SEAFOOD^{TOMORROW}

Nutritious, safe and sustainable seafood for consumers of tomorrow

Grant agreement no: 773400

Deliverable D3.6

Scientific package to support WP6

(Layman's report - health benefits for consumers

From selected ECO-INNOVATIVE SOLUTIONS developed by SEAFOOD^{TOMORROW})

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1. Summary

This deliverable intends to translate in layman's language the scientific outcomes of selected SEAFOOD[TOMORROW] econnovative solutions, in regard of their favorable impact on human health.
The favorable impact on health maintenance and promotion can be estimated in terms of increased contents of nutrients (improved nutritional status) and/or reduction of contaminants (reduced hazards), giving special attention to population groups that have enhanced nutritional needs and/or higher vulnerability to pollutants: pregnant women, children and the elderly. The measure of the impact could be viewed in comparison with “business as usual”, i.e., the current fish/seafood products without the ecoinnovative solution.
The selected ecoinnovative solutions are
- Fortified feed for farmed fish (goal: contents of essential nutrients and toxic metals)
- Use of macroalgae in sustainable fish production (implement integrated multi-trophic aquaculture -IMTA- without increasing hazards)
- Reduction of sodium intake (goal: reduced salt use in preserved fish products without risks for hygiene and shelf-life)
- Production of fish recipes for target consumer’s groups (goal: contents of essential trace elements and toxic
The eco-innovative solutions considered elicited nutrient enrichments and reductions of hazards that have the potential to favourably affect the nutritional status and health maintenance of the general consumer and, in particular, of specific groups, such as:
- fish farmed by biofortified feeds can favourably affect pregnant women and their unborn children as well as children by increasing, e.g., the intake of iodine and selenium as well as the elderly, e.g., by increasing the intake of selenium and reducing the intake of cadmium;
- IMTA may increase the sustainability and efficiency of fish farming, without any increase of toxic hazards;
- the prototype salmon pâté and smoked salmon show that the nutritional profile of highly-consumed preserved fish products can be improved through a 25% reduction of sodium content (a recognized risk factor for hypertension) without any adverse side effects on the hygiene, taste or shelf-life;
- the recipes tailored to specific population groups may support the maintenance and promotion of health, e.g. through the enrichment in Calcium achieved for products tailored to children and pregnant women, as well as the general reduction achieved in the content of Mercury, the main toxicant associated with fish/seafood consumption.
The actual benefits to consumer’s health will obviously depend on the amount and patterns of consumption of the fish/seafood from the eco-innovative solutions.
Proper communication to the general public of benefits achievable through SEAFOOD[TOMORROW] eco-innovative solutions will support the empowerment of EU citizens towards healthy and sustainable dietary choices.

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2. Objectives

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- Production of fish recipes for target consumer's groups (goal: contents of essential trace elements and toxic metals)

3. Fortified feed for farmed fish (Task 1.1)

3.1. The eco-innovative solution

Developing tailor-made fortified farmed fish is a promising solution to overcome nutritional deficiencies and increase consumer confidence in these products.
SEAFOOD[TOMORROW] explored the supplementation of fortified diets with Iodine (I)-rich seaweed, omega-3-rich seaweed and Selenium(Se)-enriched yeast in order to see whether the biofortification with essential nutrients:

a) led to an effective enrichment of fish flesh in edible species with different nutritional and physiological characteristics;

b) had any undesirable side-effect on levels of toxic contaminants in the fish flesh.

The eco-innovative solution fortified feed has been applied to three farmed fish species:
Rainbow trout – *Oncorhynchus mykiss*
Seabream – *Sparus aurata,* and
Carp – *Cyprinus carpio*)

3.2. Effects on the contents of relevant nutrients

- An increase in iodine content, compared to control diet, was observed with the magnitude order of 100-fold in *trout*, 10-fold in *carp*, 2-fold in seabream.

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Sub-clinical iodine deficiency is still a widespread problem in Europe, leading to increased susceptibility to thyroid insufficiency.
Within a balanced and varied diet, seafood (saltwater fish) is a major source of iodine for the general population. The results of the eco-innovative solution make it possible that freshwater farmed fish, such as trout and carp, become a source of iodine as well

- An increase in selenium content in the order of + 50% in sea bream and carp.

Fish features among the dietary sources of selenium. While toxic at excess intakes, Selenium is an essential trace element needed in particular for the antioxidant defences of the organism (thus, in order to cope with aging, toxicant exposures etc.) as well as to support the thyroid action.
The results suggest that the eco-innovative solution may enrich the Selenium content of fish flesh, without any excessive increase of potential concern.

- An increase in the content of "Omega 3" polyunsaturated fatty acids (PUFAs) EPA and DHA in the order of 5-fold (EPA) and 4-fold (DHA) in the carp.

Omega 3 PUFAs feature among the main nutritional benefits of fish (especially seafood) intake within a balanced and varied diet; in particular, they are essential for neurodevelopment during fetal life and up to 2 years of age as well as for cardiovascular health in adults.
While the results indicate that feed fortification may elicit different effects in different fish, it is noteworthy the significant enrichment of PUFA content in the carp flesh, because carp has a low PUFA content.

3.3. Effects on the contents of relevant contaminants

The eco-innovative solution did not have major undesirable side-effects on contaminant content.

- Mercury, in form of methylmercury, is a pollutant of major concern, in particular for developmental neurotoxicity. Seafood is the only source of methylmercury in human diet, and fish, in particular is the utmost source.

Mercury was unaltered in *trout*, showed a -10% decrease in fortified *sea bream*, while it showed a + 60% increase in *carp*.
While the finding in carp suggests that the use of fortified feed should be monitored, carp (herbivorous species) has a low mercury content compared to omnivorous or predator species such as trout and sea bream, which represent the main concern in regard of human intake. Actually the "increased" mercury content of the fortified carp was still less than 50% compared to the content of sea bream.

- The content of inorganic arsenic was consistently low, as expected, and did not show main changes.

In fish inorganic arsenic is naturally metabolized to organic compounds of low or very low toxicity; the fortified feed provided by the eco-innovative solutions.

- Some noticeable, and favourable, changes were observed with two other main heavy metals:

Cadmium showed a 9-fold decrease in *trout* and a 2-fold decrease in *seabream.*
Lead showed a 3-fold decrease in *trout.*
Besides being potential carcinogens, these two heavy metals elicit substantial health concerns for neurotoxicity (lead in children) and nephrotoxicity (cadmium) at the current intake levels in the EU population.

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Fish is not the main source of cadmium and Lead in the diet, compared to foods of vegetable origin. Nevertheless, fish farming by the eco-innovative regimen may further increase the safety of farmed fish and consumer confidence in farmed fish being a clean food; this holds especially true considering the enrichment observed in protective nutrients such as iodine and selenium.

3.4. General comment

The eco-innovative solution elicited nutrient enrichments and reductions of contaminants to a variable extent in three biologically different species of farmed fish:
Trout (carnivorous, freshwater): increased iodine, reduced lead and cadmium
Sea bream (partly carnivorous, saltwater): increased iodine and selenium, reduced cadmium
Carp (herbivorous, freshwater): increased iodine, selenium and PUFA
The beneficial impact on consumer's health due to such changes in terms of fulfilling nutritional requirements and/or reducing toxicant exposures, will depend on:

- the amount of farmed fish consumed in the diet
- the fish species making up the intake of farmed fish

Thus, a differential impact is expected in different Countries, and possibly even in different regions of the same Country.
In the meanwhile, the results of the eco-innovative solution "fortified feeds" have a remarkable potential beneficial impact on subsets of population that are vulnerable to nutritional and/or environmental hazards, in particular:

- pregnant women and their unborn children: increased iodine (trot, seabream, carp), increased PUFA (carp), reduced lead (trout);
- toddlers and children up to 10 years: increased iodine (trot, seabream, carp), increased selenium (sea bream, carp), increased PUFA (carp), reduced lead (trout);
- elderly (65 years and more): increased selenium (sea bream, carp), increased PUFA (carp), reduced cadmium (trout, seabream).

4. Use of macroalgae in sustainable fish production (Task 1.3)

4.1. The eco-innovative solution

Introduction of integrated multi-trophic aquaculture (IMTA) with seaweed at a site with salmon or trout may bring a number of benefits from several standpoints: environment (enhanced water quality), food security (increased production of biomass at a site) and economy (better utilization of production area).
In the meanwhile, the challenge is to assess whether the IMTA might bring any adverse impact on food safety, in particular by increasing the concentrations of toxic pollutants.
The IMTA developed within SEAFOOD[TOMORROW] is based on a system where the brown algae *Saccharina latissima* is grown in close vicinity of commercial salmonid fish farms, where fish is kept in cages in the sea for up to 21 months with a gradual take out of fish biomass from month 12-14.

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Selected toxic pollutants were heavy metals and polybrominated diphenyl ethers (PBDE). PBDE, formerly used as flame retardants, are widespread pollutants, persistent and fat-soluble, that bioaccumulate in fish (especially fatty species like salmon) and may exert endocrine disrupting effects in humans.
The studies show that an optimized configuration of IMTA sites where seaweed is grown close to salmon cages is achievable, if the features of the specific site are taken into account. The same consideration applies to seaweed production and quality. For instance, the direction of water current at a site modulates the utilization of dissolved waste from fish production to fertilize seaweed production.
Fish health and welfare are not adversely affected by the integrated fish and seaweed production, as compared to the "business-as-usual" (monoculture fish production), meaning also that the innovative solution does not increase the need for the possible use of drugs and disinfectants against fish pathogens and parasites.
The IMTA produced salmon showed no increase in the content of PBDEs and heavy metals of potential relevance for the safety of fish consumers, such as cadmium, lead, mercury and inorganic arsenic. Indeed, the content of PBDEs was found to be below the analytical detection limit.

4.2. General comment

By carefully taking into account site-specific conditions, IMTA can increase the site's sustainability and efficiency, without bringing any hazard (toxic pollutants or increased use of aquaculture drugs/disinfectants) to health of consumers in comparison to the "business as usual".

5. Reduction of sodium intake (Task 2.1)

5.1. The eco-innovative solution

Preserved fish products, besides being an important marketable good, are a valuable source of proteins, trace nutrients and omega-3 fatty acids (in particular salmon).
However, preserved fish products require high salt level in order to guarantee both hygiene, by preventing the growth of noxious microbes, and shelf-life. Thus, these products are a source of sodium in our diet. High dietary sodium is a recognized risk factor for hypertension, which -in its turn- is an early step in the path toward cardiovascular disease.
The challenge is to reduce sodium level without compromising hygiene or shelf-life.
SEAFOOD TOMORROW has produced two seafood products with a sodium reduction of at least 25 %:
a) salmon pâté
b) smoked salmon.

a) In order to make the innovative salmon pâté, the common table salt (ie., sodium chloride) was replaced with Saltwell, a natural salt originating from the Chilean desert. Saltwell is a mixture of sodium chloride and potassium chloride: the sodium content is 35 % lower than in sodium chloride compared to table salt.

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Analysis of microbiological content and taste showed that it is possible to replace 90% of table salt by Saltwell without an increase in microbial activity and without appreciable alterations of the taste within the expected shelf life of eight weeks.. With this level of replacement the achieved reduction of sodium intake is still in the order of at least 25%.

b) In order to make the innovative smoked salmon, the table salt was parly replaced by potassium chloride food grade (25% and 50%). The salt substitution was combined with four smoking treatments (cold smoking and natural wood, cold smoking with liquid smoke, hot smoking and natural wood, hot smoking with liquid smoke). Analyses and tests indicate that a 25% substitution, bringing a corresponding reduction of sodium content, has no adverse impact on hygiene nor on taste after the expected three weeks of storage . While the smoking treatments showed differences in the colour and taste of producs, the favorable effect of the 25 % replacement of table salt is evident with each treatment.

5.2. General comment

The two prototypes elaborated within SEAFOOD[TOMORROW], salmon pâté and smoked salmon, show that it is achievable and affordable to improve the nutritional profile of highly-consumed preserved fish products through a partial replacement of table salt and the consequent 25% reduction of sodium content. The eco-innovative solutions had no adverse side effects on the hygiene, taste or shelf-life of the products, showing a highly favourable balance between the nutritional benefit and any potential risk for safety or quality. In addition, because of the nature of the product, the salmon pâté could undertake rapid degradation leading to a unsafe product in case of microbial contamination, The work developed in Task 3.4 has proposed an alternative formulation in order to improve the safety toward potential hazards related to bacteria.

6. Production of fish recipes for target consumer's group (Task 2.2)

6.1. The eco-innovative solution

In the majority cases fishes and seafood are not eaten as such, but are consumed within recipes. These recipes can be made at home, consumed in a restaurant or marketed as ready-to-eat. While most people are fond of tasty fish and seafood dishes, there is a main question concerning consumer's safety: how to prepare recipes that improve the nutritional quality of fish/seafood meals and in the meanwhile do not bring an increased content of toxic contaminants?

SEAFOOD[TOMORROW] (work still in progress) develops semi-industrial recipes for three common edible fish/seafood species that are employed in the industrial ready-to-eat products. Some of the products are specifically tailored to meet the nutrition/food safety needs of consumer groups:

Mussel (*Mytilus edulis)* – recipe developed is Mussel soup for seniors

Blue Whiting (*Micromesistius potassou*) - recipes developed are Fishballs with vegetables and sauce for children, and Fish roulade for pregnant women.

Carp (*Cyprinus carpio*) – recipe developed is Fish sausage with vegetables for children

Pouting (*Trysopterus luscus*) – recipe developed is Fishballs with puree for children

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The fish fillets or the whole edible seafood (for mussel) were considered as "*business as usual*" to compare the effects of recipes on the contents of chemical elements with essential nutritional role or toxic effects
The *essential nutrients* considered were: Calcium (Ca), Copper (Cu), Iodine (I), Iron (Fe), Zinc (Zn).
The *toxic pollutants* considered were: Arsenic (As), Lead (Pb), Mercury (Hg).
Favorable effects on nutrient and contaminant contents were observed for all recipes in comparison with the respective "business as usual", namely:

Mussel soup for seniors: reduction by more than 95% of Hg, 90% of Pb, and 67 % of As;

Blue Whiting Fishballs with vegetables and sauce for children: enrichment in I by 5-fold, Fe by 4-fold, Ca by 2-fold, Cu by 2-fold and Zn by 1,5-fold, reduction of Hg by 67 %;

Blue Whiting Fish roulade for pregnant women: enrichment in I by 7-fold, Ca by 1.9-fold and Zn by 1,8-fold, reduction of Hg by 75 %;

Carp Fish sausage with vegetables for children: enrichment in Ca, Cu and and Zn by 1,8-1.6-fold, reduction of Hg by 50 %;

Pouting Fishball with puree for children: enrichment in Cu by 5-fold, Fe by 4-fold and Ca by 1,8-fold, reduction of Hg by 80 %.

Overall:

- Ca was enriched in children-tailored recipes Blue Whiting Fishballs, Carp Fish sausage, Pouting Fishballs and in Blue Whiting Fish roulade for pregnant women;
- Cu in children-tailored recipes Blue Whiting Fishballs, Carp Fish sausage, Pouting Fishball;
- Fe in children-tailored recipes Blue Whiting Fishballs and Pouting Fishball;
- I in both Blue Whiting recipes, Fishballs for children and Fish roulade for pregnant women;
- Zn in children-tailored recipes Blue Whiting Fishballs and Pouting Fishballs, and Fish roulade for pregnant women;
- Hg was reduced in all recipes.

6.2. General comment

Recipes developed within SEAFOOD TOMORROW and tailored to specific population group may increase the potential for fish and seafood to provide a nutrient-rich and safe contribution to the diet of EU citizems and beyond.
Of special interest for health maintenance and promotion are: the general enrichment in calcium obtained in all fish-based products for children and pregnat women, as Ca is essential for bone health and neuromuscular function; the marked enrichments in iodine (needed for thyroid function, hence for pre- and post-natal development) achieved in the Blue Whiting recipes for children and pregnant women; the general reduction achieved in the content of mercury: most, or all, Hg present in fish and seafood is Methylmercury, which is able to damage the developing brain as well as to alter blood pressure and immune function.
Thus, recipes that reduce Hg levels are of interest for diet of pregnant women, children and the elderly.

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7. Conclusions

The eco-innovative solutions considered elicited nutrient enrichments and reductions of hazards that have the potential to favourably affect the nutritional status and health maintenance of the general consumer and, in particular, of specific groups.

As main examples:

- Fish farmed by biofortified feeds can favourably affect pregnant women and their unborn children as well as children by increasing, e.g., the intake of iodine and selenium as well as the elderly, e.g., by increasing the intake of selenium and reducing the intake of cadmium;
- IMTA may increase the sustainability and efficiency of fish farming, without any increase of toxic hazards; the prototype salmon pâté and smoked salmon show that the nutritional profile of highly-consumed preserved fish products can be improved through a 25% reduction of sodium content (a recognized risk factor for hypertension) without any adverse side effects on the hygiene, taste or shelf-life;
- The recipes developed within SEAFOOD[TOMORROW] and tailored to specific population groups may support the maintenance and promotion of health, e.g. through the enrichment in Calcium achieved for products tailored to children and pregnant women, as well as the general reduction achieved in the content of Mercury, the main toxicant associated with fish/seafood consumption.

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