results suggest that the gel employed for biomaterials can be fabricated from low Td fish collagen by EDC cross-linking during fibril formation.

HYDROLYSATES

Daukšas E, Šliyte R, Rustad T, Storrø I. 2004. Bitterness in fish protein hydrolysates and methods for removal. J Aquat Food Prod Technol 13(2):101-114.

Abstract: Enzymatic hydrolysis is a processing method for recovering protein from under utilized fish biomass and fish by-products. However, the hydrolysis process often creates bitter taste in the product. The bitterness restricts the practical uses of these hydrolysates. The presence of bile in whole fish and fish viscera is shown to cause bitterness in fish protein hydrolysates. The fat and ash content could also cause bitter taste. The content of total amino acids and hydrophobic amino acids did not correlate with bitterness. Three different methods were used to eliminate or reduce bitterness from FPHs after enzymatic hydrolysis with commercial enzymes: (1) treatment with endopeptidases (Flavourzyme®), (2) extraction with butanol and (3) treatment with cholestyramine resin. Flavourzyme® did not reduce the bitterness. The use of butanol and cholestyramine resin separately or in combination reduced the bitter taste from FPH to levels barely discernible by our sensory panel in 1% concentration.

Gbogouri GA, Linder M, Fanni J, Parmentier M. 2004. Influence of hydrolysis degree on the functional properties of salmon byproducts hydrolysates. J Food Sci 69(8): 615-622.

Abstract: Protein hydrolysates from salmon heads were obtained by enzymatic treatment with Alcalase 2.4L. Response surface methodology (RSM) allowed optimization of temperature, enzyme/substrate, and pH leading to various hydrolysates (11.5% to 17.3% hydrolysis degree DH) and protein recovery ranging

from 47% to 70%. Size exclusion chromatography of hydrolysates showed that small peptides increased only at high DH. The nitrogen solubility index (NSI) of hydrolysates was higher than 75% over a wide range of pH values, whereas hydrolysates with high DH had the best solubility. Emulsifying capacity, emulsion stability, and fat absorption capacity were better when DH was low.

Hevroy EM, Espe M, Waagbø R, Sandnes K, Ruud M, Hemre GI. 2005. Nutrient utilization in Atlantic salmon (Salmo salar L.) fed increased levels of fish protein hydrolysate during a period of fast growth. Aquacult Nutr 11(4):301-313.

Abstract: The present work was designed to study whether changes in dietary protein quality by means of partial inclusion of fish protein hydrolysate (FPH) would alter fish growth, feed utilization, protein retention and metabolism and fish health in general. FPH was produced after hydrolysing whole minced herring using the industrial enzyme Alcalase®. The dietary protein source, low-temperature-dried (LT) fishmeal nitrogen was exchanged with FPH nitrogen at six levels of inclusion ranging from 0 to 300 g kg¹. The experimental diets were fed to post -smolt (1+) Atlantic salmon (Salmo salar), with mean initial weight of 174 g for a period of 68 days. All diets were iso-nitrogenous, iso-energetic and contained the same amount of amino acids. Fish fed medium inclusion of FPH (180–240 g kg¹) showed a tendency to have higher feed intake than fish fed lower and higher levels of FPH inclusions. Significant higher individual specific growth rates were present in fish fed diets with 180 and 240 g kg¹ FPH when compared with those fed 300 g kg¹. Feed conversion ratio increased significantly (R^2 = 0.61) and protein efficiency ratio decreased significantly (R^2 = 0.59) in fish fed increased levels of FPH. Further, apparent digestibility of crude protein and the amino acids arginine, lysine, methionine and phenylalanine increased significantly with increased dietary inclusion of FPH. Plasma free amino acids, ammonium and urea indicated that FPH amino acids was absorbed earlier and nonsynchronously, and may thus be more prone to be catabolized than in those fish fed the less solubilized protein. FPH inclusion did not have an impact on fish health, as evaluated by haematology and clinical parameters.

Liaset B, Julshamn K, Espe M. 2003. Chemical composition and theoretical nutritional evaluation of the produced fractions from enzymic hydrolysis of salmon frames with Protamex™. Process Biochem:38(12):1747-1760.

Abstract: An amount of 200 kg fresh salmon frames were enzymic hydrolysed with the commercial protease mixture Protamex™, which is known to produce non-bitter hydrolysates. After the enzymic procedure the frames were separated by centrifugation into five fractions: an aqueous fraction rich in peptides, an insoluble fraction, an emulsion fraction, salmon oil and a bone fraction. Approximately 48% of total crude protein present in the salmon frames were found in the aqueous fraction, in which the lipid content was reduced to <0.1% in dry samples after ultramembrane filtration (UF fraction). The UF fraction was low in tryptophan, leucine and phenylalanine+tyrosine, but high in taurine. Nearly 19% of total crude protein present in the salmon frames were found in the insoluble fraction. This fraction was high in most of the indispensable amino acids. Approximately 77% of total lipids present in the salmon frames were isolated as salmon oil, which was high in both

eicosapentaenic acid (EPA) and docosahexaenic acid (DHA). The bone fraction contained 62% of total ash present in the salmon frames and was high in the minerals Ca, P and Mg and also in the trace elements Cu, Fe, I, Mn, Se and Zn. All of the produced fractions were low in the undesirable substances As, Cd, Hg and Pb. For future studies the UF fraction and salmon oil might be interesting as health promoting agents, the insoluble fraction as dietary protein supplement and the bone fraction as dietary mineral supplement.

Ono S, Hosokawa M, Miyashita K, Takahashi K. 2006. Inhibition properties of dipeptides from salmon muscle hydrolysate on angiotensin I-converting enzyme. Int J Food Sci Technol 41(4):383-386.

Abstract: We isolated Phe–Leu as an angiotensin I-converting enzyme (ACE) inhibitor from hydrolysate of chum salmon muscle. The IC₅₀ value of this peptide was 13.6 m̄, and it showed non -competitive inhibition. The reverse sequence dipeptide Leu–Phe also showed ACE inhibitory activity. However, Leu–Phe is much less inhibitory than Phe–Leu with an IC₅₀ value of 383.2 m̄. In addition, the inhibition mode was competitive. To investigate the relationship between dipeptide sequence and ACE inhibition properties, we further measured ACE inhibitory activity and inhibition mechanism using six Trp-containing dipeptides, which had been identified from the same salmon muscle hydrolysate as ACE inhibitory peptides in a previous study. Peptides with Trp as the C-terminal residue, Ala–Trp, Val–Trp, Met–Trp, Ile–Trp, Leu–Trp showed non-competitive inhibition. On the other hand, reversed sequence peptides with Trp at the N-terminal were competitive inhibitors, except Trp–Leu. These results indicate that the sequence of ACE inhibitory dipeptides can affect both inhibitory potency and the inhibition mechanisms.

Sathivel S, Smiley S, Prinyawiwatkul W, Bechtel, PJ. 2005. Functional and nutritional properties of red salmon (*Oncoryhynchus nerka*) enzymatic hydrolysates. J Food Sci 70(6):401-406.

Abstract: The effects of different proteolytic enzymes and different reaction durations (25, 50, 75 min) on functional and nutritional properties of red (sockeye) salmon head hydrolysates were evaluated. Degree of hydrolysis values for the 75-min digestion ranged from 6.4% to 16.7%. Oil yield (4.9% to 10.6 %) from red salmon heads was affected by the enzyme used. Protein hydrolysate powders were yellowish and contained 62.3% to 64.8% protein with high levels of essential amino acids. Increased degree of hydrolysis values were weakly correlated with increased hydrolysate solubility. Maximum emulsion stability and fat adsorption were observed for the dried hydrolysate generated in the 25-min reaction time. Water adsorption of hydrolysate powders ranged from 1.0 mL to 3.3 mL water/g dried hydrolysate.

Wang Y, Zhu F, Han F, Wang H. 2008. Purification and characterization of antioxidative peptides from salmon protamine hydrolysate. J Food Biochem 32(5):654-671.

Abstract: Protamine, derived from fish milt, which is normally discarded as an industrial by-product in the process of fish plant, was hydrolyzed with pancreatin. Salmon protamine hydrolysate was found to possess antioxidative activity against hydroxyl, 2,2-diphenyl-1-picrylhydrazyl and superoxide anion radicals. Through

consecutive chromatographic methods including size exclusion, ion exchange chromatography and reverse-phase high performance liquid chromatography (HPLC), a series of peptide fractions with high antioxidative activities were obtained. Peptide with highest antioxidative activity was identified to be Pro-Arg matching 1–2 and 16–17 residues of the salmon protamine by electrospray ionization mass spectrometry and database search. These results provided sufficient and scientific information for the marketing of health food supplemented with protamine hydrolysate and added further support for the wide applications of fish milt.

LIPIDS

Dodds ED, McCoy MR, Geldenhuys A, Rea LD, Kennish JM. 2004. Microscale recovery of total lipids from fish tissue by accelerated solvent extraction. J Am Oil Chem Soc 81(9):835-840.

Abstract: A number of techniques are available for the extraction of lipids from a variety of tissues; however, conventional methods are characteristically labour intensive, typically involve large vol. of toxic solvents and usually require at least 1 g of tissue. With the availability of accelerated solvent extraction (ASE) technology, the opportunity exists to modify classical lipid extraction techniques so that automated high-pressure, high-temp. extractions may be performed with the use of far smaller volumes of costly and harmful solvents. Moreover, the high extraction efficiency attainable by ASE suggests that significantly less tissue would be required than is routinely used. In this study, previously developed lipid extraction solvent systems were adapted for use with ASE in order to extract total lipids from 100 mg of fish tissue. The efficacy of 3 solvent systems for lipid extraction from representative fish tissues, including a standard reference material, was explored using gravimetry and fatty acid analysis by GC. A triglyceride was used as a surrogate to monitor overall method performance. Results showed that microscale ASE could be achieved with a quantitative accuracy and precision that would be acceptable for many applications. The respective mean percentage recoveries of the surrogate from salmon and halibut were approx. 102.3 and 93.8 with a CHCl3/methanol solvent system, 79.8 and 87.6 with hexane/isopropanol and 108.5 and 58.3 with CH2Cl2. The fatty acid composition could be quantitatively determined from 100 g of tissue containing approx. 2–20% lipid by mass.

Gbogouri GA, Linder M, Fanni J, Parmentier M. 2006. Analysis of lipids extracted from salmon (Salmo salar) heads by commercial proteolytic enzymes. Eur J Lipid Sci Technol 108(9):766-775.

Abstract: Fresh salmon heads were submitted to controlled proteolysis using food-grade commercial enzymes (Alcalase®, Neutrase® and Protamex™). The release of oil under mild conditions (60°, 2 h) compared favourably with organic solvent extraction (19.8% *vs.* 21.5%). Lipids extracted by solvent and lipids resulting from enzymatic processes displayed a similar content of PUFA (about 35%), mainly eicosapentaenoic acid (EPA; 8.4% *vs.* 7.7%) and docosahexaenoic acid (DHA; 12.1% *vs.* 11.9%). Thin-layer chromatography (TLC-FID Iatroscan) showed that the polar lipid fraction accounted for 55% of total lipids (phosphatidylethanolamine, 20.7%; phosphatidylcholine, 14.8%). Salmon head phospholipids may be more effective

carriers of highly unsaturated fatty acids to specific tissues than triacylglycerols, as shown by their content in EPA (10.3 and 6.9%, respectively) and DHA (33.1 and 9.1%, respectively).

Kim JG, Han B-W, Kim H-S, Park Ch-H, Chung I-K, Choi YJ, Kim J-S, Heu M-S. 2005. Lipid characteristics of fish frame as a functional lipid resource. J Korean Soc Food Sci Nutr 34(3):380-388.

Abstract: Lipid characteristics of fish frames (fish processing wastes consisting of bones and attached flesh) from 6 fish species were studied in order to investigate possible use of fish frames as functional lipid resources. Frames from armored weasel-fish (ArW, *Hoplobrotula armata*), chum salmon (ChS, *Oncorhynchus keta*), Spanish mackerel (SpM, *Scomberomorus niphonius*), common mackerel (CoM, *Scomber japonicus*), conger eel (CoE, *Conger myriaster*) and skipjack tuna (SkT, *Katsuwonus pelamis*) were studied by determining total lipid contents, lipid classes and fatty acid composition. The highest yield of bone was obtained from SkT frame (64.2%), followed by ChS frame (57.9%), CoE frame (54.6%), ArW frame (41.6%), SpM frame (41.7%) and CoM frame (32.6%). The highest neutral lipid content was found in total lipid from SpM bone (23.3 g/100 g), followed by CoE bone (21.5 g/100 g), ChS bone (16.0 g/100 g) and CoM bone (15.5 g/100 g), while those from SkT and ArW bones were 7.2 and 0.4 g/100 g, respectively. The prominent lipid classes of neutral lipids from all fish bones and flesh were triglycerides, which was much lower in ArW than in other fishes. The percentage of eicosapentaenoic acid and docosahexaenoic acid in neutral lipids from fish bones was highest in ChS (29.3%), followed by SkT (27.1%), ArW (27.0%), CoM (25.7%), SpM (21.6%) and CoE (14.9%). It is concluded that, from the processing wastes examined, the frame from chum salmon is the best potential resource for the extraction of functional lipids.

Oliveira ACM, Bechtel PJ. 2005. Lipid composition of Alaska pink salmon (*Oncorhynchus gorbuscha*) and Alaska walleye pollock (*Theragra Chalcogramma*) byproducts. J Aquat Food Prod Technol 14(1):73-91.

Abstract: In Alaska, over one million metric tons (mt) per year of fish processing byproducts are produced. The objective of this study was to determine the fatty acid profile and quantitate lipid classes in the extracted oils of byproducts from pollock (heads, frames, viscera, skins) and salmon (heads, viscera). In pollock, viscera had the highest percent lipid and in salmon, heads had the highest lipid content. All fish parts from both salmon and pollock were rich in omega-3 fatty acids, which ranged from 25% to 36% in the extracted oils. Differences among byproducts in fatty acid content and percent of lipid classes were detected in both salmon and pollock.

Tanaka Y, Ohkubo T. 2004. Extraction of lipids from salmon roe with supercritical carbon dioxide. J Oleo Sci 52(6):295-301.

Abstract: Use of supercritical CO2 to extract lipids from salmon roe was investigated and the extracted and residual lipids were characterized. Freeze-dried salmon roe was extracted using supercritical CO2 at a pressure range of 9.8–31.4MPa and temp. range 40–80°C. Lipid yield and fatty acid profiles of the extracted lipids were affected by the extracting conditions. Effect of CO2 density was estimated. At 80°C, the extracts were mostly affected by the extracting pressure. At 17.7MPa the extracts

were affected by the extracting temp. The lipids extracted contained triacylglycerides and their derivatives, while the lipids not extracted contained triacylglycerides and phospholipids. Therefore, 2 groups of triacylglycerides were found in the freeze-dried salmon roe, extractable and non-extractable triacylglycerides. <30% of astaxanthin, a functional pigment in the salmon roe, was extracted. Loss of astaxanthin was <10% of the total involved in the process.

MEDICAL USES

Albert C. 2004. Fish oil – an appetizing alternative to anti-arrhythmic drugs? The Lancet 363(9419):1412-1413.

Preview: Observational and trial data have accumulated to support the hypothesis that increased consumption of the long-chain n-3 polyunsaturated fatty acids found in fish, especially eicosapentaenoic and docosahexaenoic acids, lower the risk of dying from coronary heart disease,1 and interest has focused on the anti-arrhythmic properties of these fatty acids. In the late 1980s, McClennan et al were the first to show anti-arrhythmic properties associated with these fatty acids in animal models. Billman et al3 confirmed and expanded on these experiments in a dog model.

Enari H, Takahashi Y, Kawarasaki M, Tada M, Tatsuka K. 2008. Identification of angiotensin I-converting enzyme inhibitory peptides derived from salmon muscle and their antihypertensive effect. Fisheries Sci 74(4):911-920.

Abstract: The antihypertensive effect of a salmon peptide with strong inhibitory activity against the angiotensin I-converting enzyme (ACE) was investigated in spontaneously hypertensive rats (SHR). After a single intravenous administration of the salmon peptide at a dose of 30 mg/kg body wt., systolic blood pressure (SBP) was significantly reduced compared with that in the control. Further, a double-blind, placebo-controlled, parallel-group study determined the efficacy of the salmon peptide in mild hypertensive subjects. The SBP, after a 1.0 g of salmon peptide intake, was significantly reduced at 4 wk after the intake and 2 wk after the intake finished, compared to the value before ingestion. Bioassay-guided separation of the salmon peptide, using a combination of column chromatographic techniques, led to the identification of 20 active di- and tri-peptides, including Ile-Val-Phe and Phe-Ile-Ala as 2 new ACE inhibitory tripeptides. Ile-Trp had the strongest ACE inhibitory activity (IC50 = 1.2M) in vitro, and contributed 5.2% to the total ACE inhibitory activity. The salmon peptide and Ile-Trp showed a digestive resistance by in vitro assay, which mimicked the digestive organ, and had no affinity for factors related to blood pressure regulation, except for the ACE inhibitory activity.

GISSI-HF Investigators. 2008. Effect of n-3 polyunsaturated fatty acids in patients with chronic heart failure (the GISSI-HF trial): a randomised, double-blind, placebo-controlled trial. The Lancet 373(9645):1223-1230.

Abstract: BACKGROUND: Several epidemiological and experimental studies suggest that n-3 polyunsaturated fatty acids (PUFA) can exert favourable effects on atherothrombotic cardiovascular disease, including arrhythmias. We investigated whether n-3 PUFA could improve morbidity and mortality in a large population of patients with symptomatic heart failure of any cause. METHODS: We undertook a

randomised, double-blind, placebo-controlled trial in 326 cardiology and 31 internal medicine centres in Italy. We enrolled patients with chronic heart failure of New York Heart Association class II—IV, irrespective of cause and left ventricular ejection fraction, and randomly assigned them to n-3 PUFA 1 g daily (n=3494) or placebo (n=3481) by a concealed, computerised telephone randomisation system. Patients were followed up for a median of 3·9 years (IQR 3·0—4·5). Primary endpoints were time to death, and time to death or admission to hospital for cardiovascular reasons. Analysis was by intention to treat. This study is registered with ClinicalTrials.gov, number NCT00336336. FINDINGS: We analysed all randomised patients. 955 (27%) patients died from any cause in the n-3 PUFA group and 1014 (29%) in the placebo group (adjusted hazard ratio [HR] 0·91 [95·5% CI 0·833—0·998], p=0·041). 1981 (57%) patients in the n-3 PUFA group and 2053 (59%) in the placebo group died or were admitted to hospital for cardiovascular reasons (adjusted HR 0·92 [99% CI 0·849—0·999], p=0·009). In absolute terms, 56 patients needed to be treated for a median duration of 3·9 years to avoid one death or 44 to avoid one event like death or admission to hospital for cardiovascular reasons. In both groups, gastrointestinal disorders were the most frequent adverse reaction (96 [3%] n-3 PUFA group *vs* 92 [3%] placebo group). INTERPRETATION: A simple and safe treatment with n-3 PUFA can provide a small beneficial advantage in terms of mortality and admission to hospital for cardiovascular reasons in patients with heart failure in a context of usual care.

Gunnardottir I, Tomasson H, Kiely M, Martinez JA, Bandarra NM, Morais MG, Thorsdottir I. 2008. Inclusion of fish or fish oil in weight-loss diets for young adults: effects on blood lipids. Int J Obesity 32(7):1105-1112.

Abstract: Objective: To assess the effects of fish (lean or oily) and fish oil consumption on blood lipid concentration during weight loss. Design: Randomized, controlled 8-week trial of energy-restricted diet varying in fish and fish oil content. Subjects, 324 men and women, aged 20-40 years, body mass index 27.5-32.5 kg m-2, from Iceland, Spain and Ireland, were randomized to one of four groups: (1) control (sunflower oil capsules, no seafood), (2) cod diet (3 150 g week-1), (3) salmon diet (3 150 g week-1), (4) fish oil (DHA/EPA capsules, no seafood). The macronutrient composition of the diets was similar between the groups and the capsule groups were single-blinded. Measurements: Total cholesterol (TC), high-density lipoprotein (HDL) and low-density lipoprotein cholesterol, triacylglycerol (TG) and anthropometrics were measured at baseline and end point. Results: The difference in logTG lowering between the control group and the cod diet, salmon diet and fish oil from baseline to end point was -0.036 (95% CI -0.079 to 0.006), -0.060 (-0.101 to -0.018) and -0.037 (-0.079 to 0.006), respectively. Reduction in TC was about 0.2 mmol l-1 greater in the fish groups (cod and salmon) than in the control group, but only of borderline significance when adjusting for weight loss. HDL tended to decrease less in the diet groups consuming a significant amount of n-3 fatty acids (salmon and fish oil). Conclusion: Weight-loss diet including oily fish resulted in greater TG reduction than did a diet without fish or fish oil. Controlled trials using whole fish as a test meal are encouraged to be able to elucidate the role of different constituents of fish for human health.

Harris WS, Pottala JV, Sands SA, Jones PG. 2007. Comparison of the effects of fish and fish-oil capsules on the n-3 fatty acid content of blood cells and plasma phospholipids. Am J Clin Nutr 86(6):1621-1625.

Abstract: BACKGROUND: n-3 Fatty acids (FAs) have been shown to be beneficial for cardiovascular health. Whether n-3 FAs from oily fish consumed weekly or from fish-oil capsules taken daily are equally bioavailable is not clear. OBJECTIVE: The purpose of this study was to compare the rate and extent of enrichment of blood cell membranes [ie, red blood cells (RBCs)] and plasma phospholipids with n-3 FAs from these 2 sources. DESIGN: Healthy premenopausal female volunteers were randomly assigned to consume a daily average of 485 mg eicosapentaenoic (EPA) and docosahexaenoic (DHA) acids either from 2 servings of oily fish (ie, salmon and albacore tuna) per week or from 1-2 capsules/d. RESULTS: After 16 wk, EPA+DHA in RBCs in the fish group (n = 11) increased from 4.0 ± 0.6% of total FAs to 6.2 ± 1.4%, whereas it rose from 4.3 ± 1.0% to 6.2 ± 1.4% in the capsule group ($P < 0.0001$ for both; NS for group effect). Similar results were observed in plasma phospholipids. EPA+DHA stabilized in the latter after 4 wk but continued to rise through week 16 in RBCs. EPA in RBCs increased significantly ($P = 0.01$) more rapidly in the fish group than in the capsule group during the first 4 wk, but rates did not differ significantly between groups thereafter. Total FA variances were less in RBCs than in plasma phospholipids ($P = 0.04$). CONCLUSION: These findings suggest that the consumption of equal amounts of EPA and DHA from oily fish on a weekly basis or from fish-oil capsules on a daily basis is equally effective at enriching blood lipids with n-3 FAs.

Jonganurakkun B, Nodasaka Y, Sakairi N, Nishi N. 2006. DNA-based gels for oral delivery of probiotic bacteria. Macromol Biosci 6(1):99-103.

Abstract: A single-stranded DNA, readily extracted from industrial discarded salmon milt, was used to prepare hydrogels and complex gels by cross-linking with gelatin and kappa-carrageenan, for the oral delivery of probiotic bacteria. The complex gels showed a higher protective capability over the hydrogels for approximately one log scale. However, the hydrogels were more stable during storage at 4 degrees C. The Lactobacillus and Lactococcus due to protection of the hydrogels could better tolerate to acid than the Bifidobacterium. Furthermore, food-graded hydrogels were prepared and optimized to a similar protective capability for future applications.

Kanayama T, Nagai N, Mori K, Munekata M. 2008. Application of elastic salmon collagen gel to uniaxial stretching culture of human umbilical vein endothelial cells. J BioSci BioEng 105(5):554-557.

Abstract: In this study, we investigated the potential of an elastic salmon collagen gel (e-gel) for use as stretching culture scaffold. First, human umbilical vein endothelial cells (HUVECs) were cultured on the e-gel under static condition, and their growth was evaluated by DNA content measurement, MTT test, and scanning electron microscopy. The results demonstrated steady increases in cell number with culture time. Next, HUVECs were cultured on the e-gel under static condition for 2 d, then uniaxially stretched at a constant frequency (10% elongation at 1 Hz). After the stretching culture for 2 h, the cells oriented perpendicularly to the stretch direction.

Moreover, the interleukin-6 and interleukin-8 productions of the cells significantly increased under the stretch condition compared with those under the static condition. These results were in good agreement with the published data in which an elastic silicone membrane was used as a scaffold. In conclusion, the e-gel can be used for stretching culture for vascular tissue engineering.

Lucey AJ, Paschos GK, Cashman KD, Martínéz JA, Thorsdottir I, Kiely M. 2008. Influence of moderate energy restriction and seafood consumption on bone turnover in overweight young adults. Am J Clin Nutr 87(4):1045-1052.

Abstract: BACKGROUND: Overweight and obesity are increasing in young adults. However, moderate energy restriction aimed at lowering body weight may promote bone turnover and bone loss. Inclusion of fish or fish oils in a weight-loss diet may attenuate these adverse skeletal effects. OBJECTIVE: We examined the effects of incorporating fish or fish oil into an energy-restricted diet on bone turnover markers in young overweight adults. DESIGN: While following a strict hypoenergetic (-30% relative to estimated requirements) diet for 8 wk, 276 overweight men and women [body mass index (in kg/m²): 27.5-32.5; age: 20-40 y) were randomly assigned to 1 of 4 dietary groups: sunflower-oil capsules (3 g/d; control), cod (3 x 150 g/wk), salmon (3 x 150 g/wk), and fish-oil capsules (3 g/d). Body weight, bone biomarkers, and 25-hydroxyvitamin D were measured at baseline and endpoint. Data were analyzed with repeated-measures analysis of variance and general linear models. RESULTS: The mean (±SD) weight loss was 5.14 ± 3.0 kg (5.8% ± 3.2% body weight) during the 8 wk in the 4 dietary groups combined. Urinary N-telopeptides of type I collagen and serum C-terminal telopeptide of type I collagen increased ($P < 0.05$), whereas serum osteocalcin (but not bone-specific alkaline phosphatase) decreased ($P < 0.05$) from baseline to endpoint. Increased fish or fish-oil consumption had no effect ($P > 0.1$) on the changes in bone markers induced by weight loss. In contrast, increased salmon consumption increased serum 25-hydroxyvitamin D ($P < 0.01$). CONCLUSIONS: A nutritionally adequate but energy-restricted diet, with different contents of n-3 fatty acids, which resulted in modest weight loss, unfavorably altered bone turnover markers in young overweight adults. Such changes were not prevented by increased fish or fish-oil consumption.

Moriya H, Kuniminato T, Hosokawa M, Fukunaga K, Nishiyama T, Miyashita K. 2007. Oxidative stability of salmon and herring roe lipids and their dietary effect on plasma cholesterol levels of rats. Fisheries Sci 73(3):668-674.

Abstract: The oxidative stabilities of lipids from salmon roe and herring roe were compared with those of commercial fish oils derived from sardine and tuna. Both fish roe lipids contained high amounts of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Total EPA and DHA accounted for >35% of total fatty acids in both roe lipids. On the basis of O2 consumption, fish roe lipids showed higher oxidative stability than both fish oils. This tendency in oxidative stability was also confirmed by the determination of propanal formation during oxidation. Analyses of lipid compositions suggested that the higher oxidative stabilities of fish roe lipids would be mainly due to their content of phospholipids. Dietary effects of salmon and herring roe lipids were also determined. Little increase in total cholesterol level was observed in plasma lipids in rats fed salmon and herring roe lipids, although

the cholesterol content of fish roe lipids was 6.3 and 9.7% of the total lipids in salmon roe and herring roe, respectively.

Nagai N, Mori K, Munekata M. 2008. Biological properties of crosslinked salmon collagen fibrillar gel as a scaffold for human umbilical vein endothelial cells. J Biomater Appl 23(3):275-287.

Abstract: Collagen derived from chum salmon (*Oncorhynchus keta*) was crosslinked with 1-ethyl-3-(3-dimethylaminopropyl)-carbodiimide (EDC) during collagen fibrillogenesis and applied to an in vitro cell culture to evaluate its potential use as a scaffold for vascular tissue engineering. Human umbilical vein endothelial cells (HUVEC) were cultured on the crosslinked salmon collagen fibrillar gel (EDC-SC gel), and their growth rates and production levels of cytokines, including platelet-derived growth factor-BB and von Willebrand factor, were measured. Comparison was also made with bovine collagen gel crosslinked with EDC (EDC-BC gel). The growth and cytokine production of the HUVEC cultured on the EDC-SC gel were higher than those on the EDC-BC gel. In addition, HUVEC were found to attach to the EDC-BC gel through 21 integrin for native collagen, whereas they attac hed to the EDC-SC gel through v3 integrin for denatured collagen as well as the 21 integrin, indicating that HUVEC recognized denatured domains in the EDC-SC gel. In conclusion, the EDC-SC gel can be used as a scaffold to support HUVEC growth, although the integrin-mediated attachment manner differs between the two gels.

Nishioka M, Kanosue F, Miyamoto E, Yabuta Y, Watanabe F. 2008. Bonito extract as a natural and excellent source of free vitamin B12. Curr Top Nutraceu Res 6(2):105-108.

Abstract: Vitamin B12 contents of commercially available fish soup stocks and extracts were assayed and characterized. Although vitamin B12 contents of the powdered and granule-type soup stocks were low (approx. 0.8 g/l), some of the liquid-type soup stocks contained considerable amounts of B12 (>5.0 g/l). Among the fish extracts tested, vitamin B12 content was highest (40.9 ± 5.5 g/100 g) for a bonito extract that was made with raw bonito muscles. Silica gel 60 TLC-bioautogram analysis demonstrated that the selected fish extracts (bonito, salmon and tuna) contain high amounts of true vitamin B12. Gel filtration experiments indicated that most of vitamin B12 found in the selected fish extracts (except for tuna) was recovered in the free vitamin B12 fractions. These results indicate that the fish extracts and their soup stocks would be natural sources of free vitamin B12 for elderly persons with food-bound vitamin B12 malabsorption.

Picot L, Bordenave S, Didelot S, Fruitier-Arnaudin I, Sannier F, Thorkelsson G, Berge JP, Guerard F, Chabeaud A, Piot JM. 2006. Antiproliferative activity of fish protein hydrolysates on human breast cancer cell lines. Process Biochem 41(5):1217-1222.

Abstract: Antiproliferative activity of 18 fish protein hydrolysates was measured on 2 human breast cancer cell lines grown in vitro. Three blue whiting, three cod, three plaice and one salmon hydrolysates were identified as significant growth inhibitors on the two cancer cell lines. Preliminary analysis of hydrolysates composition evidenced they contained a complex mixture of free amino acids, peptides with various sizes ranging up to 7kDa and in a lower proportion, lipids and sodium chloride. RP-HPLC fractionation of fish hydrolysates is currently undertaken to purify anticancer

peptides, lipids or other bioactive trace compounds responsible for this antiproliferative activity.

Shen X, Nagai N, Murata M, Nishimura D, Sugi M, Munekata M. 2008. Development of salmon milt DNA/salmon collagen composite for wound dressing. J Mater Sci – Mater M 19(12):3473-3479.

Abstract: This study aims to develop a novel wound dressing comprising salmon milt DNA (sDNA) and salmon collagen (SC). The sDNA/SC composites were prepared by incubating a mixture of an acidic SC solution, an sDNA solution, and a collagen fibrillogenesis inducing buffer (pH 6.8) containing a crosslinking agent (water-soluble carbodiimide) for gelation, and a subsequent ventilation-drying process to give sDNA/SC films. The conjugation between sDNA and SC were confirmed by sDNA-elution assay and fluorescence microscopy. The sDNA/SC films with various doses of sDNA (sDNA/SC weight ratios of 1:5, 1:10, and 1:20) were used for in vitro cell cultures to evaluate their growth potentials of normal human dermal fibroblasts (NHDF) and normal human epidermal keratinocytes (NHEK). It was found that NHDF proliferation was increased by sDNA conjugation, whereas NHEK proliferation was dose-dependently inhibited. In light of the in vitro results, the appropriate dose of sDNA for in vivo study was determined to be the ratio of 1:10. For the implantation in full-thickness skin defects in rat dorsal region, the sDNA/SC films were reinforced by incorporating them on a porous SC sponge, because the sDNA/SC films exhibited early contraction and inadequate morphologic stability when implanted in vivo. The regenerated tissue in the sDNA/SC sponge group showed similar morphology to native dermis, while the SC sponge group without sDNA showed epithelial overgrowth, indicating that additional sDNA could reduce epidermal overgrowth. Furthermore, blood capillary formation was significantly enhanced in the sDNA/SC sponge group when compared to the SC sponge group. In conclusion, the results suggest that the sDNA/SC composite could be a potential wound dressing for clinical applications.

Thorsdottir I, Tomasson H, Gunnarsdottir I, Gisladottir E, Kiely M, Parra MD, Bandarra NM, Schaafsma G, Martinez JA. 2007. Randomized trial of weight-loss-diets for young adults varying in fish and fish oil content. Int J Obesity 31(10):1560-1566.

Abstract: Objective: To investigate the effect of including seafood and fish oils, as part of an energy-restricted diet, on weight loss in young overweight adults. Design: Randomized controlled trial of energy-restricted diet varying in fish and fish oil content was followed for 8 weeks. Subjects were randomized to one of four groups: (1) control (sunflower oil capsules, no seafood); (2) lean fish (3 x 150 g portions of cod/week); (3) fatty fish (3 x 150 g portions of salmon/week); (4) fish oil (DHA/EPA capsules, no seafood). The macronutrient composition of the diets was similar between the groups and the capsule groups, were single-blinded. Subjects: A total of 324 men and women aged 20-40 years, BMI 27.5-32.5 kg/m2 from Iceland, Spain and Ireland. Measurements: Anthropometric data were collected at baseline, midpoint and endpoint. Confounding factors were accounted for, with linear models, for repeated measures with two-way interactions. The most important interactions for weight loss were (diet x energy intake), (gender x diet) and (gender x initial-weight). Results: An average man in the study (95 kg at baseline receiving 1600 kcal/day) was

estimated to lose 3.55 kg (95% CI, 3.14-3.97) (1); 4.35 kg (95% CI, 3.94-4.75) (2); 4.50 kg (95% CI, 4.13-4.87) (3) and 4.96 kg (95% CI, 4.53-5.40) on diet (4) in 4 weeks, from baseline to midpoint. The weight-loss from midpoint to endpoint was 0.45 (0.41-0.49) times the observed weight loss from baseline to midpoint. The diets did not differ in their effect on weight loss in women. Changes in measures of body composition were in line with changes in body weight. Conclusion: In young, overweight men, the inclusion of either lean or fatty fish, or fish oil as part of an energy-restricted diet resulted in approximately 1 kg more weight loss after 4 weeks, than did a similar diet without seafood or supplement of marine origin. The addition of seafood to a nutritionally balanced energy-restricted diet may boost weight loss.

Yang R, Zhang Z, Pei X, Han X, Wang J, Wang L, Long Z, Shen X, Li Y. 2008. Immunomodulatory effects of marine oligopeptide preparation from chum salmon (*Oncorhynchus keta*) in mice. Food Chem 113(2):464-470.

Abstract: To observe the immunomodulatory effects of marine oligopeptide preparation (MOP) from chum salmon (*Oncorhynchus keta*) by the method of enzymatic hydrolysis, female ICR mice (6-8 weeks old) were administered the MOP for four weeks with the dose of 0, 0.22, 0.45 and 1.35g/kg/body weight. In comparison with the control group, the MOP could significantly enhance the capacity of lymphocyte proliferation induced by the mitogen concanavalin A, the number of plaque-forming cells, natural killer cell activity, the percentage of CD4+ T helper (Th) cells in spleen and the secretion of Th1 (IL-2, IFN-) and Th2 (IL-5, IL-6) type cell cytokines. Nevertheless, no significant differences in weight gain, lymphoid organ indices and phagocytosis capacity were observed in our study. These results suggest that MOP is a possible immune stimulant and may strengthen the immune response of its host.

PROTEINS

Al-Holy MA, Rasco BA. 2006. Characterization of salmon (*Oncorhynchus keta*) and sturgeon (*Acipenser transmontanus*) caviar proteins. J Food Biochem 30(4):422-428.

Abstract: Solubility of protein components of caviar from salmon (*Oncorhynchus keta*) and sturgeon (Acipenser transmontanus) in distilled water, 5% (w/v) NaCl, 70% (v/v) ethanol at 65°C or 0.2% (w/v) NaOH was determined. The salt soluble proteins were the predominant fraction and constituted 84.2% of the recovered protein in salmon samples and 86.1% in sturgeon samples. The 2 most prominent protein fractions (12.5% SDS PAGE) in sturgeon caviar were most likely vitellin (96 kDa) and ovomucoid or phosvitin (28 kDa). In salmon roe, small proteins, possibly lysozyme or phosvitin (10 kDa), were also present.

Bechtel PJ, Oliveira ACM. 2006. Chemical characterization of live lipid and protein from cold-water fish species. J Food Sci 71(6):S480-S485.

Abstract: The largest US harvests of marine fish for human consumption are from Alaska waters. Livers from these fish are combined with other fish offal and made into fish meal and oil or discarded. The purpose of this study was to characterize liver lipids and proteins from important commercial species including walleye pollock (WP), pink salmon (PS), Pacific halibut (PH), flat head sole (FS), and spiny head rock

fish (RF), and underutilized species including arrow tooth flounder (AF) and big mouth sculpin (BS). Liver lipid content ranged from 50.3% in WP to 3.3% in PS. Protein content ranged from 7.7% in WP to 18.4% in BS. PS livers had the highest content of □-3 fatty acids at 336 mg/g of oil and AF had the lowest content at 110 mg/g of oil. There were significant differences in the content of 9 amino acids with methionine and lysine values ranging from 2.66% to 3.43% and 7.19% to 9.45% of the total amino acids, respectively. Protein from the cold water marine fish livers was of high quality and the oils contained substantial quantities of □-3 fatty acids. Fish livers had distinct chemical properties and can be used for the development of unique food ingredients.

Bechtel PJ, Sathivel S, Olivera A. 2005. Alkali extracted protein fractions from salmon byproducts. [unpublished]

Abstract: From 1995-2000 the harvest of wild salmon (Oncorhynchus spp.) from Alaska waters averaged 364,000 mt. It has been estimated that the major byproducts available in Alaska from Pacific salmon processing include over 50,000 mt of salmon heads and 30,000 mt of viscera, of which much is under utilized. Soluble and insoluble fractions from salmon head and salmon viscera can be produced via alkali-aided extraction for use as functional animal feed ingredients. The objective of this study was to isolate both soluble and insoluble protein fractions from salmon byproducts and characterize the chemical and functional properties of the protein powders. Pink salmon (*Oncorhynchus gorbuscha*) viscera and red salmon (*Oncorhynchus nerka*) heads were used in this study. Pink salmon viscera (PV) and red salmon head (RH) samples were collected from a commercial processing plant and stored at 20°C until thawed for protein extraction. Triplicate samples of minced samples were diluted in deionized water (1:9), homogenized, solubilized at pH 11, soluble and insoluble fractions separated by centrifugation, and the soluble fraction precipitated at pH 5.5. The freeze-dried PV-soluble (PVS) and PV-insoluble (PVIS), RH-soluble (RHS), and RH-insoluble (RHIS) fractions were analyzed for proximate composition, TBA values, lipid classes and amino acid contents. Evaluations of functional properties included emulsion stability (ES), fat absorption, solubility and color. RHIS, PVIS, RHS, and PVS contained 50.7%, 69.4%, 80%, and 87.2% protein, respectively. Emulsion stability of RHS (79.5%) was greater than that of RHIS (73.1%), PVIS (61.1%) and PVS (57.1%). Both insoluble fractions (RHIS and PVIS) had higher fat adsorption values than PVS and RHS. All the salmon protein powders were white to lightly yellow and had desirable amino acid profiles. The soluble and insoluble fish protein isolates from red salmon head and pink salmon viscera have potential as functional protein ingredients.

Choi YJ, Kim YS, Park JW. 2003. New approaches for the effective recovery of fish proteins and their physiochemical characteristics. Fisheries Sci 69(6):1231–1239.

Abstract: Pacific whiting protein solubility was significantly affected as the pH shifted away from the isoelectric point (pH 5.5). The highest breaking force of gels was measured for fish proteins treated at pH 11, while high deformation values were obtained at pH 2 and 11. Sodium dodecylsulfate-polyacrylamide gel electrophoresis revealed that fish proteins were highly degraded by acid or alkali treatment. High activity of cathepsin B-like enzyme was detected from acid-aided fish proteins.

Strong cathepsin L-like activity was found in fish proteins treated at pH 10.5, corresponding well to the lower breaking force and deformation. Disulfide bonds were thought to contribute to the high texture value of fish proteins treated at pH 11.

Herrmann M, Pei X, Dong LC, Fong QS, Crapo C. 2006. Rating Alaska salmon protein concentrate in China. J Food Prod Market 12(1):57-85.

Abstract: Intense market competition resulting from the worldwide production of farmed salmon has led to a financial disaster for the Alaskan wild salmon capture industry. The need to develop new products and markets for Alaskan salmon products is paramount. This study reports on a project to develop an Alaskan salmon protein concentrate derived from Alaskan pink and chum salmon. The product was targeted at the market for nutritional supplement foods for children in China. The nutritional characteristics of the salmon protein concentrate made from pink and chum salmon compare favourably to those of protein concentrates produced from Chinese aquacultured domestically produced grass carp. Surveys of Chinese consumers were conducted in 5 Chinese cities/regions and survey results indicate a substantial market potential for this product in China.

Nolsøe H, Undeland I. 2008. The acid and alkaline solubilization process for the isolation of muscle proteins: state of the art. Food Bioprocess Technol [online].

Abstract: The acid and alkaline solubilization processes for isolating muscle protein from ground fish raw materials are investigated by scrutinizing the literature. Following an introduction to the processes, with some underlying chemistry, patents related to the acid and alkaline solubilization process are described together with previously patented methods for processing of protein isolates. Focus is then placed on comparing a range of factors important in fish muscle protein isolation between the acid and alkaline solubilization processes, and classic washing-based surimi technology. The factors addressed were: protein yield, gel quality, color, lipid reduction, lipid oxidation, microbial stability, and frozen storage stability. A long series of studies made with different fish/shellfish species have been used for this purpose. Certain results are summarized in table form (protein yields, gel strength, and whiteness), others only in text form. From this part of the review, it is obvious that the acid process often has certain advantages (e.g., protein yield) and the alkaline process other ones (gel strength, whiteness, lipid removal, lipid oxidation, and total microbial count). Thus, the choice of method depends on the application. It is clear that most species respond differently to acid and alkaline solubilization, which is why the two methods are initially compared. In a section about new processing attempts, the use of the acid and alkaline methodology for isolating proteins from whole fish/shellfish and fish by-products is reviewed together with attempts to recover waste water proteins and attempts to modify the process. Tentative uses of the new protein isolates, e.g., as coatings, protein brines, and emulsifiers are finally described together with some conclusions and future opportunities for the acid and alkaline processes.

Sathivel S., Bechtel PJ, Prinyawiwatkul W. 2006. Physicochemical and rheological properties of salmon protein powders. Int J Food Engin 2(2). Available from: http://www.bepress.com/ijfe/vol2/iss2/art3.

Abstract: This study demonstrated feasibility of producing soluble protein powders from pink (PSP) and red (RSP) salmon heads. Differences were observed between physicochemical properties of the two protein powders, including nitrogen solubility, emulsion stability, and fat adsorption capacity. The flow and viscoelastic properties of the emulsions prepared with PSP and RSP were investigated using a parallel plate rheometer. The power law model and the Casson model were used to determine the flow behavior index (n), and consistency index (K) and yield stress. The emulsion containing PSP (PSPE) had a higher K value (8 Pa.s) than that (4.2 Pa.s) of the emulsion containing RSP (RSPE). Both PSPE and RSPE emulsions exhibited pseudoplastic behavior and viscoelastic characteristics. The G' (an elastic or storage modulus) and G" (a viscous or loss modulus) values for PSPE were higher than RSPE.

Thawornchinsombut S, Park JW. 2006. Frozen stability of fish protein isolate under various storage conditions. J Food Sci 71(3):C227–C232.

Abstract: A novel process using pH-shift to recover fish proteins was intensively studied. However, little information of its frozen stability was revealed. The highest gel texture was found for samples frozen at pH 5.5 (5) and 7.0 (7) with cryoprotectants (C) and without freeze/thaw (F), whereas the lowest gel texture was obtained from frozen/thawed samples without cryoprotectants (NC). 5NC-F and 7NC-F demonstrated the lowest surface hydrophobicity and total sulfhydryl (SH), perhaps suggesting more protein aggregation through hydrophobic interactions and disulfide bonds. A slightly less stability of alkali-treated protein isolates (AKPI) kept at pH 5.5 than at pH 7 was noticed. AKPI, whether kept at pH 5.5 or 7.0, requires cryoprotectants to maintain frozen stability for longer shelf life.

Thawornchinsombut S, Park JW, Meng GT, Li-Chan ECY. 2006. Raman spectroscopy determines structural changes associated with gelation properties of fish proteins recovered at alkaline pH. J Agr Food Chem 54(6): 2178–2187.

Abstract: Structural changes of alkali-treated rockfish protein isolate (AKPI) during frozen storage were elucidated using a Raman spectrometer and scanning electron microscope (SEM). The results were compared to conventional surimi (CS). No significant textural difference was noted between AKPI stored at pH 5.5 and 7.0. The strongest texture was found for AKPI frozen with cryoprotectants and CS, while the weakest texture was observed in AKPI frozen without cryoprotectants. SEM revealed the most discontinuity in gels of AKPI with no cryoprotectants and a more aggregated microstructure after storage at pH 5.5 than at neutral pH. Raman spectral analysis demonstrated refolding of AKPI by pH readjustment to 7.0, although the refolded structure was not identical to that before the pH shift. CS showed higher □-helix content (~50%) than AKPI (~20–30%). Frozen storage induced a decrease and an increase in the □-helix content of CS and AKPI samples, respectively. AKPIs were slightly less stable than CS during frozen storage.

OTHER

Bechtel PJ. 2005. Properties of stickwater from fish processing byproducts. J Aquat Food Prod Technol 14(2):25-38.

The objective of this study was to determine selected chemical and nutritional properties of stickwater protein obtained from the processing of fish byproducts. Raw materials for three stickwater samples were pollock and cod fish processing byproducts and one was salmon processing byproducts. Stickwater samples were approximately 6% protein on a wet weight basis, and after freeze drying, samples contained 70.5% to 86.2% protein, 10.6% to 13.9% ash, with variable amounts of lipid. The pH of the stickwater samples ranged from 6.5 to 7.0. Samples had high levels of proline and hydroxyproline and the calculated connective tissue protein as a percent of total protein was 22.8% to 25.7%. On a dry matter basis, calcium content was below 0.1% and potassium content was 1.7% to 2.8%. Percent soluble protein ranged from 54 to 70% at 30°C. Major proteins bands observed using SDS gel electrophoresis had molecular weights of 198,000, 120,000 and 39,000. All samples had protein digestibility in excess of 95%, and calculated rat protein efficiency ratios from amino acid analysis data ranged from 1.6 to 1.8.

Chiou BS, El-Mashad HM, Avena-Bustillos RJ, Dunn RO, Bechtel PJ, McHugh TH, Imam SH, Glenn GM, Orts WJ, Zhang R. 2008. Biodiesel from waste salmon oil. Trans ASABE 51(3): 797-802.

Abstract: Salmon oils separated from salmon processing waste and hydrolysate and their derived biodiesel were analyzed and compared with corn oil and its biodiesel. These materials were characterized for their fatty acid profiles, viscosity, volatility, thermal properties, low temperature properties, oxidative stability, and heating value. The salmon oil methyl esters contained 26.64% saturated fatty acid methyl esters compared to 13.68% for corn oil methyl ester. Also, salmon oil methyl esters contained relatively high concentrations of eicosapentaenoic acid (C20:5) and docosahexaenoic (C22:6) acid methyl esters. Despite these differences in fatty acid composition, salmon and corn oil methyl esters had comparable physical properties. In addition, the methyl esters produced from acidified and non-acidified salmon oils showed little difference in their physical properties.

Conte M, Aliberti F, Fucci L, Piscopo M. 2008. Antimicrobial activity of various cationic molecules on foodborne pathogens. World J Microb Biot 23(12):1679-1683.

Abstract: Antibacterial effects of various arginine- and lysine-rich polycationic proteins and polymers were evaluated using broth and solid dilution assays and a range of foodborne pathogens, and Gram-positive and Gram-negative bacteria. The min. inhibitory concn. (MIC) and the min. bactericidal concn. (MBC) of □-poly-L-lysine, □-poly-L-arginine and protamines from herring sperm (clupeine sulfate) and salmon sperm (salmine sulfate) were determined using *Bacillus subtilis*, *B. cereus*, *Staphylococcus aureus*, *Listeria monocytogenes*, *Salmonella Typhimurium*, *Shigella sonnei*, *Escherichia coli* O157:H7 and *Pseudomonas aeruginosa*. All these molecules showed antibacterial activity on all strains with different MIC and MBC values. It is suggested that the molecular mechanisms underlying the antibacterial effect of □-poly-L-arginine may be related to entry of the molecule into the cell. In fact, □-poly-L-arginine labelled with 7-diethylamino coumarin-3-carboxylic acid, succinimidyl ester was found to permeate the cell membrane of *B. cereus* and *E. coli* O157:H7.

El-Mashad HM, Zhang R, Avena-Bustillos RJ. 2008. A two-step process for biodiesel production from salmon oil. Biosyst Eng 99(2):220-227.

Abstract: Salmon oil, a by-product of salmon processing, was used as a feedstock for biodiesel production via transesterification in a two-step process. Two different types of salmon oil were tested: salmon oil extracted from acidified salmon hydrolysate and salmon oil extracted from salmon by-products. Optimal amounts of chemicals required to give the highest biodiesel yield from each oil were determined using batch production procedures. It was found that due to the high acid value of salmon oil, alkaline-catalysed transesterification was not an effective method for producing biodiesel from the salmon oil. Therefore a two-step process was applied, in which a sulphuric acid-catalysed pre-treatment was used in the first step to reduce the acid value from 12.0 to 3 mg [KOH] g [oil]-1 and then, in the second step, KOH-catalysed transesterification was applied. All experiments were performed at a temperature of 52±2 °C with a mixing intensity of 600 rpm. Based on the total weight of salmon oil used, the maximum biodiesel yield of 99% was achieved using a total methanol/molar ratio of 9.2% and 0.5% (w/w) KOH. Ester loss due to the formation of emulsion during the washing and drying steps was 15% maximum. This loss could be reduced in practical applications by better design of washing and drying techniques. A preliminary economic analysis showed that the cost of biodiesel production from salmon oil was almost twice that produced from soybean oil.

Espósito TS, Amaral IPG, Buarque DS, Oliveira GB, Carvalho LB, Bezerra RS. 2009. Fish processing waste as a source of alkaline proteases for laundry detergent. Food Chem 112(1):125-130.

Abstract: Proteases were extracted from the viscera of Colossoma macropomum and precipitated with ethanol (30-70%, v/v). The enzymatic extract was partially purified with a yield of 75% (2926U/g of tissue); at least five caseinolytic proteases bands were observed in zymogram. The optimum pH of the preparation was in the alkaline pH range (10-12). The optimum temperature of activity was 60°C and only about 15% of the initial activity was lost after an incubation period of 30min at the above mentioned temperature. Both trypsin and chymotrypsin-like enzymes were detected in the proteases, but with a stronger prevalence for the former. These proteolytic enzymes remained stable in the presence of non-ionic (Tween 20 and Tween 80) and ionic surfactants (saponin and sodium choleate). They also revealed high resistance (60% residual activity) when incubated with 10% H_2O_2 for 75min. Furthermore, the preparation retained approximately 80% of its proteolytic activity after incubation for 1h at 40°C with the commercial detergent.

Falch E, Velasco J, Aursand M, Andersen ML. 2005. Detection of radical development by ESR spectroscopy techniques for assessment of oxidative susceptibility of fish oils. Eur Food Res Technol 221(5):667-674.

Abstract: Detection of radical development by two different Electron Spin Resonance (ESR) spectroscopy techniques has been evaluated for obtaining objective analytical information about oxidative susceptibility of fish oils under mild oxidation conditions. Two oils from different by-products in the fish industry, salmon viscera oil (SVO) and cod liver oil (CLO), were used. In addition, radical formation in the

ethyl ester of docosahexaenoic acid (DHA) was studied as representing polyunsaturated fatty acids in fish oils that are very prone to oxidation. The ESR spin trapping technique, using the spin trap □-phenyl-*N*-*tert*-butylnitrone, and the ESR spin scavenging technique, using the stable nitroxyl radical 2,2,6,6-tetramethyl-1-piperidinyl-1-oxyl (TEMPO) to be scavenged by radicals generated in the oxidative process, were applied to detect radical development at 40 °C in the dark. For comparative purposes, oxidative susceptibility was evaluated by determination of peroxide value (PV) and the TBARS test under the same oxidation conditions. Results were also compared to the oil stability index (OSI) obtained at 60 °C. Results obtained by ESR spin trapping were consistent with results obtained in the OSI test, as well as those obtained for PV and the TBARS test. Therefore, detection of radical formation by ESR spin trapping provided objective information upon the relative oxidative susceptibility of SVO and CLO. On the other hand, results obtained by ESR spin scavenging were not concluding to establish the different oxidative susceptibility of the two oils found by the other determinations applied. The kinetic curves of TEMPO were similar for both oils, which suggests that mechanisms other than that based on the expected radical-radical interactions might be involved.

Gildberg A. 2004. Enzymes and bioactive peptides from fish waste related to fish silage, fish feed and fish sauce production. J Aquat Food Prod Technol 13(2): 3-11.

Abstract: This paper gives a brief survey of research and developments concerning enzymes and bioactive peptides from fish waste or by-catch applied for fish silage, fish feed or fish sauce production. The fish silage processing technology developed in the late 1970s revealed the possibility of recovering pepsins and bioactive peptides from fish silage. Whereas the pepsins are used for gentle bioprocessing of certain fishery products, the peptides may be valuable immuno stimulants. In vitro and in vivo studies have shown that certain peptide fractions in fish protein hydrolysates may stimulate the non-specific immune defense system. Both fish sauce and fish silage are protein hydrolysates with immune stimulating properties. Generally fish sauce is regarded as a typical Asian product made from tropical fish species, but ancient literature reveals that fish sauce was a common food product in Southern Europe more than 2000 years ago. Recent studies have shown that it can be made also from cold water species.

Hongyu L, Xuefen J, Hongbin C. 2007. Study on extraction and antimicrobial activities of protamine from spermary of *Oncorhynchus keta*. Food Sci, China 28(2):37-39.

Abstract: The extraction process of protamine from the spermary of chum salmon (*Oncorhynchus keta*) was optimized and its antimicrobial activities were studied. Optimal conditions were found to be: H2SO4 concn. 7.5% with vol. 3.5× higher than that of the spermary; 95% alcohol solution at a vol. 3× that of the spermary; and extraction time 2 h. Under these conditions the extraction rate of protamine was 7.38%. The nutritional values of the protamine were analysed. Results showed that the protein content was 89.7% and arginine content was 53.34%. Results of antimicrobial tests showed that the protamine had high antimicrobial activity against Gram-positive bacteria (Bacillus subtilis and Staphylococcus aureus), Gram-negative bacteria (Escherichia coli and Pseudomonas aeruginosa) and yeast (Saccharomyces

cerevisiae). It is concluded that protamine from the spermary of chum salmon could be used as an effective natural antiseptic.

Hou CT, Shaw JF. 2008. Biocatalysis and Bioenergy. Hoboken (NJ): John Wiley & Sons.

Book Summary: With the high price of petroleum and researchers worldwide seeking new means of producing energy, this comprehensive book on biocatalysis for bioenergy and biofuel applications is very timely. It combines information on state-of-the-art advances and in-depth reviews of the latest achievements in biocatalysis and bioenergy, emphasizing biodiesel, bioethanol, and industrial products. The advantages of biocatalysis include high specificity, efficiency, energy conservation, and pollution reduction. Biocatalysis and Bioenergy details advances in the field, with:

Three primary sections, covering biodiesel research, bioethanol, and industrial products

Information on enzyme catalysis, biotransformation, bioconversion, fermentation, genetic engineering, and product recovery

Contributions from leading experts worldwide who share their research and findings

The prospect of using biocatalysis for the production of energy has great potential due to its cost-effectiveness, the fact that it does not require a limited resource such as oil, and its potential universality of application and use globally. This is the definitive reference for biochemists and biochemical engineers, bioprocess and bioenergy scientists, physical and oil chemists (oleochemists), microbiologists, industrial microbiologists, molecular biologists, metabolic engineers working in biocatalysis, bioethanol, and biodiesel fuels, DOE scientists working on renewable energy, and other professionals in related fields.

Huang J, Sathivel S. 2008. Thermal and rheological properties and the effects of temperature on the viscosity and oxidation rate of unpurified salmon oil. J Food Eng 89(2):105-111.

Abstract: The effects of temperature on the magnitude of viscosity and lipid oxidation rates of unpurified salmon oil were measured and modeled using the Arrhenius equation. The melting point of salmon oil ranged from -61.3 to 31.2°C. The flow behavior index of the oil samples was less than one, which indicated that the salmon oil exhibited non-Newtonian fluid behavior. The apparent viscosity at 5°C was significantly higher ($P<0.05$) than those at 10, 15, 20, 25, 30, and 35°C. The average magnitude of activation energy for apparent viscosity of the oil was 21.8kJ/mol. The estimated viscosity obtained by the Arrhenius equation agreed with the experimental viscosity. The rate of lipid oxidation for unpurified salmon oil was temperature dependent ($R2=0.99$). The apparent activation energy for lipid oxidation of the oil was 51.3kJ/mol.

Imam SH, Chiou BS, Woods D, Shey J, Glenn GM, Orts WJ, Narayan R, Avena-Bustillos RJ, McHugh TH, Pantoja A, Bechtel PJ. 2008. Starch/pulp – fiber based packaging foams and cast films containing Alaskan fish by-products. Bioresources 3(3):758-773.

Abstract: The total Alaska seafood harvest is over two million MT per year, which results in over one million MT of fish processing by-products. The major by-products of salmon processing are estimated at 60,000 MT of salmon heads and 30,000 MT of viscera per year. The objective of this study was to characterize the lipid fraction in these by-products. On separate days, three sets of pink salmon samples were obtained from commercial processing plants in Alaska during the midseason and included whole fish, headed and gutted salmon, heads, and viscera. Samples were ground and stored at '70oC until extracted with solvent. An Iatroscan MK-6s was used for percent triglycerides, free fatty acids, diglycerides, monoglycerides, sterols and phospholipid in the oils. Fatty acid profile was determined by GC/FID analysis of fatty acid methyl esters. Data was statistically analyzed and differences ($p>0.05$) reported. Fat content of salmon heads (11.5%) was significantly higher then other fish parts. Viscera contained the lowest lipid levels at 1.81%. Percent phospholipids and sterols averaged about 10% of total lipid. Salmon heads and whole fish had at least 50% of its lipids in the form of triglycerides. However, viscera had only about 10% triglycerides and the highest level of FFA, indicating possible lipase activity during storage. The quantity of 22 fatty acids was determined including long chain polyunsaturated omega-3 fatty acids, which ranged from 28 to 35% of total fatty acids in all samples except viscera. Differences were found in the lipid composition of whole salmon, head and viscera by-products. The lipid composition of the individual by-products is becoming increasingly important as different fish processing by-products are being used for distinct end products.

Li DK, Lin H, Kim SM. 2007. Application of recombinant chum salmon cystatin to Alaska pollock (*Theragra chalcogramma*) surimi to prevent gel weakening. J Food Sci 72(5):C294-C299.

Abstract: Recombinant chum salmon cystatin (RC) expressed in Saccharomyces cerevisiae was purified by His-select nickel affinity chromatography. The specific inhibitory activities of RC against papain and cathepsin L were 7.45 and 10.24 U/mg, respectively. RC was stable over pH 5.0 to 7.0 and at temp. below 65°C. RC was used to prevent the gel weakening of Alaska pollock surimi. RC at 100 g/g showed the highest inhibitory activity against the autolysis of surimi based on the analysis of TCA-soluble peptides. As the concn. of RC increased, both the breaking force and deformation of modori gel greatly increased ($P < 0.05$). The addition of RC resulted in less expressible drip, which coincided with the increase of whiteness. More myosin heavy chain (MHC) was retained as the addition of RC increased. Therefore, RC could prevent the degradation of proteins in Alaska pollock surimi and was better than egg white (EW). Thus, RC could be applied to Alaska pollock surimi to prevent gel weakening and RC at 100 g/g was the optimal concn.

Li DK, Lin H, Kim SM. 2008. Purification and characterization of a cysteine protease inhibitor from chum salmon (*Oncorhynchus keta*) plasma. J Agr Food Chem 56(1):106-111.

Abstract: A cysteine proteinase inhibitor (CPI) in chum salmon (*Oncorhynchus keta*) plasma (CSP) was detected after performing inhibitory activity staining against papain under nonreducing conditions. The CPI was purified from CSP by affinity chromatography with a yield and purification ratio of 0.94% and 30.36-fold,

respectively. CSP CPI had a molecular mass of 70 kDa based on the results of SDS-PAGE and Sephacryl S-100 gel filtration. CSP CPI was a glycoprotein based on the periodic acid-Schiff (PAS) staining of the SDS-PAGE gel and classified as a kininogen. CSP CPI was stable in the pH range of 6.0–9.0 with max. stability at pH 7.0. CSP CPI was stable at temp. <50°C and exhibited max. activity at temp. of 20–40°C. CSP CPI was determined to be a noncompetitive inhibitor against papain, with an inhibitor constant (Ki) of 105nM.

Mol S, Turan S. 2008. Comparison of proximate, fatty acid and amino acid compositions of various types of fish roes. Int J Food Prop 11(3):669-677.

Abstract: Proximate compositions, amino acid compositions and fatty acid compositions of various types of fish roe were measured and compared. Samples included: black caviar (beluga, imperial and osetra) from beluga (*Huso huso*), Russian sturgeon (*Acipenser gueldenstaedti*) and Persian sturgeon (*A. persicus*), respectively; red salmon (*Salmo trutta labrax*) roe; and waxed mullet (*Mugil cephalus*) roe. Glutamic acid, aspartic acid, lysine and serine were the major amino acids present in the roes. However, imperial-type caviar also included high amounts of tryptophan ($P < 0.05$). The ratio of essential to non-essential amino acids (E/NE) was within the range 0.93–1.23, and n3/n6 ratio was 2.56–8.06. Major fatty acids were C16:0, C18:1 n9c, C16:1 n7, C20:5n3 and C22:6 n3. Results show that fish roes contain high amount of lipids and energy, but are also rich sources of unsaturated fatty acids, proteins and amino acids.

Nagai T, Nagashima T, Abe A, Suzuki N. 2006. Antioxidative activities and angiotensin I-converting enzyme inhibition of extracts prepared from chum salmon (*Oncorhynchus keta*) cartilage and skin. Int J Food Prop 9(4):813-822.

Abstract: The extracts from cartilage and skin of chum salmon were prepared using a pressure cooker. As a result, protein and collagen contents in extracts from cartilage and skin was higher than those only in cartilage. The inhibition activity of linoleic acid oxidation was high in extract from cartilage. The scavenging activity of cartilage extract was higher than those of cartilage and skin against all reactive oxygen species, such as superoxide anion, hydroxyl, and DPPH radicals. On the other hand, angiotensin I-converting enzyme inhibitory activity of cartilage extract was about seven times as high as that of cartilage and skin extract. The present studies indicate that the extracts, particularly from cartilage, have angiotensin I-converting enzyme inhibitory activity that functions to depress hypertension, and antioxidant activity, which acts to prevent of life-style related diseases such as cancer, cardiovascular diseases, and diabetes. The data should be useful for developing a novel type of functional seasoning.

Reyes JF, Sepulveda MA. 2006. PM-10 emissions and power of a Diesel engine fueled with crude and refined Biodiesel from salmon oil. Fuel 85(12-13):1714-1719.

Abstract: Power response and level of particulate emissions were assessed for blends of Diesel-crude Biodiesel and Diesel-refined Biodiesel. Crude Biodiesel and refined Biodiesel or methyl ester, were made from salmon oil with high content of free fatty acids, throughout a process of acid esterification followed by alkaline transesterification. Blends of Diesel-crude Biodiesel and Diesel-refined Biodiesel

were tested in a diesel engine to measure simultaneously the dynamometric response and the particulate material (PM-10) emission performance. The results indicate a maximum power loss of about 3.5% and also near 50% of PM-10 reduction with respect to diesel when a 100% of refined Biodiesel is used. For blends with less content of either crude Biodiesel or refined Biodiesel, the observed power losses are lower but at the same time lower reduction in PM-10 emissions are attained.

Sathivel S. 2005. Thermal and flow properties of oils from salmon heads. J Am Oil Chem Soc 82(2):147-152.

Abstract: Thermal and flow properties of unrefined oils from the heads of red or pink salmon were evaluated. Major thermal degradation of the salmon oils occurred between 200 and 450°C. Red and pink salmon oils were completely decomposed at 533 and 668°C, respectively. The phase transition of salmon oils occurred over a wide range of temperatures. The melting points of 69.6 to 0.36°C and 64.7 to 20.8°C were observed for red and pink salmon oils, respectively. The enthalpy was 40 j/g for red salmon oil and 39 j/g for pink salmon oil. Specific heat capacity ranges of 0.8 to 1.6 and 1.3 to 2.3 j/g/°C were observed for red and pink salmon oils, respectively. Both salmon oils exhibited Newtonian flow behavior. Red salmon oil required higher magnitudes of energy (kj·mol^{-1}) to flow than pink salmon oil. The viscosity of salmon oils was temperature-dependent and could be predicted by the Arrhenius equation.

Skara T, Sivertsvik M, Birkeland S. 2004. Production of salmon oil from filleting byproducts--effects of storage conditions on lipid oxidation and content of omega-3 polyunsaturated fatty acids. J Food Sci 69(8):E417-E421.

Abstract: Filleting byproducts (heads, frame bones, skin, and down-graded gutted fish) from farmed Atlantic salmon (Salmo salar) were separated into a solid/aqueous phase and a lipid phase (oil) using a scraped-surface heat exchanger (90 degrees C to 95 degrees C) and a decanter centrifuge (93 degrees C). Effects of storage temperature (4 degrees C and 23 degrees C), atmosphere (air and N2), and time (0 to 180 d), as well as an additional process step-a separator introduced after the decanter centrifuge, were investigated on the quality and storage stability of the produced oil. Samples were analyzed for the quality parameters peroxide (PV), anisidine (AV), and Totox value (TxV), content of free fatty acids (FFA), content of fatty acid methyl esters (FAME), especially the n-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) and degradation of EPA and DHA related to the content of hexadecanoic acid (HDA) (ratios EPA/HDA and DHA/HDA). Storage temperature had significant effect on all the investigated quality parameters, especially on AV, PV, and TxV where a high storage temperature (23 degrees C) caused a 10-fold, 2.5-fold, and 4-fold increase in AV, PV, and TxV, respectively. Storage atmosphere had significant effect on all the investigated parameters, except on the DHA/HDA ratio, where storage under an N2 atmosphere significantly preserved the quality of the oil compared with storage in air. Generally, no significant effect of storage time on the investigated quality parameters was observed before 120 d of storage. No effect on quality was observed when introducing an additional processing step (separator) after the decanter centrifuge. Salmon oil is a stable product, and even more so when stored at appropriate conditions (under nitrogen atmosphere at refrigerated temperatures).

Sun T, Xu Z, Prinyawiwatkul W. 2006. FA Composition of the oil extracted from farmed Atlantic salmon (Salmo salar L.) viscera. J Am Oil Chem Soc 83(7):615-619.

Abstract: The FA composition of visceral oil extracted from farmed Atlantic salmon (Salmo salarL.) viscera was studied. Seventeen FA were identified in the extracted visceral oil, and the major FA were 18?1n9, 16?0, 16?1n7, 20?5n3 (EPA), 14?0, and 22?6n3 (DHA). The percentages of saturated, monounsaturated, and polyunsaturated FA in the total FA were 31.7, 36.0, and 32.2%, respectively. Compared with other fish oils, oil from farmed Atlantic salmon had much higher EPA (1.64 g/100 g) and DHA (1.47 g/100 g) contents. The FA profile of the salmon visceral oil was similar to that of the salmon fillet. Thus, the salmon visceral oil could be a replacement for the oil obtained from edible salmon fillet and used in functional foods or feeds requiring a high level of omega-3 FA. Furthermore, producing visceral oil is also beneficial to salmon fish industry by adding value back to the processing waste.

Takeda H, Iida T, Okada A, Ootsuka H, Ohshita T, Masutani E, Katayama S, Saeki H. 2007. Feasibility study on water solubilization of spawned out salmon meat by conjugation with alginate oligosaccharide. Fisheries Sci 73(4):924-930.

Abstract: A feasibility study was carried out to determine whether water-soluble salmon meat could be manufactured by conjugating a glycosyl unit using the Maillard reaction. Spawned out salmon meat was washed, mixed with alginate oligosaccharide (AO) and sorbitol, lyophilized, and then heated at 60°C and 5–95% relative humidity (RH) to introduce AO (the mean degree of polymerization was six) into the myofibrillar proteins through the Maillard reaction. The reaction progressed with an increase in the reaction humidity and the amount of AO bound to the protein reached >150 g/mg at RH 65 and 90%. However, the protein glycosylation under high humidity impaired protein solubility and the meat protein became effectively water-soluble with the conjugation with AO at reaction conditions of 60°C and RH 35%. The improved characteristics of the meat protein were highly stable at room temperature. Further, the water-soluble protein can be prepared from the frozen salmon meat stored at −25°C for 60–90 days. These results indicate that protein glycosylation has strong potential for use with spawned out chum salmon. The suppression of protein denaturation during processing is important to obtain the high water-soluble meat protein.

Velasco J, Aursand M, Andersen M. 2005. Detection of radical development by ESR spectroscopy techniques for assessment of oxidative susceptibility of fish oils. Eur Food Res Technol 221(5): 667-674.

Abstract: Detection of radical development by two different Electron Spin Resonance (ESR) spectroscopy techniques has been evaluated for obtaining objective analytical information about oxidative susceptibility of fish oils under mild oxidation conditions. Two oils from different by-products in the fish industry, salmon viscera oil (SVO) and cod liver oil (CLO), were used. In addition, radical formation in the ethyl ester of docosahexaenoic acid (DHA) was studied as representing polyunsaturated fatty acids in fish oils that are very prone to oxidation. The ESR spin trapping technique, using the spin trap α-phenyl-N-tert-butylnitrone, and the ESR spin scavenging technique, using the stable nitroxyl radical 2,2,6,6-tetramethyl-1-

piperidinyl-1-oxyl (TEMPO) to be scavenged by radicals generated in the oxidative process, were applied to detect radical development at 40 °C in the dark. For comparative purposes, oxidative susceptibility was evaluated by determination of peroxide value (PV) and the TBARS test under the same oxidation conditions. Results were also compared to the oil stability index (OSI) obtained at 60 °C. Results obtained by ESR spin trapping were consistent with results obtained in the OSI test, as well as those obtained for PV and the TBARS test. Therefore, detection of radical formation by ESR spin trapping provided objective information upon the relative oxidative susceptibility of SVO and CLO. On the other hand, results obtained by ESR spin scavenging were not concluding to establish the different oxidative susceptibility of the two oils found by the other determinations applied. The kinetic curves of TEMPO were similar for both oils, which suggests that mechanisms other than that based on the expected radical-radical interactions might be involved.

Wu TH, Bechtel PJ. 2008. Ammonia, Dimethylamine, Trimethylamine, and Trimethylamine Oxide from raw and processed fish by-products. J Aquat Food Prod Technol 17(1):27-38.

Abstract: Concentrations of ammonia, monomethylamine (MMA), dimethylamine (DMA), trimethylamine (TMA) and trimethylamine oxide (TMAO) in raw and processed fish by-products were determined in cold water marine fish using a capillary electrophoresis (CE) method. The CE method provides a fast and sensitive procedure to simultaneously quantify volatile amines and TMAO in raw and processed fish samples. Total volatile bases nitrogen (TVB-N) values were calculated from the concentrations of the respective individual volatile amines detected within the samples. TVB-N calculated concentrations ranged from a low of 14.6 ± 4.5 mg/100g (n=3) to a high value of 259 ± 86.1 mg/100g (n=3) wet weight for the raw fish by-products and from 106 ± 73.2 mg/100g (n=3) to 871 ± 101 mg/100g (n=3) dry weight for the processed fish by-products. No MMA was detected in any of the samples tested. Raw viscera samples contained increased concentrations of DMA and TMA relative to the other samples tested. High levels of TMAO and TMA in the freeze dry stickwater suggested decomposition of TMAO and/or fractionation into the stickwater during processing since these compounds are water soluble. Results indicated there is a wide distribution on the levels of TMAO, ammonia, TMA and DMA and calculated TVB-N in the materials tested. It is possible these values can be used as quality indicators of raw material freshness and as indicators for the potential to spoil. Values for processed fish by-product tested can also be use as quality indicators.

CONFERENCE PAPERS

BYPRODUCTS / WASTE – GENERAL

Bower CK, Malemute CL. 2005. Utilization of salmon by-products in rural Alaska. 2005 Arctic Science Conference; 2005 Sept 27-29; Kodiak, AK. Available from: http://www.arcticaaas.org/meetings/2005/2005_abstract_book.pdf.

Abstract: Salmon oils separated from salmon processing waste and hydrolysate and their derived methyl esters were analyzed and compared with corn oil and its methyl ester. These materials were characterized for their fatty acid profiles, viscosity, volatility, thermal properties, low temperature properties, oxidative stability, and heating value. The salmon oil methyl esters contained 26.64% saturated fatty acid methyl esters compared to 13.68% for corn oil methyl ester. Salmon oil methyl esters also contained relatively high concentrations of eicosapentaenoic acid (C20:5) and docosahexaenoic (C22:6) acid methyl esters. Despite these differences in fatty acid composition, salmon and corn oil methyl esters had comparable physical properties. In addition, the methyl esters produced from salmon oils extracted from fish processing by-products and hydrolysate showed little difference in their physical properties.

Bower C. 2007. The value of acidic-electrolyzed water for stabilizing salmon by-products. In: Institute of Food Technologists 2007 Annual Meeting and Food Expo; 2007 July 28-Aug 1; Chicago. Chicago: Institute of Food Technologists.

Abstract: Alaska's fishing industry generates over one million metric tons of fish by-products each year, much of which is discarded during processing unless fishmeal plants are located nearby. Other preservation methods, such as ensilage and fermentation, are less common, but can acidify perishable by-products to inhibit growth of spoilage bacteria. Electrolyzed water produces an acidic component with a high oxidation-reduction potential capable of decreasing bacterial numbers. The objective of this study was to evaluate the efficacy of acidic-electrolyzed water for stabilizing salmon by-products. Pink salmon (*Oncorhynchus gorbuscha*) heads, viscera, and head-viscera mixtures were homogenized with 2.5% NaCl. Acidic-electrolyzed water (pH 2.85; ORP 1100 mV) was applied directly to head and viscera samples, and was also used as a pre-wash for salmon heads to reduce the bacterial load. Containers were held at 21°C and sampled at 30, 60, and 120-days to determine percent liquefaction, compositional analyses (moisture, ash, protein, and lipids), soluble nitrogen, pH, bacterial counts (total CFU/g, lactic acid bacteria, and coliforms), and chemical analyses (ammonia and lactic acid levels). Results were compared with other stabilization procedures including direct acidification (ensilage using 1% formic acid or 2% phosphoric acid), acidification through lactic acid bacteria (fermentation using six homofermentative strains and 15% sucrose), and combinations of both techniques. All silages and fermentates (except controls) stabilized at pH 4.5 or lower. Acidic-electrolyzed water, when used as a pre-wash in combination with lactic acid bacteria, inhibited growth of coliforms and mold, with pH and CFU/g similar to non-washed controls. However, direct addition of acidic-electrolyzed water required large volumes (10:1) to decrease fish homogenates below pH 4, and did not retain acidity beyond 48 hours. Exploration of new methods, such as acidic-electrolyzed water, for preserving food processing wastes is needed to increase utilization and offset environmental impact of excessive by-product disposal.

Bower, C. 2008. Sustainable harvests through increased utilization of salmon by-products [abstract]. World Aquaculture Society meeting; 2008 May 20-23; Busan, Korea. Available from: https://www.was.org/Meetings/AbstractData.asp?AbstractId=15559.

Abstract: The growing demand for fish meals and oils has produced a steady rise in the market price garnered by these commodities. However, the practice of discarding fish-processing wastes is still widespread. Alaska's fishing industry generates over one million metric tons of fish by-products each year, much of which is discarded during processing when fish meal facilities are not located nearby. To take advantage of the increasing world market for fish oils and protein, remote and seasonal processors may have to adopt a by-products strategy of preserve them now, deal with them later. In Alaska, fish meal production is the most common method for preserving fish by-products. Other techniques, (ensilage, fermentation, and hydrolysate production), are less prevalent, but can also successfully stabilize perishable fish. The objective of this study was to compare the efficacy of different methods of acidification for stabilizing salmon heads, viscera, and mixtures of both. Increased knowledge in this area will provide fish processors with more choices for preserving the underutilized fish components for later sale. In this study, Pink Salmon (*Oncorhynchus gorbuscha)* heads, viscera, and head-viscera mixtures were preserved using either direct acidification with formic acid or through pH reduction using lactic acid bacteria (LAB). Control samples were not acidified, relying entirely on endogenous proteolytic enzymes to break down tissues. Bacterial cell counts and lactic acid concentrations were recorded as a measure of LAB viability. All samples were analyzed for moisture, ash, and lipid composition. The distribution of nitrogen was also followed (Table 1), since proteins degrade into shorter peptides and free amino acids during storage. Results from this study demonstrated that control samples were unable to prevent spoilage of salmon by-products. Only silages and fermentates stabilizing at pH 4.5 or lower successfully preserved samples for 120 days. Significant differences were apparent among initial pH values of salmon viscera, heads, and mixtures, and differences remained for the entire 18 weeks of storage, suggesting that individual by-product varieties may require separate handling for best preservation. Increased utilization of fish processing wastes promises environmental and economic benefits while conserving valuable fish resources. By-products preserved without protein loss can be used in agriculture and aquaculture feeds. However, silages with shorter peptides resulting from longer storage times may be more suitable for use as fertilizers, compost, and as feedstocks for energy production.

Chiou BS, El-Mashad HM, Avena-Bustillos RJ, Dunn RO, Bechtel PJ, McHugh TH, Zhang R. 2006. Rheological and thermal properties of salmon processing byproducts. 2006 ASAE Annual Meeting; 2006 July 16-19; Portland (OR).

Abstract: Salmon oils separated from salmon processing waste and hydrolysate and their derived biodiesel were analyzed and compared with corn oil and its biodiesel. These materials were characterized for their fatty acid profiles, viscosity, volatility, thermal properties, low temperature properties, oxidative stability, and heating value. The salmon oil methyl esters contained 26.64% saturated fatty acid methyl esters compared to 13.68% for corn oil methyl ester. Also, salmon oil methyl esters contained relatively high concentrations of eicosapentaenoic acid (C20:5) and docosahexaenoic (C22:6) acid methyl esters. Despite these differences in fatty acid composition, salmon and corn oil methyl esters had comparable physical properties. In addition, the methyl esters produced from acidified and non-acidified salmon oils showed little difference in their physical properties.

DeWitt C, Rowland S, Patil K, Bower C. 2008. Gasification of salmon processing waste [abstract]. 99th AOCS Annual Meeting and Expo; 2008 May 18-21; Seattle. Available from: http://www.aocs.org/archives/am2008/session.cfm?session=PCP+1%3A+Non-Food+Utilization+of+Animal+Protein+By-Products.

Abstract: The seasonal salmon harvest is often conducted in isolated areas in Alaska. Infrastructure is often lacking and traditional waste remediation strategies, such as rendering, often are not economically feasible. An alternative approach was therefore sought to capture value from salmon waste. Gasification is a process that uses high temperatures (700°C) in a low oxygen environment to produce gas (syngas). This project attempts to determine whether high moisture products, such as salmon waste, can be gasified. Production of syngas from high moisture products is difficult. A drying agent is therefore needed to reduce moisture. A good source of dry material is municipal solid waste (i.e. paper, corrugate, and wood pallets). Therefore, salmon waste products were dried to 20% moisture content using wood pellets. Products evaluated were whole fish, heads, viscera, or frames (raw or de-oiled). Syngas heating value was measured from H2, CO, CH4, C2H2, C2H4, and C2H6 produced from biomass during gasification. Results demonstrated that the heating value of salmon waste mixed with pellets was not significantly different from whole pellets. Efficiency of gas production in the pilot scale gasifier, however, was only about 25% when compared to maximum values obtained using bomb calorimetery. Results demonstrate gasification is possible when salmon biomass is dried using wood pellets.

GELATINS

Bower CK, Avena Bustillos RD, Olsen CW, McHugh TH, Bechtel PJ. 2005. Characterization of fish skin gelatin gels and films containing the antimicrobial enzyme lysozyme. Annual Meeting of the Institute of Food Technologists; 2005 July 15-20; New Orleans.

Abstract: Fish skins are rich in collagen and can be used to produce food-grade gelatin. However, fish collagens have fewer proline and hydroxyproline residues, resulting in less hydrogen-bonding and lower gelling temperatures than mammalian-derived counterparts. Films cast from fish skin gelatins are stable at room temperature and can act as a barrier when applied to foods. Lysozyme is a food-safe, antimicrobial enzyme that can also produce a gel. We believe that fish skin gelatin films can be enhanced with lysozyme and applied as food coatings to increase microbial safety. The objective of this study was to characterize the effect on strength and barrier properties of lysozyme-enhanced fish skin gelatin gels and films, and evaluate their activity against potential spoilage bacteria. Alaskan pollock skins were washed and dried before gelatin extraction. A commercial cold water fish skin gelatin was also used. Solutions containing 6.67% gelatin were formulated to contain varying levels of hen egg white lysozyme. Gels were evaluated for strength, clarity, and viscoelastic properties. Films were evaluated for water activity, water vapor permeability and antimicrobial barrier capabilities. Fish skin gels containing 0.1% to 1.0% lysozyme had pH (4.8) and gelling-temperatures (4.4°C) similar to the lysozyme-free fish skin gelatin controls. However, gel strength decreased (up to 20%). Turbidities of gels,

with or without lysozyme, were comparable at all concentrations. Films cast with gelatin that contained lysozyme demonstrated similar water vapor permeabilities (< 5% difference from control), and water activities (0.37). Lysozyme was still detectable in most fish gelatin films. More antimicrobial activity was retained in films cast with higher lysozyme concentrations, and in films where lysozyme was added after the gelatin had been initially heated. These results suggest that fish skin gelatin gels and films, when formulated with lysozyme, may provide a unique, functional barrier to increase the shelf-life of food products.

Bower CK. 2006. Barrier properties, gel strength, and microbial safety of fish skin gelatin gels and films [abstract]. Aquaculture America 2006; 2006 Feb 13-16; Las Vegas, NV. Available from: https://www.was.org/Meetings/AbstractData.asp?AbstractId=9601.

Abstract: Collagen from fish skins can be used to produce food-grade gelatin, however cold-water fish-skin gelatins solidify at lower temperatures (8 to 10 °C) than their mammalian counterparts (30 to 35 °C). The differences in gelation and melting temperatures are due to the amino acid composition and molecular weight distribution of the gelatins. This makes it difficult for cold-water fish-derived gelatin gels to substitute for gels prepared from the skins of cattle and pigs. Fortunately, fish-skin gelatins have unique functional properties that set them apart from other gelatins. For example, films cast from fish-skin gelatins are stable at room temperature and have moisture barrier properties superior to mammalian-derived gelatins. Current fish processing operations can now mechanically separate skins from other fish components, making it economically feasible to collect discarded skins for production of high value fish-skin gelatin of acceptable quality for food and pharmaceutical use. The purpose of this study was to evaluate the properties of cold-water fish-skin gelatin gels and films in terms of gel strength, barrier properties, and the potential for retaining antimicrobial activity when antibacterial agents such as lysozyme are incorporated. Although the water activities of fish-skin gelatin films were identical (0.37 +/- .01), regardless of whether an antimicrobial agent had been added, the water vapor permeabilities were higher when 1.0% lysozyme was present, (an increase from 0.94 to 1.20 g.mm/m2.h.kPa at 25°C, 80 %RH), thereby decreasing the value of the film as a bather to moisture. The addition of lysozyme did not affect gelling temperatures, which occurred at the same temperature as the control (4.4°C). However, the lysozyme did reduce the solubility and gave a lower overall gelatin gel strength (by up to 20%). Antimicrobial activity was still detectable in most lysozyme-enhanced fish-skin gelatin films. Some bacteria were present in the dry gelatin powders being tested, however no colonies survived at high (gelatin-processing) temperatures and none demonstrated gelatinase activity. Cold-water fish-skin gelatin gels and films may prove valuable, (either alone or produced with antimicrobial agents) as unique, functional bathers for increasing the shelf-life of foods.

HYDROLYSATES

Bechtel PJ, Subramaniam S, Oliveira ACM, Smiley S, Babbitt J. 2003. Properties of hydrolysates from pink salmon heads and viscera [abstract]. First Joint Trans Atlantic Fisheries Technology Conference. 2003 June 10-14. Reykjavik, Iceland. Proceedings of the TAFT 2003 Conference. Icelandic Fisheries Laboratory. p. 284-285.

Five species of Pacific salmon are commercially harvested in Alaska (genus *Oncorhynchus*), with pink salmon (*Oncorhynchus gorbuscha*) harvested in the highest volume. The major by-products of salmon processing are heads and viscera. The objective of this study was to make dried hydrolysates containing all protein and fat from both salmon heads and viscera and characterize their chemical and nutritional properties.

Approximately 1,000 kg of both fresh pink salmon heads and viscera were obtained from commercial plants and immediately processed in a pilot plant sized hydrolysis unit (ASTA Ltd.). Heads or viscera were continuously ground, mixed with a constant amount of papain and the hydrolyzed at 61-65 °C. The reaction was terminated by denaturing papain at approximately 85 °C and the hydrolysates concentrated in an evaporator to 40-45% solids. At a latter time hydrolysates were dried to powder using a Littleford dryer and then mixed with ethoxyquin to 150 ppm. Characterization of hydrolysates included, proximate analysis, amino acid profiles, mineral analysis, fat characterization, percent peptide bond cleavage with the OPA method (DH), protein solubility and size, pepsin digestibility and physical properties.

Raw heads and raw viscera had a composition of 75.1 and 79.7 % moisture, 15.8 and 16.2 % protein, 3.2 and 1.5 % ash and by subtraction 5.9 and 2.6 % fat, respectively. Composition of the final dried head and viscera hydrolysates was 6.6 and 7.4 % moisture, 59.6 and 74.6- % protein, 5.5 and 6.8 ash, and 29.8 and 12.8 % fat, respectively. DH values of samples were 12.0 to 14.5 and 16.3 to16.9 for dried hydrolyzed head and viscera products, respectively. Pepsin digestibility values for both raw and hydrolyzed heads and for viscera was over 94%. Calculated rat PER values for the dried hydrolysates from heads and viscera were greater than 2.6 and 2.8, respectively. All major proteins present in raw heads and viscera were reduced in size to small peptides, amino acids or other compounds in the corresponding hydrolysates.

In conclusion, dried hydrolysates made without removal of fat from both pink salmon heads and viscera had many desirable properties.

Bower CK, Bechtel PJ, Malemute CL. 2006. Endogenous enzymes in pink salmon as a function of spawning maturity. Institute of Food Technologists Annual Meeting and Food Expo; 2006 June 24-28; Orlando. Chicago: Institute of Food Technologists.

Abstract: Hydrolysate production is a low-cost method of preservation that could decrease the amount of fish byproducts discarded by Alaska's salmon industry. However, endogenous enzymes of fish vary with spawning maturity, and must be controlled in the raw material to ensure a consistent hydrolysate. Inactivation of these enzymes is accomplished by heating the raw materials, despite the loss of protein quality. The objective of this study was to evaluate the changes in proteolytic activity of pink salmon destined for use in hydrolysates, based on the spawning maturity of the fish. Both male and female adult pink salmon (*Oncorhynchus gorbuscha*) were harvested at three different levels of maturity. Four different tissue groups (fillets, heads, livers, viscera) were removed from each fish and immediately vacuum packaged and frozen (-70°C) until testing. Crude extracts of each tissue were tested for proteolytic activity (pH 3.5, 6.5, and 7.3) using a spectrophotometric method

hydrolyzing either casein or hemoglobin as a substrate. Corresponding protein, fat, moisture, and ash levels were also determined. Ocean salmon (premium quality with silver scales and no watermark) demonstrated a greater proteolytic activity per mg soluble protein at pH 3.5 for heads, fillets, and livers, while enzymes from viscera were more active at pH 7.3. Similar results were obtained for more mature salmon (displaying prominent watermarks and loss of scales). Terminal salmon, harvested from the river just prior to spawning, contained higher levels of activity at pH 3.5 in all tissues. Proteolytic activity decreased with salmon maturity in fillets and viscera, but increased in livers regardless of pH. This demonstrates that proteolytic activity within different tissues changes as salmon move from salt water to their fresh water spawning grounds. This will have implications for reduced-heat processing of hydrolysates when different maturity levels of pink salmon are used.

Guerard F, Sumaya-Martinez MT, Fouchereau-Peron M, Gildberg A, Stenbert E, Fruitier I, Bordenave S, Sannier F, Piot JM, Berge JP, Le Gal Y. 2004. Recent developments of marine processing waste up-grading: production of hydrolysates with biological properties. In: Waldron K, Faulds C, and Smith A, editors. Total food: exploiting co-products - minimizing waste. Proceedings of the 2004 Total Food Conference; 2004 April 25-28; Norwich. Norwich (UK): Institute of Food Research. p 86-92.

Abstract: In recent years, a large number of biologically active peptides has been isolated from bacterial, fungal, plant and animal sources or generated from proteins by enzymatic hydrolysis. The preparation of hydrolysates from fishery wastes and by-products (e.g. heads, frames, viscera) through enzymatic processes also shows to generate biologically active factors such as peptides inhibiting the angiotensin I-converting enzyme, thus exhibiting an antihypertensive effect or hormonal-regulating peptides such as (i) the small gastrointestinal peptides like gastrin and cholecystokinin (CCKs), and (ii) calcitonin and calcitonin gene related peptide (CGRP). In vitro and in vivo immunostimulatory activities are also detected in Shrimp hydrolysates. In addition to the biological activities described above, the presence of antioxidant compounds in marine by-products hydrolysates is reported.

All these by-products of fish and shellfish wastes are now considered in the context of the production of functionnal molecules exhibiting nutrition and health properties.

Olson DA, Avena-Bustillos RJ, Lane S, Chiou BS, Bechtel PJ, McHugh TH. 2006. Drum drying evaluation of salmon hydrolysate. Institute of Food Technologists Annual Meeting and Food Expo; 2006 June 24-28; Orlando. Chicago: Institute of Food Technologists.

Abstract: Salmon hydrolysate has unique advantages as a fish feed ingredient when compared to fish meals. Short chain peptides and amino acids formed during enzymatic hydrolysis can leach out from fish feeds and act as a feeding attractants. Drying at high temperature and short time could stabilize the salmon hydrolysate with minimal thermal damage to facilitate storage and shipping without the use of acid and chemical preservatives. This study evaluated the effect of drum drying under controlled feeding rate conditions on the physical properties of dried salmon hydrolysates. Controlled feed drum drying of a commercial salmon hydrolysate was done at four different temperatures and three drum speeds. Products were compared in terms of protein solubility, differential scanning calorimeter (DSC) profile, water

activity, moisture content, and color. Freeze dried salmon hydrolysate and a commercial salmon meal were also evaluated. As drum drying time increased at a constant temperature, the cook value and color lightness increased and the water activity, and moisture decreased linearly ($p<0.05$). There was little effect of drum drying temperature or drum speed on protein solubility of the hydrolysates. Freeze dried salmon hydrolysate had the lowest Aw and moisture and was lighter in color. Protein solubility and moisture content were significantly lower in salmon meal than in drum dried salmon hydrolysates with cook times of less than 30 s at 121°C, although no difference in Aw or color were found. However, there were significant differences in Aw and moisture for salmon hydrolysate samples dried with cook times higher than 30 s at 121°C, but color was not different than to salmon meal. DSC profiles indicated that enzymatic hydrolysis and partial evaporation of salmon hydrolysate had resulted in loss of protein structure. Drum drying is a feasible drying technology for salmon hydrolysate stabilization.

MEDICAL USES

Elvevoll EO. 2004. Fish waste and functional foods. In: Waldron K, Faulds C, and Smith A, editors. Total food: exploiting co-products - minimizing waste. Proceedings of the 2004 Total Food Conference; 2004 April 25-28; Norwich. Norwich (UK): Institute of Food Research. p. 49-57.

Abstract: Scientific research constantly provides new insights in the interaction between genetic predisposition, specific health risks and nutritional needs, and the functioning of separate nutrients. The role of food as an agent for improving health has been proposed as a new class of food- functional foods.

Every year 30 million tons of such waste is dumped around the world, and Norway alone has been "wasting" 150,000 tons a year. Fish waste may be sources for of proteins of high biological value, unsaturated essential fatty acids, vitamins and antioxidants, minerals or trace metals and physiological beneficial amino acids and peptides.

Scientific data shows that the consumption of fish or fish oil containing omega-3 polyunsaturated fatty acids (PUFAs) reduces the risk of coronary heart disease, decreases mild hypertension, prevents certain cardiac arrhythmia, and sudden death, lowers the incidence of diabetes, and appears to alleviate symptoms of rheumatoid arthritis. It appears that omega-3 PUFAs play a vital role in the development and function of the nervous system (brain), photoreception (vision), and the reproductive system.

Additional components in seafood may be of importance for development of life style diseases. Potent peptides with high anti hypertensive activities and petides, which may modulate neuropeptide levels, have been isolated from fish waste. Protease inhibitors of the serpin family, or serine protease inhibitors, are a family of glycoproteins that include members involved in the control of blood coagulation, fibrinolysis, complement activation and inflammation processes, are also found. Calcium and vitamin D are other candidates. Antioxidants (tocopherols, ubiquinone,

selenium, taurine, fish protein) have attracted special attention due to their possible prevention of low-density lipoprotein (LDL) oxidation.

Oliveira AM, Bechtel PJ, Smiley S, Plante S. 2008. Fish oils from Alaskan seafood processing: an unexploited resource of omega-3 rich nutraceuticals [abstract]. In: Institute of Food Technologists Annual Meeting and Food Expo; 2008 June 28-July 1; New Orleans. Chicago: Institute of Food Technologists.

Abstract: Alaska fish oils produced during seafood processing have the potential to increase the availability of this food ingredient for nutraceutical use. In Alaska, fish oils are produced from the byproduct stream of sustainable food fisheries and current production, while difficult to document, is probably between 30,000 and 45,000 mt per annum. Interestingly, it is estimated that the annual production of oil in Alaska could reach 70,000 mt under appropriate conditions. The fatty acid profiles (mg/ g oil), lipid classes' distribution (% total lipids), levels of organic contaminants (ppm), and concentration of fat soluble vitamins A, D and E (IU/100g) were examined in commercial Alaska crude oils produced from walleye pollock (*Theragra chalcogramma*), pink salmon (*Oncorhynchus gorbucha*) and sockeye salmon (*Oncorhynchus nerka*), Pacific Ocean perch (*Sebastes alutus*) and sablefish (*Anapoploma fimbria*). Additionally, analysis of commercial menhaden (*Brevoortia tyrannus*) and canola (*Brassica napus)* oils were conducted for comparison. All Alaska fish oils investigated had high levels of ω-3 and ω-9 fatty acids, particularly 22:6ω3 (DHA), 20:5ω3 (EPA) and 18:1ω9 (oleic acid), and very low levels of 18:1ω7 (palmitoleic acid) and 18:2ω6 (linoleic acid). The major lipid class detected in Alaska oils was triacylglycerides at about 95%. Diacylglycerides, monoacylglycerides and free fatty acids were determined at less then 1% each. Phospholipids ranged from a maximum of 2% in pollock oil to a minimum of 0.3% in sablefish oil. Analysis of the 29 most important pesticides (PCBs) reveled that all PCBs concentrations were very low with the exception of 4,4'-DDD and 4,4'-DDE in sablefish oil quantified at 0.5 and 0.25 ppm, respectively. Levels of fat soluble vitamins were highly variable according to fish species. As global demand for omega-3 rich edible oils increases, purification of fish oil derived from Alaskan seafood processing for nutraceutical use may be of interest to food ingredient manufacturers.

Wu TH, Bechtel PJ. 2007. Antioxidant activity in oil extracts from pink salmon (*Oncorhynchus gorbuscha*) heads and viscera. In: Institute of Food Technologists 2007 Annual Meeting and Food Expo; 2007 July 28-Aug 1; Chicago. Chicago: Institute of Food Technologists.

Abstract: There is a plethora of scientific evidence that the consumption of long chain polyunsaturated fatty acids from marine fish oils have beneficial health effects. However, fish oils also contain antioxidants and there is very limited work on the antioxidant activity of marine fish oils. The objective of this research was to evaluate antioxidant activity of oils extracted from pink salmon heads and viscera with varying degrees of freshness stored at two temperatures. Pink salmon heads and viscera were collected from a commercial plant in Kodiak, AK. The heads and viscera were mixed together and aged at two temperatures (6 and 15C) for 4 days. Samples were removed from both treatments on days 0, 1, 2, 3 and 4 and the oil extracted for analysis. The raw samples were analyzed for volatile amines and thiobarbituric acid reactive

substances (TBARS), while oil samples were analyzed for lipid soluble antioxidant activity using a photochemiluminescence detection method. Results showed a linear decrease for antioxidant activity of the extracted oils during the 4 days of storage. No significant difference in the regression lines between the two storage temperatures ($p < 0.05$) was observed. The antioxidant activity of the pink salmon oils (n=3) at day 0 and day 4 at 15C was 0.89±0.15 and 0.41±0.12 mmole Torlox equivalence/L of oil, respectively. Analysis of raw samples suggested TBAR value was a better indicator than volatile amine value for antioxidant activity in the extracted oils with a high correlation coefficient ($r = 0.88$). These data suggest that storage temperatures of 6 or 15C were of less importance than the storage time for reducing the antioxidant activity in the extracted fish oil and TBAR values in the raw material may be used as a predictor for antioxidant activity in the extracted fish oil.

PROTEINS

Bechtel PJ, Sathivel S, Oliveira ACM. 2005. Extracting high quality protein from salmon byproducts using new high pH methodology [abstract]. 2005 Arctic Science Conference; 2005 Sept 27-29; Kodiak, AK. Available online: http://www.arcticaaas.org/meetings/2005/2005_abstract_book.pdf.

Abstract: The two major byproducts produced from salmon canning and H&G processing are heads and viscera. In addition, smaller amounts of frames and skin are produced from the processing of boneless and skinless fillets. It has been estimated that the major byproducts available in Alaska from Pacific salmon processing include over 50,000 mt of salmon heads and 30,000 mt of viscera, most of which is under utilized. Soluble and insoluble fractions from salmon head and salmon viscera can be produced using a newly developed alkali-aided extraction for use as functional animal feed ingredients. The objective of this study was to isolate both soluble and insoluble protein fractions from salmon byproducts and characterize the chemical and functional properties of the protein powders. Pink salmon (*Oncorhynchus gorbuscha*) viscera and red salmon (Oncorhynchus nerka) heads were used in this study.

Pink salmon viscera (PV) and red salmon head (RH) samples were collected from a commercial processing plant and stored at 20°C until thawed for protein extraction. Triplicate samples of minced samples were diluted in deionized water (1:9), homogenized, solubilized at pH 11, soluble and insoluble fractions separated by centrifugation, and the soluble fraction precipitated at pH 5.5. The freeze-dried PV-soluble (PVS) and PV-insoluble (PVIS), RH-soluble (RHS), and RH-insoluble (RHIS) fractions were analyzed for proximate composition, TBA values, lipid classes, amino acid contents, and SDS PAGE molecular weight analysis of the proteins. Evaluations of functional properties included emulsion stability (ES), fat absorption, solubility and color. RHIS, PVIS, RHS, and PVS contained 50.7%, 69.4%, 80%, and 87.2% protein, respectively. Both insoluble fractions (RHIS and PVIS) had higher fat adsorption values than PVS and RHS. All the salmon protein powders were white to lightly yellow and had desirable amino acid profiles.

Soluble protein isolates from red salmon head and pink salmon viscera have functional and nutritional properties that have potential applications in the food industries. Insoluble protein fractions could be utilized in feed industries. Other

studies have indicated that high quality protein with excellent functional characteristics can be readily extracted from the frames and heads of Pollock and flat fish.

Bower C, Hietala K. 2008. Preserving high-protein fish by-products through silages and fermentates [abstract]. 99th AOCS Annual Meeting and Expo; 2008 May 18-21; Seattle. Available from: http://www.aocs.org/archives/am2008/session.cfm?session=PCP+1%3A+Non-Food+Utilization+of+Animal+Protein+By-Products.

Abstract: In Alaska, over three million metric tons of fish by-products are generated each year. However, due to the remote locations and seasonal nature of salmon fisheries, by-products are generally not fully utilized unless a fish meal plant is located nearby. Acidification is a common method for inhibiting microorganisms and promoting autolysis of animal tissues, thereby preserving perishable foods such as fish. In these studies, salmon by-products were stabilized using a variety of acidification methods, then the quality of the high-protein fish was evaluated. Hot-smoking technologies reduced the pH to 4.8, preserved proteins, and eliminated all fishy odors. Fermentation by lactic acid bacteria lowered the salmon by-products to pH 4.5 during 18 weeks of storage, but destroyed much of the fish protein. Fermentations using local agricultural discards such as potatoes as a carbohydrate source were not effective for stabilizing the pH of salmon. Ensilage through direct acidification using organic and inorganic acids decreased protein quality, but maintained a pH below 4.5 for 18 weeks. Alternative methods of preservation are needed to decrease the loss of valuable marine proteins and oils, and to provide salmon processors with environmentally sound options for adding value to by-products currently discarded as waste.

OTHER

Huang J, Sathivel S. 2007. Purifying red salmon oil (*Oncorhynchus nerka*) using a combined neutralization and adsorption process [abstract]. In: Institute of Food Technologists 2007 Annual Meeting and Food Expo; 2007 July 28-Aug 1; Chicago. Chicago: Institute of Food Technologists.

Abstract: Red salmon oil is an abundant source of polyunsaturated fatty acids, especially eicosapentaenoic acid and docosahexaenoic acid. Increasing the value of salmon oil is a critical concern for the Alaska salmon industry. Finding more lucrative markets for this unrefined fish oil requires well-designed purification steps to reduce impurities such as free fatty acids (FFA), oxidative components, and moisture. The objective of the study was to purify the red salmon oil using a combined neutralization and adsorption process and evaluate the quality of the purified salmon oil. Fresh, unrefined red salmon oil obtained from an Alaska fishmeal processor was produced from salmon processing byproducts including viscera, heads, skins and frames. Unrefined salmon oil was neutralized by adding 9.5% sodium hydroxide at 65C and stirred for 30 min. The neutralized oil was further purified using 5% (wt/wt of oil) activated earth in a batch absorption process at 25C for 60 min to remove oxidative components and moisture from the unrefined oil. Purified salmon oil was evaluated for fatty acid profile, vitamin E, FFA, peroxide values (PV), moisture,

water activity, and color. Triplicate experiments were conducted. Data were statistically analyzed (α=0.05). No significant reduction of omega-3 fatty acids and vitamin E content of the oil were observed during neutralization and adsorption process. FFA of unrefined salmon oil was 3.5% and it was significantly reduced ($P<0.05$) to 0.12% by neutralization. After adsorption process, PV of neutralized oil was decreased from 2.4 to 1.5mN/kg. Purified salmon oil had a lower water activity (0.24) than unrefined oil (0.43). Moisture content of unrefined salmon oil (0.18%) was reduced ($P<0.05$) to 0.05%. Purified salmon oil was lighter ($L^* = 46.1$) than that of unrefined oil ($L^* = 27.0$). This study demonstrated that the combined neutralization and adsorption process effectively reduced FFA, PV, and moisture content of red salmon oil.

Klaypradit W, Huang YW. 2006. Fish oil encapsulation with chitosan using ultrasonic atomizer [abstract]. In: Institute of Food Technologists Annual Meeting and Food Expo; 2006 June 24-28; Orlando. Chicago: Institute of Food Technologists.

Abstract: Fish oils are an excellent dietary source of the important polyunsaturated fatty acid, EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid), which easily undergo oxidation when exposed to the environment. To overcome this drawback, this work studied the feasibility of chitosan-based encapsulation of fish oil by the new microencapsulation technique using an ultrasonic atomizer. Encapsulation was completed in three stages: (1) emulsification (homogenizer/high pressure homogenizer); (2) atomization (ultrasonic atomizer); and (3) freeze drying. The optimization for variables encountered during preparation such as concentration and ratio of wall materials used (chitosan, maltodextrim [MD], whey protein isolate [WPI]), fish oil concentration (10%, 20%, 30%), rpm of homogenizer, amplitude of atomizer (50, 55, 60, 65) were determined. The emulsions were determined for droplet size and stability while antioxidant effect was measured over time for emulsion stored at 50°C. After freeze drying, different formulated powders were characterized for level of fish oil, EPA and DHA composition, and surface morphology of formed microspheres. The results indicated the ratios of chitosan to MD and chitosan to WPI were 1:10 and 1:1, respectively; however, the optimum concentration of chitosan alone was 1%. The emulsification process was at 5,000 rpm, 15-20 min followed with atomization at amplitude of 55. There was significant difference in size ($p<0.05$) of the particles in the emulsions when the preparation conditions were varied. No significant difference in antioxidant effects was observed. The ratio of EPA and DHA in encapsulated powder was found to decrease 3%-5%. These results implied that chitosan alone or chitosan mixed with MD or WPI have the potential to be wall materials for fish oil encapsulation using an ultrasonic atomizer. Factors that increase the rate of oxidation also need to be prevented throughout the entire process.

Sathivel S, Huang J. 2008. Purifying salmon oil using adsorption and neutralization methods [abstract]. World Aquaculture Society meeting; 2008 May 20-23; Busan, Korea. Available from: https://www.was.org/Meetings/AbstractData.asp?AbstractId=15559.

Abstract: Large amounts of salmon byproducts are produced in Alaska every year. It is estimated that around 99,000 metric tons of salmon byproducts were produced out of 331,798 metric tons of salmon harvested in Alaska. These salmon byproducts

include salmon heads, skin, and viscera. Producing and purifying fish oil from salmon byproducts for the growing fish oil market can benefit the fishing industry in Alaska. The unpurified salmon oil contains free fatty acids, primary oxidation products, minerals, pigments, moisture, phospholipids, and insoluble impurities that reduce the oil quality. Removal of impurities from unpurified salmon oil is very important to producing purified oil with desirable and acceptable shelf life. The objectives of this study were to determine the performance of activated earth or chitosan as an adsorbent to remove FFA and peroxides from the unpurified salmon oil and to purify salmon oil using three methods including the activated earth adsorption process, neutralization process, and combined neutralization and activated earth adsorption processes.

Unpurified salmon oil (UPO) was produced from processing salmon byproducts including viscera, heads, skins, frame, and discarded fish obtained from a large commercial plant in Alaska. Activated earth and shrimp chitosan with high viscosity were used as an adsorbent for the batch adsorption process. The UPO was neutralized according to AOCS Official Method. The neutralized oil was further purified using activated earth in a batch absorption process at 20oC for 90 min.

The purified salmon oil samples were evaluated for FFA, peroxide values (PV), minerals, color, tocopherols, moisture content, insoluble impurities, and water activity. Neither chitosan nor the activated earth adsorption process was effective in removing FFA from the salmon oil. FFA of unpurified salmon oil was 3.5% and was significantly reduced ($P<0.05$) to 0.12% by neutralization. No significant reduction of tocopherols content of the oil was observed in any of the three purification processes. After the adsorption process, PV of neutralized oil had decreased from 2.4 to 1.5mmole/kg. All three purification process increased the lightness (L*) and decreased the redness (a*) and reduced mineral, insoluble impurities, moisture content, and water activity of the salmon oil.

The results indicated that the combined process was more effective in reducing FFA, peroxides, and moisture content than either the activated earth adsorption or neutralization purification processes alone.

Tacon AGJ. 2004. Fish meal and fish oil use in aquaculture: global overview and prospects for substitution. In: Lyons TP, Jacques KA, editors. Nutritional Biotechnology in the Feed and Food Industries: Proceedings of Alltech's 20th Annual Symposium. Nottingham (UK): Nottingham University Press. p. 443-448.

No summary available

OTHER PAPERS

Falch E. 2006. Lipids from residual fish raw materials: quality assessment by advanced analytical methods [doctoral thesis]. Trondheim, Norway: Norwegian University of Science and Technology.

Summary: Fisheries and aquaculture generate considerable volumes of biomass that are wasted or applied for low value products. These biomasses may have potential as

high value products due to their content of health beneficial nutrients, in particular the marine lipids that have been investigated in this current thesis. To upgrade these raw materials into high value lipids, more knowledge about availability, chemical composition and deterioration of the lipids is required.The work was divided into the following activities: (1) Provide data on the composition and quality of lipids in by-products from gadiform species (2) Study the applicability of different Electron Spin Resonance (ESR) spectroscopy techniques for assessment of the early stages of lipid oxidation in residual raw materials from fish (3) Study the applicability of 1H Nuclear Magnetic Resonance (NMR) to evaluate lipid oxidation of marine oils and (4) Generate more knowledge of lipid composition and deterioration of cod lipids by adapting High resolution (HR) NMR applications for analysis of heterogeneous lipid extracts.

McBride D. 2003. Trends in the US pet food industry: the potential for Alaska seafood products. Anchorage (AK): Alaska Department of Community and Economic Development: Office of Fisheries Development. Available from: http://www.dced.state.ak.us/oed/seafood/pub/PetFoodIndustryReport.pdf.

Introduction: The U.S. pet food industry is a $30 billion business. Bolstered by growing numbers of domestic and foreign pet populations, industry figures place average annual growth from 1994 through 2003 at over 9%.1

Concerns among pet owners in the 1990s about the nutrition and health of their dogs and cats led to a trend toward premium, healthy pet foods and treats. This has translated into a growing market for specialty pet products in the U.S. and around the world.

Research indicates today’s pet owners are frustrated by the quality of many pet foods and attracted by the benefits of the omega-3 fatty acids found in fish oils. Alaska seafood based pet products may provide the type of alternative pet food sought by conscientious pet owners. Alaska provides an abundance of seafood by-products ideal for pet food. The flesh of chum salmon caught for roe, for example, is unpalatable to humans, but the State of Alaska requires full utilization of the material once harvested. Such inexpensive protein makes an ideal and abundant pet food ingredient. If properly developed and marketed, Alaska seafood not directed towards human consumption may provide a healthy, valuable pet food alternative.

Ramírez A. 2007. Salmon by-product proteins. Rome: Food and Agricultural Organization. FAO Fisheries Circular. No. 1027.

Abstract: This Circular describes the potential of by-products from salmon as a source of protein. It lists the main geographic sources of raw material and by-products from salmon aquaculture, namely Canada, Chile, Norway and the United Kingdom of Great Britain and Northern Ireland. It provides an overview of available technologies for preserving the nutritional value of proteins and how to obtain value from their functional properties. A detailed description is provided on the various uses and functions of the proteins deriving from salmon by-products with various cost estimates given for a number of products: hamburger patties, pet food, silage, salmon meal and hydrolysates.

The Circular describes the various markets for protein and the particularities related to the use of salmon by-products as raw material for protein production. It concludes that with adequate and cost-effective technology, by-products from salmon can provide important quantities of protein for the world's protein markets.

Tacon AGJ, Hasan MR, Subasinghe RP. 2006. Use of fishery resources as feed inputs for aquaculture development: trends and policy implications. Rome: Food and Agriculture Organization. FAO Fisheries Circular. No. 1018.

Abstract: Although aquaculture's contribution to total world fisheries landings has increased ten-fold from 0.64 million tonnes in 1950 to 54.78 million tonnes in 2003, the finfish and crustacean aquaculture sectors are still highly dependent upon marine capture fisheries for sourcing key dietary nutrient inputs, including fishmeal, fish oil and low value trash fish. This dependency is particularly strong within aquafeeds for farmed carnivorous finfish species and marine shrimp. On the basis of the information presented within this fisheries circular, it is estimated that in 2003 the aquaculture sector consumed 2.94 million tonnes of fishmeal and 0.80 million tonnes of fish oil, or the equivalent of 14.95 to 18.69 million tonnes of pelagics (using a dry meal plus oil to wet fish weight equivalents conversion factor of 4 to 5). Moreover, coupled with the current estimated use of 5 to 6 million tonnes of trash fish as a direct food source for farmed fish, it is estimated that the aquaculture sector consumed the equivalent of 20–25 million tonnes of fish as feed in 2003 for the total production of about 30 million tonnes of farmed finfish and crustaceans (fed finfish and crustaceans 22.79 million tonnes and filter feeding finfish 7.04 million tonnes). At a species-group level, net fish-consuming species in 2003 (calculated on current pelagic input per unit of output using a 4–5 pelagic:meal conversion factor) included river eels, 3.14–3.93; salmon, 3.12–3.90; marine fish, 2.54–3.18; trout, 2.47–3.09 and marine shrimp, 1.61–2.02; whereas net fish producers included freshwater crustaceans, 0.89–1.11; milkfish, 0.30–0.37; tilapia, 0.23–0.28; catfish, 0.22–0.28; and feeding carp, 0.19–0.24. Particular emphasis within the report is placed on the need for the aquaculture sector to reduce its current dependence upon potentially food-grade marine capture-fishery resources for sourcing its major dietary protein and lipid nutrient inputs. Results are presented on the efforts to date concerning the search for cost-effective dietary fishmeal and fish oil replacers, and policy guidelines are given for the use of fishery resources as feed inputs by the emerging aquaculture sector.

WEB RESOURCES

Arctic AAAS: The AAAS Arctic Division Website [Internet]. Fairbanks (AK): Arctic Division of AAAS. Available from http://www.arcticaaas.org/meetings/.

The Arctic Division of AAAS organizes annual conferences for scientific scholars working on Arctic, Alaskan, Canadian, northern or Antarctic issues. Arctic AAAS maintains a website that includes information about each of the annual conferences, including abstracts from all conference presentations.

BIM Corporate – Fish Farming – Environment – Waste Management. Dublin (Ireland): BIM (Bord Iascaigh Mhara—Irish Sea Fisheries Board). Available from: http://www.bim.ie/.

BIM is the Irish State agency with responsibility for developing the Irish Sea Fishing and Aquaculture industries. The organization is investigating alternatives to disposing of fish waste and byproducts, as well as non-organic processing wastes, in landfills. These alternatives include composting.

By-Product Development [Internet]. Juneau (AK): Alaska Department of Commerce, Community and Economic Development, Office of Fisheries Development. Available from: http://www.dced.state.ak.us/oed/seafood/by_products.htm.

Resource description: Website addressing by-product development in Alaska. Includes data on production and value through 2001, as well a limitations and opportunities in by-product development in Alaska.

Converting Alaska Fish By-Products into Value Added Ingredients and Products [Internet]. [updated 2008 Oct 8]. Washington, D.C.: US Department of Agriculture, Agricultural Research Service. Available from: http://www.ars.usda.gov/research/projects.htm.

Resource description: Project website for ongoing research conducted under the Agricultural Research Service (ARS) program at US Department of Agriculture.

Project description: ARS and Fishery Industrial Technology Center (FITC) scientists will characterize chemical and physical properties of fish by-products and co-products obtained from the processing of fish in Alaska. Characterization of the chemical and physical properties will be conducted by ARS and FITC scientist in the well equipped laboratories in Fairbanks and Kodiak, Alaska. ARS and FITC scientist in collaboration with UI and OI scientists will identify and develop higher valued products that can be derived from fish by-products. Processing and fractionation studies and the production of feed ingredients to be tested will be done at the University of Alaska fish processing pilot plant in Kodiak, Alaska. Feeds incorporating these products will be formulated, manufactured and nutritionally tested at UI and OI.

IFFO--International Fishmeal and Fish-Oil Organisation [Internet]. Hertfordshire, United Kingdom: IFFO Limited. Available from: http://www.iffo.net/.

Resource Description: IFFO is an international non-profit organization which represents fishmeal and fish oil producers and related trades throughout the world. IFFO's website includes information on the fishmeal and fish oil industry, benefits of the use of fishmeal and fish oil, products specifications and quality, and the organization's annual conferences and past conferences.

IFT – Research, Reports & Policy [Internet]. Chicago, IL: Institute of Food Technologists. Available from: http://members.ift.org/IFT/Research/.

The Institute of Food Technologists is a non-profit scientific society. Its members work in food science, food technology, and related professions. IFT maintains a website with reports, policy paper, peer reviewed documents, and technical abstracts

from their annual conference, among other resources. IFT's annual conferences regularly include presentations and posters by researchers working with fish byproducts.

Market Reports [Internet]. Rome, Italy: GLOBEFISH, Fisheries Department, Food and Agriculture Organization of the United Nations. [Updated 2008 December 2]. Available from: http://www.globefish.org/.

GLOBEFISH is the unit in the FAO Fisheries Department responsible for information on international fish trade. GLOBEFISH produces regular market reports for various key fishery commodities and products, including fish oil and fish meal. GLOBEFISH reports examine characteristics of international production, market prices, and other characteristics of markets and production. GLOBEFISH also produces special periodic research products, including commodity price reports and special market analyses.

Proceedings WEFTA annual meetings [Internet]. Tromsø, Norway: West European Fish Technologists Association (Nofima). Available from http://www.wefta.org/default.asp?ZNT=S0T1O214.

The West European Fish Technologists Association is an association of fish technology institutes from Western European nations. WEFTA organizes an annual meeting and also is one of the joint participants in the Trans-Atlantic Fisheries Technology Conference. Proceedings from WEFTA conferences in 1998 and 2003 to present area available on the organization's website. These conferences regularly include presentations from people working in seafood byproducts, including salmon.

RUBIN [Internet]. Trondheim (Norway): Stiftelsen RUBIN. Available from www.rubin.no/eng.

RUBIN is a foundation that works for more profitable utilization of by-products from fisheries and fish farming in Norway. Their website provides information on their organization, their objectives and strategies, numbers and figures related to by-products in Norway, and their projects.

Seafood Science and Technology Society Conference Proceedings. Gainesville (FL): Seafood Science and Technology Society. Available from: www.http://sst.ifas.ufl.edu/proceed.html.

The Seafood Science and Technology Society of the Americas is a professional and educational association of aquatic food product technologists. They meet annually and publish conference proceedings, including some conference presenter presentations, on their website.

Seafood Technology Project [Internet]. [Updated 2008 Aug 11]. Newport, OR: Hatfield Marine Science Center, Oregon State University. Available from: http://osulibrary.orst.edu/guin/seafood/index.html.

Resource Description: The Seafood Technology Project is a set of bibliographies produced by researchers at various West Coast Sea Grant programs and other agencies and organizations. The project includes a bibliography on seafood by-

products, which was last updated in December 2003. The bibliographies are searchable.

POPULAR LITERATURE

BIO-FUEL

Biodiesel from fish processing waste. 2008 Nov 26. The Bioenergy Site. www.thebioenergysite.com. Accessed 2008 Nov 28.

> VTT Technical Research Centre of Finland and its partners have launched ENERFISH, a three-year project concerned with producing biodiesel from the waste generated at a fish processing plant.
>
> To ensure the viability and rapid commercialisation of the technology, the partners are constructing a biodiesel production plant next to the Vietnamese fish processing plant Hiep Thanh Seafood JSC.

Bridges T. 2007 Jan 26. Sizzling mission: Journey powered by cooking oil: Duo are driving from Alaska to Argentina in a firetruck powered by a biodiesel engine that can run on used cooking oil. The Miami Herald. Miami, FL.

> The kayaking dudes drove across Alaska powered by salmon oil from canneries, across Mexico on lard from deep-fry joints, and will head south from Lima fueled by oil that was used to cook French fries.
>
> Seth Warren and Tyler Bradt have been driving since July from Dead Horse on the northern tip of Alaska on their way to Argentina's southern tip in a Japanese firetruck converted to run on used vegetable oil and other types of oils.

DeMarban A. 2008 July 4. Rural Alaska communities seek way to lower energy costs. The Tundra Drums. www.newsminer.com. Accessed 2008 Dec 3.

> A group of Dillingham, Alaska, fishermen hoping to reduce gas costs for the Bristol Bay fleet are sketching plans to turn salmon waste into fuel.
>
> In Nunam Iqua in Western Alaska, a tiny utility hopes to spin power from the wind electric use will jump when a new school opens and flush toilets arrive.

Faludi J. 2007 Oct 31. Fish for fuel. Worldchanging. www.worldchanging.com. Accessed 2008 Nov 28.

> We're all familiar with biodiesel being made from soy oil, or canola, or waste cooking oil. But fish waste? Yes, it appears to be a good feedstock for the fuel. Companies and local governments in Canada, Alaska, Hawaii, Honduras, and other places have been experimenting with fish-based biodiesel for years, and some commercial enterprises are using and selling it profitably.
>
> This should come as no surprise to anyone who remembers that before the petroleum age dawned, the world used whale oil for light and heat. In fact, petroleum was an eco-friendly alternative when first discovered, as several whale species were roaring into the fast lane on the road to extinction. Don't worry about fish fuel speeding up

the depletion of the oceans, though -- all the fuel described here is made from oil left over from fish processing.

Kram J. 2008 Aug. From fish farm to fuel. Biodiesel Magazine:46-52.

The steep rise in fuel prices is creating opportunities for entrepreneurs to innovate and discover new low-cost feedstocks for biofuels production. Neptune Industries, a Florida company, is looking to collect waste generated by its fish farming operation to fertilize algae production for biodiesel feedstocks.

Welch L. 2008 March 9. Alaska's next big oil boom may come from fishy source. Alaska Journal of Commerce. http://alaskajournal.com. Accessed 2008 Nov 18.

Alaska's future fortunes could soon be fueled by another oil boom - and it won't be from crude.

Fish oils are the biggest buzz in the bio-products world, said Peter Bechtel, a U.S. Department of Agriculture researcher at the University of Alaska Fairbanks.

White R. 2008 June 22. Alaskans learn how to make their own fuel: BIODIESEL: It's not easy, but the result is a $2 a gallon alternative. Anchorage Daily News. Anchorage, AK.

Two bucks a gallon to make your own biodiesel sounds like a bargain compared to $5 to pump a gallon of gas or heating oil. But operating a processing plant in your garage might be more of a hobby than you're willing to take on.

Sandi Wilson heats her Knik-Goose Bay home with heating oil. At about $5 a gallon for a 500-gallon tank, a full tank runs $2,500. Ouch. What's not to like about cutting that to $1,000?

So with that idea in mind, Wilson joined 18 other students for Will Taygan's Backyard Biodiesel class June 14 at the Spring Creek Farm north of Palmer.

BYPRODUCTS / WASTE – GENERAL

New group set up to add value to fish by-products in Ireland. 2003 Sep 16. Intrafish Media [Internet]. www.intrafish.no. Accessed 2008 Dec 11.

The Irish Sea Fisheries Board and the Irish Department of the Marine & Natural Resources, along with fish farmers and fish processors, formed a new group to help find uses for wastes and by-products from the fisheries and fish farming sectors. The group will have a finite duration and will produce a final report and recommendations.

Bradner T. 2005 March 13. Projects to put fish waste to good use explored. Alaska Journal of Commerce. http://alaskajournal.com. Accessed 2008 Nov 18.

Information from the state's first comprehensive review of salmon waste utilization - covering areas such as ocean disposal, new markets and products for human consumption, and industrial uses - has been released by the Juneau Economic Development Council.

"Normally, 50 percent of the fish harvested each year becomes waste and this becomes a big problem for processors. We wanted to see what could be done to create new products and reduce waste," said Lance Miller, JEDC executive director.

Cherry D. 2003 Dec 15. Asia presenting unique opportunities for salmon – skin, bones and all. Intrafish Media. www.intrafish.no. Accessed 2008 Dec 11.

The Norwegian Seafood Export Council's representative in Southeast Asia reports good opportunities for the use of full fish, including heads, bones, and tails. He also notes a shift from "wet" fish markets to supermarkets for sale of sushi products.

Goldhor S. 2006 Nov 1. Alaska's massive opportunity: fish waste. Seafood International [Internet]. www.seafood-international.com. Accessed 2008 Dec 15.

At present, an estimated 500,000 tonnes of waste from fish processing plants in Alaska are ground up and pumped annually into the Pacific Ocean. Susan Goldhor reports on the efforts being made to fully utilise the huge seafood catch of this vast US state.

Mutter R. 2004 Dec 1. Turning waste to wealth. Seafood International [Internet]. www.seafood-international.com. Accessed 2008 Dec 15.

The by-products from seafood processing are often viewed as "waste," but companies like Marine Harvest Ingredients are finding profitable ways of utilising material such as salmon oil and scrap meat. This issue of Seafood Processor looks at the development of by-product utilisation and the technologies and economics behind it.

On the same subject, we report on the results of recent trials of seafood waste composting and find that they have been so encouraging that the UK's Sea Fish Industry Authority is planning to run demonstrations on the various techniques involved.

Rozell N. 2008 Sept 21. Alaska fare from a northern science conference. The Fairbanks Daily News-Miner. www.newsminer.com. Accessed 2008 Dec 3.

Ted Wu of the USDA Agricultural Research Service at UAF has been gathering up fish guts and heads by the bucketful at Kodiak fish processors and bringing them back to Fairbanks. In the lab, he and his co-workers have ground up the heads and guts of salmon, and the bones, heads, skin, and guts of pollock. They have found that those byproducts of Alaska fisheries are rich in oils that are great sources of polyunsaturated fatty acids and fat-soluble vitamins. The oils, not widely exploited at the moment, could be used for human consumption (in pill form), animal feed, or possibly for biodiesel fuel.

Schmid C. 2003. Carcasses to cash. Juneau Empire. www.juneauempire.com. Accessed 2008 Nov 20.

Most people would be hard-pressed to say anything positive about the smell of decomposing fish carcasses. But some fishermen and processors in Southeast Alaska are learning to smell opportunity in them.

Salmon carcasses are what's left of the fish after processors turn the flesh into fillets or steaks.

Tournay B. 2007 Aug 1. Nordic partners progress functional products. Seafood International [Internet]. www.seafood-international.com. Accessed 2008 Dec 15.

> The Nordic Network for Marine Functional Food - known as Marifunc - is one of six Nordic functional food projects being sponsored by the Nordic Innovation Centre (NICe), based in Norway. Started in June 2006 and set to last two and a half years, the Marifunc network is made up of 13 partners from five Nordic countries - Norway, Denmark, Iceland, Sweden and Finland - and includes scientists from disciplines such as food technology, consumer science and nutrition as well as professionals from the fish processing and seafood ingredients industry.
>
> 'The functional food market has been booming for many years in Japan and the USA and is becoming more and more important in Europe, ' says Marifunc co-ordinator Dr Joop Luten of Fiskeriforskning in Tromso in Norway.
>
> 'Functional components derived from seafood such as polyunsaturated fatty acids (PUFAs), phospholipids, amino acids, peptides, fish hydrolysates, chondroin sulphate, chitosan, glucoseamine, pro-biotics and selenium have gained interest as having potential to be bioactive health-promoting ingredients. PUFAs, phospholipids, proteins, amino acids, peptides and selenium are present in the edible part of seafood while the other components such as chitosan, which comes from crustaceans shells, can be isolated or refined from fish by-products.'

FASHION / ACCESSORIES

Can I interest you in a salmon-skin kilt? 2003 Feb 23. Intrafish Media [Internet]. www.intrafish.no. Accessed 2008 Dec 11.

> A company is producing Scottish kilts from salmon skins. Company personnel hope that the new product will provide an economic boost to the salmon farming industry in Scotland.

Could the salmon skin’s catwalk success save fish farms from closure? 2003 Jul 14. Intrafish Media [Internet].www.intrafish.no. Accessed 2008 Dec 11.

> Salmon skin clothing is making progress in clothing design, with John Galliano selling salmon-skin shoes. The skins are sourced from a Scottish supplier. French fishermen are also tanning fish skins, and the United Nations Unesco program is developing a program with Senegalese fishermen.

Bates Q. 2004 Oct 1. Fish leather the latest Paris fashion. Seafood International [Internet]. www.seafood-international.com. Accessed 2008 Dec 15.

> Icelandic company Atlantic Leather has been developing a market for leather made from fish skins that have found its way to top Paris designers.
>
> Prada and Dior have both used fish leather from Atlantic Leather to produce handbags, and Pelicano has used it for jackets.

Chittenden M. 2003 July 13. Salmon skin is fashion’s latest leap. The Sunday Times: 9.

> IT sounds more high street than haute couture but salmon is the skin to be seen in this summer.

Just as orange is being touted as the new black, the shiny scales of cuir de mer (sea leather) is the latest alternative to crocodile and mink.

According to designers, it is tougher than cow hide and has a natural elasticity that returns clothes to their intended shape each time they are worn. Equally important, its smell, once processed, moves from Grimsby docks to Paris catwalk.

Fiorillo J. 2004 Apr 29. Value-added? Chilean company pushes salmon skin clothing line. Intrafish Media. www.intrafish.no. Accessed 2008 Dec 11.

A Chilean company is producing salmon-skin wallets, belts, shoes and handbags for sale in upscale European and Japanese markets. The products are being marketed as an ecologically sound alternative to other skin products.

Mete W. 2003 Dec 15. Kodiak wildlife biologist perfects system of tanning salmon skins. Alaska Journal of Commerce. http://alaskajournal.com. Accessed 2008 Nov 18.

Jeff Barnhart is a Kodiak wildlife biologist with a rather unusual sideline. As a teen, Barnhart tanned deer and cowhides into leather. He's still tanning hides today, only now he uses an entirely different medium.

Looking at the beautiful display of handcrafted leather wallets, checkbook covers and other accessories, all hand tooled down to the tiniest stitch, it's hard to reconcile these works of art with a smelly fish. So Barnhart understands when people seeing his products for the first time all share the same common reaction.

Siggins L. 2006 Jan 26. Turning fish skins into wallets. The Irish Times.

Biodiesel fuel from salmon oil, construction piping from mussel rafts, and even wallets from fish skin...just some of the conversions which Irish fish farmers hope to introduce under a new EU recycling initiative.

The "Aqua by-products" programme involves fish farmers from Ireland, Trondelag in the middle of Norway and Galicia in northwest Spain, and aims to foster co-operation on waste management solutions that may embrace the wider seafood industry. A new website has been set up in English, Spanish and Irish to share information on disposing of fishfarm by-products, underpinned by national and EU regulations.

Stiles H. 2002 Aug 31. Dahling, salmon is the new alligator. The Times (United Kingdom).

John Fitzgerald pulls on a pair of surgical gloves and says: "Tommy doesn't like me in his car if I've got fish all over my hands." Then he starts riffling through a large bin of fish offal, looking for the raw ingredients for his business, the Irish Salmon Skin Leather Company. Twice a week he and his tanning technician Tommy Ogara drive to Howth, a pretty fishing port outside Dublin, where farmed salmon from the west coast is processed.

"If the skins smell at all it would be too late to start tanning them, so as soon as the salmon come in the guys at the fish processing plant call us and we collect them." John stuffs handfuls of glistening silver skins into bin liners which Tommy places gingerly into the boot of his car.

Von Reppart-Bismarck J, Anthes E. 2003 July 9. New material scales heights of fashion: ‘leather’ from fish. Wall Street Journal – Eastern Edition. Accessed 2008 Dec 10.

> Reports on the increase in the demand for fish skin, which is being used in the fashion industry as an alternative for leather. Pascal Vuadelle's perfection of the art of tanning; Christian Dior designer John Galliano's creation of pink salmon-skin shoes; Skini's launch of a line of salmon-skin bikinis; Ocean Leather's offering of salmon-skin handbags.

FISH OIL / NUTRACEUTICALS

$12 million expansion for fish oil supplier Ocean Nutrition. 2008 Oct 22. Intrafish Media [Internet]. www.intrafish.no. Accessed 2008 Dec 10.

> Ocean Nutrition is expanding its capacity to produce its MEG-3 omega-3 products. The company says the expansion is in response to the “exponential growth in consumer demand for omega-3 food and supplement products.”

Another study show fish oil delays onset of Alzheimer’s. 2008 Jan 2. Seafood.com News [Internet]. www.seafoodnews.com. Accessed 2008 Dec 15.

> A daily dose of fish oil capsules could help prevent the development of Alzheimer's disease, according to research.
>
> Psychologists already know that the omega-3 fatty acids in fish oils boost intelligence.

Fish oil gets MSC eco-friendly certification. 2004 July 19. Intrafish Media [Internet]. www.intrafish.no. Accessed 2008 Dec 17.

> The Sockeye Salmon Oil Dietary Supplement being sold by Vital Choice Seafoods is produced from freshly caught wild sockeye salmon in Bristol Bay, Alaska. It is made in a dedicated processing facility and meets all of MSC's requirements for sustainable and well-managed fisheries.
>
> "We are using Alaska sockeye salmon in this product because it is the highest of all wild salmon in the powerful biological antioxidant, astaxanthin," said Vital Choice founder Randy Hartnell. "With this MSC labeled Vital Choice product, customers know the origin of the fish oil and are assured that it comes from abundant wild salmon stocks, a healthy habitat and a carefully managed fishery."

Fish oil seems to improve post-op recovery. 2008 Oct 14. Seafood News.com [Internet]. www.seafoodnews.com. Accessed 2008 Dec 17.

> Fish oil may speed the rate of recovery after surgery. Patients given daily spoonfuls of the oil for four days after major surgery had lower levels of inflammation, a study has shown.
>
> Patients also spent up to 25 per cent less time in intensive care if they were given this fish oil.

Krill, salmon get green light for calcium supplement. 2005 Sept 12. Intrafish Media [Internet]. www.intrafish.no. Accessed 2008 Dec 18.

Osteos21 Ltd. has received a patent to use krill and salmon processing byproducts to assist in calcium intake, which it says may help sufferers of osteoporosis.

The presence of polyunsaturated fatty acids, as well as proteins rich in proline and hidroxiproline, and the fluorine from krill, are fundamental in helping calcium deposition on bones, Dimitri Sclabos, co-owner of the company, told IntraFish.

Marine Harvest enters the fish oil business. 2005 Jun 23. Intrafish Media [Internet]. www.intrafish.no. Accessed 2008 Dec 10.

Marine Harvest, the world's largest salmon farming company, announced the launch of a new product, Xalar Salmon Oil, to meet growing demand.

Mothers who take fish oil in last trimester may reduce risk of child developing asthma. 2008 July 9. Seafood News.com [Internet]. www.seafoodnews.com. Accessed 2008 Dec 17.

Mothers who take fish oil supplements during the last trimester of their pregnancy could be reducing the risk of their child going on to develop asthma, claims a study published today in the American Journal of Clinical Nutrition (9th July, Volume 87, Issue 7).

The research, carried out by a team from Denmark as part of the EC-funded EARNEST project, traced the children born to mothers who had taken part in a trial conducted in1990. In this original trial, more than 500 pregnant women were randomised into three different groups for the last 10 weeks of their pregnancy.

Salmon oil: A secret weapon in the fight against violent crime. 2005 Dec 27. Intrafish Media [Internet]. www.intrafish.no. Accessed 2008 Dec 10.

Scientists treated offenders in prisons in American and British jails with compounds found in oily fish such as salmon. They found that the treatment could reduce their violent tendencies.

Why fish salmon is better than fish oil pills. 2008 Dec 10. Intrafish Media [Internet]. www.intrafish.no. Accessed 2008 Dec 10.

New Zealand scientists find that eating salmon provides benefits that are not available from fish oil supplements in capsule form. People who ate salmon had significantly higher levels of the anti-oxidant selenium in their blood than those who only took fish oil capsules.

Bauman M. 2007 June 10. Juneau firm aims to cash in on Alaska's salmon waste. Alaska Journal of Commerce. http://alaskajournal.com. Accessed 2008 Nov 18.

A salmon protein recovery venture, rooted in a fish processor's passion for fully utilizing the resource, plans to have a pure salmon oil soft gel for human consumption on the market by autumn.

The product, to be sold as Alaska Omega Pure, will be marketed over the Internet, through retail and wholesale outlets, said Sandro Lane, president of Alaska Protein Recovery LLC. It will be marketed as a less refined, more natural product, for those who care about such things.

Bauman M. 2008 April 13. Cold-pressed natural salmon oil soft gels hit market. Alaska Journal of Commerce. http://alaskajournal.com. Accessed 2008 Nov 18.

A Juneau processor that aims to fully utilize seafood resources has begun to market pure, cold-pressed wild Alaska salmon oil in soft gel capsules as a daily nutritional supplement.

The Pure Alaska Omega Natural Salmon Oil is the product of Sandro Lane's Alaska Protein Recovery LLC. The product is packaged in bottles of 90, which cost $22, or the $36 bottle of 180 soft gels.

Browning J. 2008 Nov. Wringing every cent from salmon. National Fisherman. Portland: (89)7:43-44.

The market for human consumption grade salmon oil is growing dramatically, along with its wholesale value. The foundation is partnering with Subramaniam Sathivel, formerly of the Fishery Industrial Technology Center in Kodiak, now with Louisiana State University Agricultural Center and the Kodiak Fishmeal Co., to investigate adsorption technology to extract human consumption-grade salmon oil.

Bowden R. 2008 Sep 1. Fish oil found to protect against heart disease. The Tech Herald. www.thetechherald.com. Accessed 2008 Dec 10.

An Italian study finds that daily dosages of omega-3 polyunsaturated fish oil help reduce mortality and hospitalization for cardiovascular reasons.

Cherry D. 2006 June 1. Get in on the fish oil boom. Intrafish Media. www.intrafish.no. Accessed 2008 Dec 10.

Fish oil demand is increasing. The market for supplements topped $300 million in the US in 2005. The author explores whether firms should enter the fish oil market.

Stromsta K-E. 2008 July 30. Consumption fueling sky-high fish oil prices. Intrafish Media. www.intrafish.no. Accessed 2008 Dec 10.

Demand for omega-3 oils for human consumption is driving prices to record levels. The market demand for human-grade fish oil is reducing the amount of fish oil available to fish farmers, who have been the customary users of the product. Some regulatory changes may impact the market, but the author suggests the strong price trend may continue.

Welch L 2004 Aug 6. Oil from Bristol Bay Salmon good for you and the planet. Alaska Journal of Commerce. http://alaskajournal.com. Accessed 2008 Nov 18.

Fish oil supplements made from Bristol Bay sockeye salmon are the world's first non-food item to gain an eco-label from the Marine Stewardship Council. The sockeye salmon oil product was launched just last month by a company called Vital Choice, founded by former Bristol Bay fisherman, Randy Hartnell. "Most consumers who are interested in health are also interested in the health of the planet," he said in a phone interview.

The international MSC aims to harness customer preference for seafood products that come from fisheries that are well managed and friendly to the environment. All five

species of Alaska salmon were the first fisheries to get the MSC "green" label four years ago.

FISH MEAL

‘Responsible’ fishmeal certification trials under way. 2008 Dec 5. Intrafish Media [Internet]. www.intrafish.no. Accessed 2008 Dec 10.

The International Fishmeal and Fish Oil Organization (IFFO) has partnered with U.K. retailer Tesco, aquaculture feed manufacturers and environmental groups to begin development of a Code of Responsible Practice. The group hopes to develop a certification scheme to audit fishmeal used in aquaculture feed. A trial audit is presently underway to test the certification scheme.

Salmon Oil to use salmon farm waste to make fishmeal and oil. 2004 Nov 10. Intrafish Media [Internet]. www.intrafish.no. Accessed 2008 Dec 10.

Chilean-owned Salmon Oil has constructed a new salmon waste fishmeal and fish oil plant. The project will use salmon waste to produce its products. The products will be used in paint and pet food industries.

Robinson, Steve. 2008 Nov 26. Aquaculture to dominate fishmeal use by 2013. Intrafish Media. www.intrafish.no. Accessed 2008 Dec 10.

Aquaculture feed is expected to account for 66% of total world fishmeal use by 2013, according to forecasts by the International Fishmeal and Fish Oil Organization. New premium niche fishmeals and oils could be part of changing trends.

Welch L. 2005 March 20. Kodiak scientists work to make fish meal out of other fish. Alaska Journal of Commerce. http://alaskajournal.com. Accessed 2008 Nov 18.

For years scientists at the Fishery Industrial Technology Center in Kodiak and others have been looking at ways to find value in byproducts of seafood processing. By some estimates, as much as 40 percent of Alaska's fish and shellfish catches (roughly 1.5 million tons) are thrown away each year instead of being turned into other useful products.

One promising new project stems from dried fish testicles used in feeds. "It turns out that some factors found in testes can apparently assist fish in strengthening their immune systems to resist viral challenges," said Scott Smiley, director of the University of Alaska's Fishery Industrial Technology Center, or Fish Tech. He said researchers originally planned to experiment with cod testes, but there was no market, so instead they switched to pink salmon and pollock gonads.

OTHER MEDICAL USES

Ditch the itch with fish. 2008 Sept. Better Nutrition 70(9):12.

Supplementing with the omega-3 fatty acid DHA (docosahexaenoic acid), which is found primarily in certain fish, helps relieve eczema symptoms, a new study finds. Published in the British Journal of Dermatology, the study focused on 44 adults with eczema who were given either 5.35 g of DHA or a placebo daily for eight weeks. Over the course of the study, symptoms improved only in those using DHA. Bump up

your diet with DHA-rich, cold-water fish, such as salmon, tuna, mackerel, sardines, and herring, and consider adding a fish oil supplement (about 2 teaspoons per day) to your regimen. Evening primrose oil, which is rich in anti-inflammatory omega-6 fatty acids, has also been shown to help ease symptoms of eczema.

Dry-eye defense. 2005 Sept. Natural Health 35(8):20.

The article presents information on precautions for preventing dry eye syndromes. Parched peepers may be a natural byproduct of aging, especially for women. But anything that further lessens the production of tears can lead to a burning, gritty, something's-in-your-eye feeling. Triggers range from long-term contact lens wear and LASIK surgery to high blood pressure to rheumatoid arthritis. Researchers at Harvard Medical School found that omega-3 fatty acids are beneficial for preventing dry eye. Diet can also help.

Omega-3s greatly reduces sudden cardiac death – Study. 2005 Feb 28. Intrafish Media [Internet]. www.intrafish.no. Accessed 2008 Dec 18.

Omega-3's are commonly found in oily fish such as herring, mackerel, sardines and salmon and are contained in cod liver oil capsules, tuna oil used in processed food, certain bread types as well as salmon oil health supplements.

Researchers found that sudden cardiac death decreased by as much as 50 percent in people with a modest dietary intake of omega-3 fatty acids from fish rich in EPA and DHA.

Salmon skins could aid drug research 2004 Oct.. Alaska 70(8):21.

Reports on the potential use of skins of Alaska salmon for research of heparin, a natural product available by prescription. Use of heparin to dissolve or prevent formation of blood clots; Extraction of heparin from skins of cod, tuna and grouper through a hydrolysis process; Federal grant received by research chemist Erwin Coyne at Loyola University Medical Center to study the content and potential of heparin in tuna and salmon.

Lantin B. Seafood News.com [Internet]. 2008 April 8. Anecdotal evidence suggests fish oil may help autism.

The American Psychiatric Association has said that patients with mood disorders should consume at least 1g a day of the fatty acids EPA and DHA, found in oily fish. In February, a study in the Australian and New Zealand Journal of Psychiatry showed that the omega 3 fatty acid EPA was as effective as Prozac at controlling symptoms of depression and that EPA and Prozac together were more effective than either taken alone.

There has been less research on fatty acids and autistic spectrum disorders but small trials suggest fatty acid supplements can reduce hyperactivity and improve language skills in autistic children.

'Scientific evidence suggests imbalances or deficiencies of certain fatty acids may contribute to a range of behavioural and learning difficulties including ADHD, dyslexia, dyspraxia, and autistic spectrum disorders, ' says Dr Alex Richardson, director of Food And Behaviour Research, a charity that investigates the links between nutrition and behaviour.

Welch L. 2004 May 10. Alaska is sitting on “a gold mine for pharmaceuticals” from salmon hydrolysates, says researcher. Seafood.com News [Internet]. www.seafoodnews.com. Accessed 2008 Dec 15.

> Thanks to a Cordova fisherman, salmon skins could soon prove to be a prime source for a life saving product called heparin. Heparin is a natural product, available by prescription, which is used to dissolve or prevent formation of blood clots after surgery and in other settings.
>
> Using a hydrolysis process, scientists have extracted heparin in skins from cod, tuna, grouper and soon – Alaska salmon. That exciting prospect is based on early work by Erwin Coyne, a research chemist at Loyola University Medical Center and the Hines Veterans Administration Hospital. Using a small sample from skin taken from a side of Copper River salmon his wife found at an Illinois supermarket, Coyne's analysis (using a process called NMR, or nuclear magnetic resonance) revealed the presence of heparin.

Welch L. 2004 May 17. Early tests show that Alaska salmon skins could become life-savers. Alaska Journal of Commerce. http://alaskajournal.com. Accessed 2008 Nov 18.

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OTHER

China Marine Food Group earns government award for collagen recovery from byproducts. 2008 June 20. Seafood.com News [Internet]. www.seafoodnews.com. Accessed 2008 Dec 20.

> China Marine Food Group Ltd. (OTC Bulletin Board: CMFO), a China-based processor and distributor of fresh and processed seafood products, announced it received approval to list its fish by-product recycling project in China's National Spark Program and received funding of 400,000 RMB (approximately US$58,000) from China's Ministry of Science and Technology.
>
> China's National Spark Program is aimed at popularizing modern technology in rural areas. The program started in 1986 and focuses on the agricultural sector.

Converted Organics gains Washington state organic certification for Pacific Choice fish hydrolysate. 2008 Aug 6. Seafood.com News [Internet]. www.seafoodnews.com. Accessed 2008 Dec 16.

Converted Organics Inc. (NASDAQ:COIN) announced that, on July 8, the Company received certification from the Washington State Department of Agriculture's (WSDA) Organic Food Program for its Pacific Choice(TM) Hydrolyzed Fish fertilizer for use in organic agriculture.

Pacific Choice(TM) Hydrolyzed Fish is an all-natural fertilizer whose nutrients are derived from the by-products of oceangoing fish and stabilized with phosphoric acid. Converted Organics developed the product in partnership with Pacific Choice Seafood, a Pacific Seafood Group company.

Container cuts fish oil costs. 2004 Apr 1. Seafood International [Internet]. www.seafood-international.com. Accessed 2008 Dec 15.

Alaska's Westward Seafoods has significantly reduced its operating costs by changing the intermediate bulk container (IBC) in which its fish oil by-product is shipped.

Strapping costs have been cut by at least 40%, spillage by 25% and handling time by more than 25%. The new IBCs can also be stacked higher so that 24 totes are loaded per seatainer compared with 18 before.

Says Butch Brown, Westward Seafoods' fishmeal plant supervisor: “The 260 gallon (1,182 litre) Weyerhaeuser's SpaceKraft corrugated containers we are now using have really raised our productivity and made our work easier. The tote is easier to handle, quicker to fill and safer than the previous brand IBC.”

Eyeing non-food growth. 2007 Jan 1. Seafood International [Internet]. www.seafood-international.com. Accessed 2008 Dec 15.

EFFORTS to rebuild South Korea's seafood industry include a broad range of scientific and technological initiatives far beyond the usual steps taken to revive depleted capture fisheries.

Besides reviving domestic production, South Korean research is developing a range of nutriceutical health and beauty aids now on the market and the more distant possibility of cures for cancer, Alzheimer's disease and arthritis.

Recovers edible meat from backbones. 2005 Apr 1. Seafood International [Internet]. www.seafood-international.com. Accessed 2008 Dec 15.

DENMARK'S Uni-Food Technic (UFT) will be featuring at least two new processing machines at SPE 2005 - its Model SP50 salmon scraping machine for backbones and the Model 1400-H pinbone remover.

UFT's newest processing machine, the SP50, is designed to recover edible meat from salmon backbones.

It was developed at the request of customers to meet the increasing focus in the salmon industry on maximising yield.

Bauman M. 2007 April 22. Stalwart in the pet business, Alaska Mill and Feed, continues to grow. Alaska Journal of Commerce. http://alaskajournal.com. Accessed 2008 Nov 18.

Amid growing competition among purveyors of pet products, Anchorage old-timer Alaska Mill and Feed is not only keeping its stride, it's expanding to meet increasing customer needs.

Like its main competitors, national chain Petco and Alaska-owned Sunny Day Distributing LLC, Alaska Mill and Feed offers a variety of pet foods and equipment, ranging from kibble and kennels to shampoos, cleaning products and toys.

Bauman M. 2008 Feb 17. Alaska salmon treats bark up yummy sales. Alaska Journal of Commerce. http://alaskajournal.com. Accessed 2008 Nov 18.

Brett Gibson's salmon is going to the dogs - in neat little bite-sized treats. The Arctic Paws owner, and pups across the country, couldn't be happier.

In 2008, Gibson hopes to purchase up to 1.5 million pounds of wild Alaska salmon for production of his high-protein Yummy Chummies canine treats, now selling at supermarkets and pet stores in a growing number of stores throughout North America.

DeSantis J. 2003 Aug. Starlets' lips may shine with processing byproducts. National Fisherman. Portland: 84(4):16.

Louisiana State University researchers are perfecting a process of using marine by-products to manufacture collagen, and for other cosmetics use. That process could help generate fishing industry profits.

"We can make the world prettier with fish waste," says Mark Schexnayder, fisheries agent with the university's Cooperative Extension Service.

Loomis B. 2007 March 29. EPA fine spurs compost plan for fish plant. Anchorage Daily News. www.adn.com. Accessed 2008 Nov 28.

A fish processor who acknowledged waste-handling violations knocked about $27,000 off of its federal fine by setting up a composting company that other Kenai Peninsula processors may use to turn carcasses into fertilizer and erosion-control products.

The U.S. Environmental Protection Agency announced Monday that Snug Harbor Seafoods, at the mouth of the Kenai River, would pay $8,016 for violations including failing to grind fish waste into half-inch pieces before discharging into the plant's tidal area. The fines would have totaled about $35,000 if not for a pollution-prevention program that Snug Harbor's owners are calling "Fish and Chips."

Rozell N. 2008 Oct 25. Taste tests may spur more oil in pink salmon cans. Anchorage Daily News. www.adn.com. Accessed 2008 Nov 28.

A steady flow of twenty-somethings wearing jeans and backpacks entered a room that smelled slightly of fish. They sat down in front of paper plates holding three helpings of pink salmon. The crowd -- mostly college students -- had responded to a sign outside: "Do you like to eat fish?"

About 120 people sat down that day at the University of Alaska Fairbanks to rate Alaska pink salmon on such features as saltiness, texture, fattiness and fish flavor.

Perhaps lured by the reward of a few cookies, those fish tasters were helping Trina Lapis earn her degree.

Tkacz B. 2002 Sept 16. Kake profits from salmon, sawdust. Alaska Journal of Commerce. http://alaskajournal.com. Accessed 2008 Nov 18.

Combining two waste products commonly produces more waste, but a Southeast Alaska Native village corporation is mixing salmon and wood waste to produce business profits and a national award.

Kake Foods Inc., a wholly-owned subsidiary of the Kake Tribal Corp., is using all the salmon gurry, unmarketable chum carcasses and other seafood processing waste it can collect, along with a virtually unlimited supply of sawdust and other logging leftovers to produce "Alaska Thunder Dirt," a high quality compost.

Welch L. 2004 Sept 20. Entrepreneur lets pets join people in enjoying Alaska salmon. Alaska Journal of Commerce. http://alaskajournal.com. Accessed 2008 Nov 18.

Pet treats made from Alaska salmon are making big inroads into some major market outlets.

Since 1997, a small Anchorage business called Arctic Paws has been turning out Yummy Chummies - pet treats that dogs and cats find irresistible. Owner Brett Gibson said the company now purchases roughly 400,000 pounds of roe stripped salmon (up from 8,000 just a few years ago), which produces 20,000 pounds of finished product per month. Arctic Paws has moved into a larger facility and purchased more equipment to keep pace with demand.

Welch L. 2006 June 11. Seafood industry looks to reach the youngest customers. Alaska Journal of Commerce. http://alaskajournal.com. Accessed 2008 Nov 18.

Cruise the baby food aisles of any American supermarket and you'll see jars of beef, chicken, lamb, eggs - every kind of protein except fish. That could soon change if an initiative by Alaska food scientists and the seafood industry is successful.

Fueled by $443,000 in federal funding from the Alaska Fisheries Development Foundation, a project is underway at the University of Alaska Fisheries Industrial Technology Center in Kodiak to create baby food made from salmon. AFDF is an industry based nonprofit created in 1978 to help provide a bridge between research and the marketplace.

Wray T. 2004 Dec 1. Composting seafood: Compositing – Encouraged by results from seafood composting trials, the UK’s Sea Fish Industry Authority is planning to run a series of demonstrations. Seafood International [Internet]. www.seafood-international.com Accessed 2008 Dec 15.

'Waste from fish processing is so rich in minerals that it can be extremely good material for composting for which there is a large and increasing market, ' the UK's Seafood Industry Authority's (Seafish) fish technologist Michaela Archer tells Seafood Processor.

'Our first commercial seafood composting project will probably be in north-west England and, once this gets up and running, we intend to run demonstrations in other regions of the UK.