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Benefit and risk assessment of replacing of sodium chloride by other salt/substances in industrial seafood products

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Abstract

Sodium (Na) is primarily consumed as salt (sodium chloride, NaCl), which is a critical food ingredient that contributes to improve preservation, shelf-life and sensory attributes (e.g. texture and taste). On the other hand, the excessive Na intake is a risk factor for cardiovascular diseases including stroke and heart diseases. The actual NaCl intake in most countries is far above recommended level of 5 g NaCl/day. Therefore, the reduction of NaCl is among top priorities for health authorities around the globe and the World Health Organization (WHO) adopted a strategy to reduce NaCl intake by 30% until 2025. Integral part of the reduction strategy is to limit NaCl intake from seafood, which is especially relevant for regions with a significant fish and shellfish consumption. The purpose of the project was to (i) review the current situation of relevant strategies to reducing NaCl content in seafood (literature review), (ii) assess benefit/risk of NaCl replacement with other substances/ingredients in seafood and (iii) disseminate results obtained. In the first phase of the project, the literature review was performed and the review paper was prepared. The second part of the project was focused on the experimental studies on smoked trout which commercially available products can deliver up to 4 g NaCl in 100 g. The aim of this study was to optimise the development process of smoked trout with reduced NaCl content without compromising quality and safety attributes. Another part of the project was related to the dissemination of results which resulted in the preparation of three conference abstracts and two experimental papers.

Keywords: salt reduction, sodium chloride (NaCl), potassium chloride (KCl), seafood, fish, trout

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1. Introduction

Reducing **salt (sodium chloride, NaCl)** intake has been identified as one of the most cost-effective measures that can be taken to improve the health of worldwide population (WHO, 2020). The excessive NaCl intake is linked with cardiovascular diseases such as stroke or heart disease (Strazzullo et al., 2009). It is estimated that reaching a global target of a 30% reduction in salt intake by 2025 (compared to 2010 levels) would save about 40 million lives over 30 years (WHO, 2012). The recommended daily intake is 5 g NaCl but the actual intake in Europe is two to three times higher (EFSA, 2019) (Figure 1).

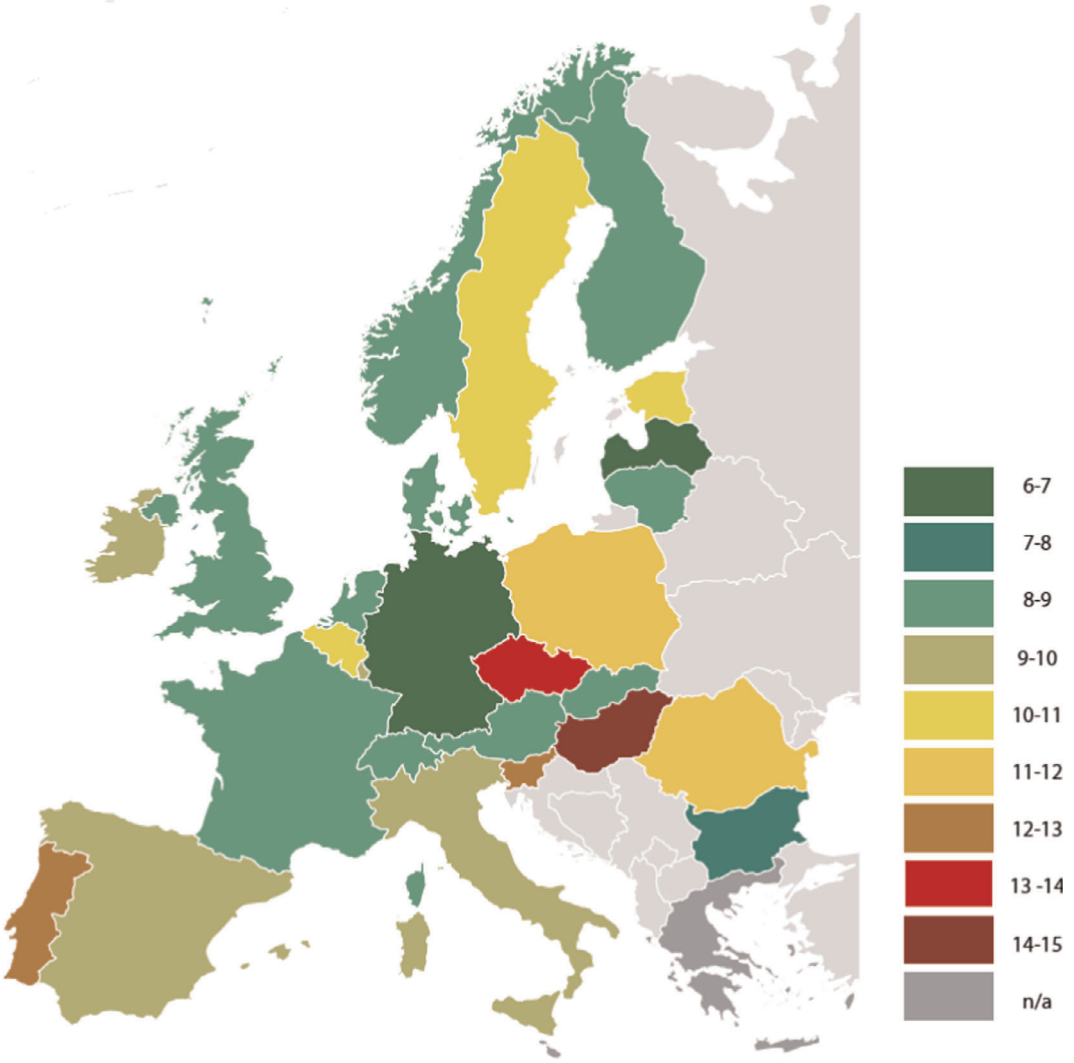

Figure 1: Daily intake of salt (presented in g of NaCl per person per day) in Europe [European Commission, 2012]

Different strategies for salt reduction include governmental polices, co-operation with food industry to reformulate products, social campaigns and monitoring the population salt intake (European Commission, 2012; WHO, 2020). Most initiatives apply to NaCl reduction in ready-to-eat products and meals served in schools or nurseries. In terms of particular food category, they primarily apply to bakery products (bread), snacks and cheese. The **food reformulation** is mostly based on lowering NaCl content during processing, the replacement of NaCl by substitutes such as KCl, $MgCl_2$, $CaCl_2$, amino acids and the addition of flavour enhancers or their combinations. KCl. The most often used a replacer is KCl which has similar properties to NaCl and its consumption can promote a protective effect against high blood pressure, stroke or osteoporosis (Hall, 2003). However, a very limited number of studies was conducted for salt reduction in seafood products so far.

The reduction of salt intake from fish and shellfish products is especially important for regions with high seafood consumption such as such as Iceland, Maldives, Micronesia and Hong Kong (≥ 70 kg per capita/year; global average = 20 kg per capita/year) (Statista, 2021). On the other, smoked seafood are eagerly chosen by many consumers due their specific taste, aroma and colour. Smoked fish and shellfish should be given a special attention as processing of raw fish significantly increases NaCl content in the product. The portion of 100 g of commercially available **smoked fish** often deliver up to 100% of recommended daily intake of NaCl. Therefore, the project was focused on the benefit and risk assessment of NaCl replacement with other salts/substances in seafood.

2. Description of work programme

2.1. Aim and activities/methods

The project was aimed at three **tasks**:

1) preparation and submission of guidelines for the application of relevant strategies to reduce NaCl content in seafood (literature review);
2) assessing benefit/risk of NaCl replacement with other substances/ingredients in seafood;
3) elaborating and disseminating results obtained.

3. Results, discussion and conclusions

The time schedule of the project is presented in Table 1.

Table 1: The schedule of the project

Year	2021											
Month number	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
Month	Jan	Febr	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
EFSA induction training												
Task 1. Guidelines for salt reduction in seafood												
1.1. Data extraction												
1.2. Manuscript preparation												
1.3. Manuscript submission												
Task 2. Experimental studies												
2.1. Experimental I												
2.2. Experimental II												
Task 3. Dissemination												
3.1. Research papers												
3.2. Conferences												

3.1. Task 1: Guidelines for salt reduction in seafood

Taking into account COVID-19 restrictions in Portugal at the beginning of 2021, the project was conducted in a remote version from February 1 until March 31. It was agreed that project will initially include the preparation of a review paper on substitution of NaCl by other ingredients in seafood products. The aim was to: (i) discuss the Na content in seafood, (ii) indicate the positive and negative roles of NaCl in seafood processing, (iii) identify the main strategies to reduce NaCl in seafood products, (iv) categorise the ingredients used as substitutes of NaCl, (v) specify how the current substitutes of NaCl affect its technological function in seafood production and (vi) discuss the nutritional (dietary) impact of NaCl substitution, (vii) debate the influence of NaCl replacement on physicochemical properties of seafood products, (viii) discuss the influence of NaCl replacement on sensory attributes of seafood products and (ix) discuss the influence of NaCl replacement on microbiological safety of seafood products. The preparation of the paper included three subtasks presented in Table 1: data extraction, manuscript preparation and manuscript submission. Subtask 1 was performed within close collaboration between the fellow and supervisor and included the following steps (Figure 2).

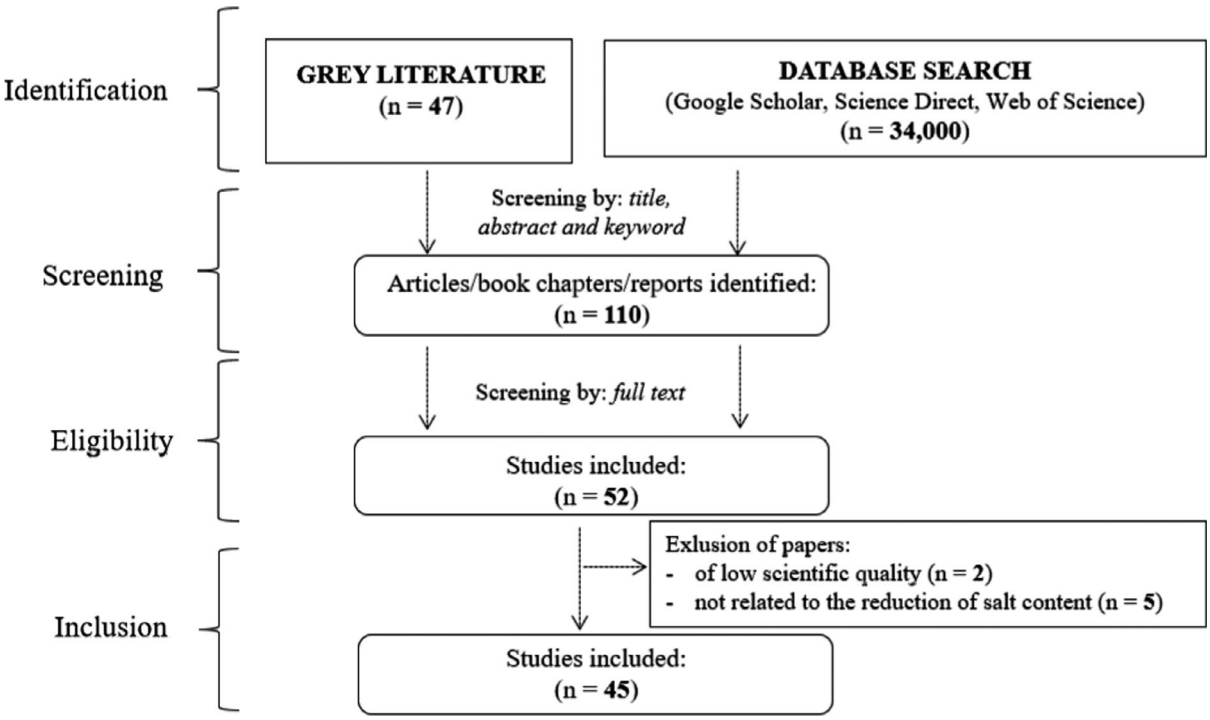

Figure 2: Studies comprised in the review paper [adapted from draft of the paper]

Once the data were collected, the manuscript was prepared by the fellow first and then revised by the team from the hosting site. From April 1, the preparation of the review paper was continued in the hosting site and was finalised in August 23 by submitting it to the scientific journal. As of November 9, the manuscript status is 'under revision' in Food Control (Elsevier).

3.2. Task 2: Experimental studies

Task 2 applied to experimental studies on the replacement of NaCl with other substances/ ingredients in smoked trout. The aim of these studies was to assess the benefit and risk of this substitution in terms of multiply chemical, physical, microbiological and sensory attributes.

Task 2.1. Experiment I

The study was conducted in April–June 2021 using hosting site facilities. It covered all steps of experimental study namely: conceptualisation, investigation and formal analysis. The fellow was personally involved in all steps.

AIM: To develop safe, healthy and attractive smoked trout with reduced content of NaCl
MATERIAL: Hot smoked rainbow trout (*Oncorhynchus mykiss*) developed using eight formulations with different concentrations of NaCl, KCl, sugar and bitterness masking agent

Collecting the fish **Filleting** **Salting** **Smoking**

Figure 3: Experiment I: the development of smoked trout with reduced content of NaCl [own data]

METHODS: Determinations in raw material and smoked products included:

- microbiological analysis,
- instrumental texture/colour,
- sensory analysis

RESULTS: Satisfactory results were obtained for microbiological, texture and colour factors, however, the results obtained for sensory analysis (very high/high scores for salty taste) precludes the application of conditions applied in the experiment.

Task 2.2. Experiment II

The study was conducted in July–November 2021 and included conceptualisation, investigation and formal analysis. The fellow was personally involved in all steps. The results from Experiment I were carefully taken into consideration and appropriate corrections were included in the Experiment II.

AIM: To develop safe, healthy and attractive smoked trout with reduced content of NaCl

MATERIAL: Hot smoked rainbow trout (*Oncorhynchus mykiss*) developed using eight formulations with different concentrations of NaCl, KCl, sugar, microencapsulated plants + spices (ME) and bitterness masking agent

METHODS: Determinations in raw material and smoked products included the following analyses:

- microbiological,
- moisture, fat, protein,
- chlorides, Na, K,
- pH, water activity (a_w),
- water holding capacity (WHC),
- instrumental texture/colour,
- sensory

RESULTS: The last results for Experiment II were obtained in mid-November. Results allowed for identification of formulations with most desirable attributes especially in relation to NaCl reduction/sensory attributes ratio. The results indicate that the replacement of NaCl with KCl and ME, with or without masking agent, is a potential solution towards more sustainable and healthy diets (with lower Na and higher K content).

As expected, there was a significant Na reduction in smoked trout developed either with KCl, or with microencapsulated plants + spies (with or without bitterness masking agent). Smoked trout with reduced NaCl levels delivered significantly less NaCl which can limit its intake to the recommended level of 5 g of per day (EFSA NDA Panel, 2019). An increase in the K level was also observed for formulations developed with KCl addition and is expected to bring other health benefits. Smoked trout produced with KCl can be labelled as a 'source of K' according to the definition of this claim (Regulation (EC) No 1924/2006) (European Commission, 2006), which is essential for supporting blood pressure, cardiovascular health, bone and muscle strength (EFSA NDA Panel, 2016). Moreover, the Na: K ratio, which is also positively associated with blood pressure and is a predictor of cardiovascular risk,

decreased in products prepared with NaCl replacement compared to traditional smoked products. These ratios observed in samples prepared with reduced Na levels are closer or in line with the WHO that recommended Na:K ratio ≤ 1 (O'Halloran et al., 2016).

3.3. Task 3: Dissemination

This task included dissemination of results by the preparation of research article and conferences participation. First dissemination activity applied to the description of salt reduction strategies utilised in the European food industry. The 1st International Conference on Quality and Management Sciences 2021 (**conference 1**) was organised by Poznan University of Economics and Business in September 13–15, 2021, in Poznan (Poland). The abstract entitled 'European strategies for salt reduction in food' was authored by Iga Rybicka, António Marques, Amparo Gonçalves, Helena Oliveira and Maria Leonor Nunes and presented by fellow during remote participation in the conference.

The results from experimental studies (Experiments I and II) are being analysed and the **manuscript 1** is under preparation. It is projected to finish the draft of the paper by the end of December 2021. After its revision by the research team, the manuscript will be submitted to the journal (expected date: 1st Q of 2022). Working title of the manuscript is 'Development and quality assessment of smoked rainbow trout with reduced sodium content' by Iga Rybicka, Marlene Silva, Amparo Gonçalves, Helena Oliveira, António Marques, Maria João Fraqueza and Maria Leonor Nunes. Moreover, results from Experiments I and II were summarised and described in abstract for ONE – Health, Environment, Society – Conference 2022 which is organised by, e.g. EFSA in June 21–24, 2022, in Brussels (Belgium) (**conference 2**). The submission (entitled 'Development of safe, nutritious and attractive smoked trout with reduced salt content', which was authored by Iga Rybicka, Marlene Silva, Amparo Gonçalves, Helena Oliveira, Maria João Fraqueza, António Marques and Maria Leonor Nunes) was already accepted by organising committee. Depending on the organisational and financial capabilities of the fellow her participation will be in physical or remote attendance (organisers allow both possibilities).

Dissemination activities were expanded by the elaboration of results obtained for smoked mackerels with reduced content of NaCl which were developed and analysed in CIIMAR at the beginning of 2021. The fellow did not participate in person in the experiment, but the results from this experiment were analysed and the draft of the **manuscript 2** was prepared by Iga Rybicka. The draft of the manuscript is now revised by the research team and its submission is planned for the end of November 2021 (title 'Development and quality of smoked mackerel (*Scomber japonicus*) with reduced sodium content' by Iga Rybicka, Marlene Silva, Amparo Gonçalves, Helena Oliveira, António Marques, Maria José Fernandes, Maria Helena Fernandes, Maria João Fraqueza and Maria Leonor Nunes). Moreover, the results from this experiment were already presented in the 35th EFFoST International Conference: Healthy Individuals, Resilient Communities, and Global Food Security (**conference 3**) which was held November 1–4, 2021, in Lausanne (Switzerland) among fellow's physical attendance in the event (funded by EU-FORA programme). The title of the poster was 'Salt reduction strategies in processed seafood'.

Additionally, to the work programme, the fellow participated in the experimental study aimed at optimising smoking conditions for the development of industrial seafood. In October 2021, the fellow was involved in the preparation of raw rainbow trout for further processing of the fish which are planned for the 1st quarter of 2022. The fellow and supervisor will be co-authors of the research results published in **manuscript 3** by the end of 2022.

All dissemination outputs (papers and conference submissions) are and will be acknowledged by EFSA EU-FORA programme. Posters for conference 1 and conference 2 are attached as annexes to the technical report.

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Abbreviations

a_w	water activity
ME	microencapsulated herbs and spices
WHC	water holding capacity
WHO	world health organization

Glossary

Salt	Applies to sodium chloride (NaCl) as it is a major salt used in food industry
Salt reduction	Applies to the reduction of NaCl as ~ 95% of Na intake originates from NaCl

Annex A – The poster for conference 1

EUROPEAN STRATEGIES FOR SALT REDUCTION IN FOOD

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OBJECTIVE

The aim of the study was to **review** the current status of (1) salt (NaCl, sodium chloride) intake and (2) activities related to salt reduction in Europe

METHODS & RESULTS

RECOMMENDATIONS

- The World Health Organization (WHO) recommends reducing salt intake to ≤ 5 g per day [1]
- 5 g of NaCl (~1 tablespoon) corresponds to 2 g of sodium (Na)

SOURCES OF NaCl

- EUROPE: 75-95% processed food
- WORLD: America – mainly from processed food; Asia – majority from salt added during cooking at home (incl. soya sauce)[2]]

Fig. 1. Salt (NaCl) content in food products [g NaCl/100 g of product] (adopted from [3])

(1) SALT INTAKE

CURRENT STATUS IN EUROPE

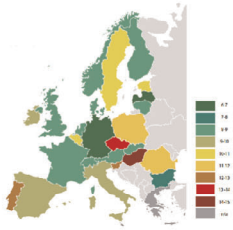


Fig. 2. Salt intake [g/person/day] in some European countries [4]

- NaCl intake is above the WHO recommended levels in approximately 99% of the world's adult population (in 181 of 187 countries),
- [WORLD: The highest intake in Tianjin (China); the lowest in Yanomamo Indians (Brazil) [2]

CONSEQUENCES

HEALTH

- NaCl is a main source of Na. Na intake around the world is well in excess of physiological need and a diet high in Na is ranked as the second most important dietary risk factor to health globally [5]
- Excessive Na intake is strongly linked with raised blood pressure and increased risks of cardiovascular disease (CVD), as well as with kidney disease, gastric cancer, and osteoporosis [5]
- Raised blood pressure is responsible for 62% of stroke and 49% of coronary heart disease [3]

SOCIAL

- CVD is one of the leading causes of mortality and morbidity from non-communicable disease globally. In 2017, high Na intake led to approximately 3 million deaths and the loss of 70 million disability-adjusted life-years (with four out of five of these deaths occurring in low- and middle-income countries) [6]

ECONOMICAL

- The total global cost of CVD was approximately $863 billion in 2010 and it is predicted to raise up to $1,044 billion by 2030. The costs per episode of hypertension/generic CVD ranges between $500 and $1500 [7]

APPROACHES

- ✓ Twenty-nine WHO member states have committed to reduce the salt intake by 30% until 2025 [1]
- ✓ Efforts to reduce Na have been increasing at national, regional, and global levels: 1) the number of countries that have national Na reduction strategies doubled from 2010 to 2014; 2) since 2016–2017, eighty-nine countries have national policies that support Na reduction [6]

Tab. 1. Existing salt/sodium reduction strategies [6]

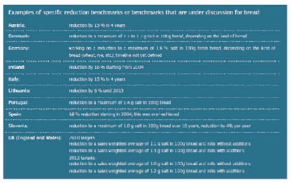
Salt/sodium from packaged foods
Labelling: front-of-pack labelling regulations
Labelling: mandatory nutrient declaration on labels
Labelling: nutrition/health claims on food packaging
Reformulation targets for packaged food (voluntary or mandatory)
Regulation of foods marketing of foods and beverages to children
Fiscal policies: taxation on high salt/sodium foods
Supermarket interventions using products placements, price, or promotion strategies (4Ps)
Salt/sodium from food prepared outside home
Standards for salt/sodium as part of food procurement policies for public institutions
Restaurants: menu labelling of high or low salt/sodium items (primarily chain restaurants)
Restaurant: removal of salt shakers and high salt/sodium condiments from tables
Restaurants: chef training to reduce salt/sodium in food
Restaurants: providing the provision of low salt/sodium or no salt/no sodium added items on menus
Restaurants: food reformulation targets for restaurants (voluntary or mandatory; primarily chain restaurants)
Salt/sodium added at home
Mass media campaigns
Community education (e.g., through schools, community venues, workplaces, etc.)
Individual education and counselling (usually through primary health care)
Increase the variety of low salt/low sodium (preparation, distribution, availability)

(2) SALT REDUCTION

BY FOOD CATEGORY

- In Europe, bread is frequently identified as the main source of NaCl (in average: a 20% contribution to salt intake; up to 28% in France)
- 2nd: meat and meat products (from 8% in Switzerland to 26% in Spain)
- 3rd: cheese and other dairy products (approximately 10% in most of European countries)
- Other important categories: ready-to-eat products/meals and soups [4]
- Generally, labels for processed food can be grouped into:
  - Low-salt (< 0.3 g NaCl/100 g of product)
  - Medium-salt (0.3 – 1.5 g NaCl/100 g)
  - High-salt (>1.5 g NaCl/100 g)

Tab. 2. Examples of specific reduction benchmarks for bread [4]



BENEFITS

- Salt reduction is considered as a simple, low-cost and effective way to protect public health
- The reduction of salt intake to the recommended level is predicted to save an estimated 1.65 million lives each year
- It is assumed that $1 spent on salt reduction efforts can save up to $19 as a result of reduced disability and mortality in high-income countries [7]
- **United Kingdom (UK) example:** In 2003, the UK was one of the first countries introducing a salt reduction program to reduce the incidence of cardiovascular disease (CVD). Between 2000 and 2018, the NaCl intake was limited to 1 g (from 9.4 to 8.4 g/day) which was calculated as: 194K CVD cases averted + 542K quality-adjusted life-years added + £1,640m saved [8]

CONSLUSIONS

- ✓ Reducing NaCl/Na intake is among the main priority interventions for WHO members and contributes toward achieving UN Sustainable Development Goals, especially Goal 3 (ensuring healthy lives and promoting well-being for all at all ages) and Goal 12 (ensuring sustainable consumption and production patterns)
- ✓ Strategies to reduce NaCl intake are focused on governmental policies, including taxation, social campaigns aimed at increasing consumer awareness, support producers to manufacture healthier foods and regular monitoring such intake. They mainly apply to bread and meat products which are main contributors to the daily intake of salt in all European countries
- ✓ Public health efforts should be maximized to achieve the ambitious 30% reduction target, as no country has yet achieved recommended level of salt intake [7]
- ✓ Future areas of work are likely to include work on modelling the economic costs of salt intakes and the positive impact of salt reductions [1]

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Annex B – The poster for conference 3

SALT REDUCTION STRATEGIES IN PROCESSED SEAFOOD – SMOKED MACKEREL CASE

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INTRODUCTION

High NaCl intake [1]:

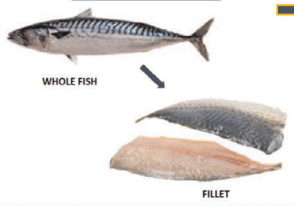
- ↑ risk of cardiovascular diseases
- 3 M deaths and 70 M disability-adjusted life-years each year
- global cost: $850 B in 2010
- global cost: $1,044 B by 2030

- World Health Organization recommendations [1]: NaCl ≤ 5 g per day
- Actual daily NaCl intake is 9-12 g in Europe and 15 g in Asia [2]
- NaCl in commercial smoked mackarel – up to 4 g/100 g

AIM: Developing safe, nutritious & attractive smoked mackerel with reduced NaCl/Na content

MATERIAL & METHODS

PREPARATION



SALTING

- **BRINE 5%** (1 h, 7 °C):
  - 5A – 100% NaCl
  - 5B – 75% NaCl + 25% KCl
  - 5C – 50% NaCl + 50% KCl
  - 5D – 25% NaCl + 75% KCl
- **BRINE 10%** (1 h, 7 °C):
  - 10A – 100% NaCl
  - 10B – 75% NaCl + 25% KCl
  - 10C – 50% NaCl + 50% KCl
  - 10D – 25% NaCl + 75% KCl

HOT SMOKING

- Conditions: drying (40-55 °C, 90-95% relative humidity, 2 h); smoking (65 °C, 85% relative humidity, 40 min) in a semi-industrial unit

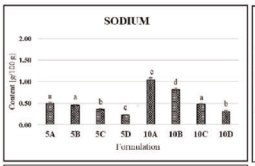
ANALYSIS

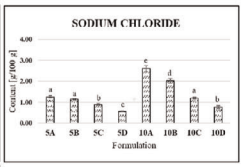
- Chemical: moisture, protein, fat, sodium, potassium
- Physical: pH, water activity (a_w), water holding capacity (WHC), colour, texture
- Microbiology: Total viable counts (TVC), Enterobacteriaceae, *Listeria monocytogenes*
- Sensory evaluation
- Statistical analysis was performed using factorial analysis of variance (ANOVA) and Tukey's HSD test ($p < 0.05$)

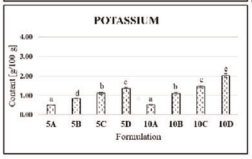
RESULTS

CHEMICAL COMPOSITION AND PHYSICAL PARAMETERS

- **No significant differences** for:
  - Moisture (49-56%)
  - Protein (28-30%)
  - Fat (9.2-10.5%)
  - pH (6.1-6.2)
  - a_w (0.94-0.96)
  - WHC (58-65%)
  - Yield (78-81%)
- **Significant differences** for:
  - Sodium
  - Sodium chloride (NaCl = Na x 2.5)
  - Potassium





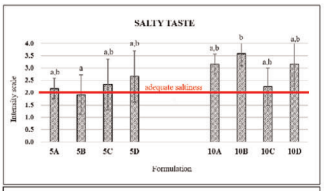


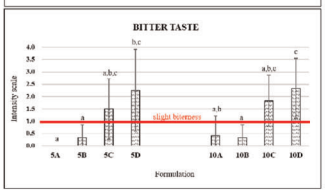
- Results are given as mean values ± standard deviations;
- Different small letters indicate significant differences between formulations

TEXTURE

- **No significant differences** for:
  - Hardness (33-40 N)
  - Springiness (~0.5 N)
  - Cohesiveness (~0.4 N)
  - Chewinesss (7.2-.86 N)

SENSORY





- **No significant differences** for:
  - Smoking taste/aroma (1.5-2.8)
  - Firmness (1.5-3.0)
- **Significant differences** for:
  - Saltiness
  - Bitterness
- Formulation with the best attributes (negligible bitterness and moderate saltiness): **5B**
- Limited saltiness and bitterness perception were also noticed in Na-reduced smoked salmon (replaced by KCl) [3]

- Results are given as mean values ± standard deviations
- Different small letters indicate significant differences between formulations
- Intensity scale: 0 – absent, 1 – slight, 2 – moderate (adequate for salty), 3 – strong, 4 – extreme

COLOUR

- **No significant differences** for:
  - L^* (49-56)
  - a^* (2.5-3.5)
  - b^* (18-21)

MICROBIOLOGY

- All products were considered **safe**
- **No significant differences** for:
  - TVC (1.3 – 2.1 log CFU/g)
  - Enterobacteriaceae (<LOQ)
  - *L. monocytogenes* (<LOQ)

CONCLUSIONS

- ✓ Chemical composition, physical parameters and safety of smoked mackerel were not affected by the different formulations used to reduce NaCl content
- ✓ The formulation **5B (5% brine** and **75% NaCl + 25% KCl)** provided the best relation sodium reduction: sensory properties
- ✓ 5B formulation allowed for a **70% reduction of Na/NaCl compared to conventional commercial products**
- ✓ Higher sodium chloride substitution may be possible through the addition of bitterness masking ingredients, such as aromatic herbs

REFERENCES

[1] WHO, 2021, https://www.who.int/activities/reducing-population-sodium-salt-intakes (accessed: August 31, 2021)

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[3] Muñoz, I., Guàrdia, M. D., Arnau, J., Dalgaard, P. & et al. 2020. https://doi.org/10.1016/j.fct.2020.111554

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