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Preface

Navigating the depths of marine lipids: From extraction efficiency to flavour enhancement

Introduction

Marine lipids are recognised to have substantial importance in biology and human health. These remarkable lipids, which originate from the rich biodiversity of the oceans, hold a unique status for several reasons. Marine lipids provide long-chain omega-3 fatty acids (n-3 LCPUFAs), specifically eicosapentaenoic acid (EPA, C20:5) and docosahexaenoic acid (DHA, C22:6) (Ahmmed, Ahmmed, et al., 2021; Ahmmed, Carne, et al., 2021; Ahmmed et al., 2022a, 2022b; Ahmmed et al., 2023), that play an important role in health and wellbeing (Zhang et al., 2019), and especially brain health (Ahmmed et al., 2020; Ahmmed et al., 2023; Burri et al., 2012).

The long-chain n-3 fatty acids, including EPA, DPA, and DHA, have received particular interest. These fatty acids have garnered significant attention because of their crucial physiological functions, coupled with the fact that the human body cannot synthesize them. The brain of humans, in particular, stands out with its unique lipid composition compared to other organs, in containing a substantial amount of DHA, making up 40%–50% of the total fatty acids (Ahmmed et al., 2020; Ahmmed et al., 2023; Singh, 2005; Zhang et al., 2019). However, the composition of the fatty acids in the brain varies depending on factors such as diet, age, gender, and regional distribution, underscoring the complex interplay between these elements (Lange, 2020). DHA, considered to be a fundamental fatty acid for brain development, plays a pivotal role in various brain functions, including cell survival, neurogenesis, and neuroinflammation (Zhang et al., 2019). It serves as a key contributor to central nervous system development, and a DHA-derived neuroprotection, D1, has shown promise in combating neurodegenerative disorders and age-related brain conditions (Lukiw & Bazan, 2008).

Additionally, DPA in the human brain, acts as an intermediate between EPA and DHA, contributing to the synthesis pathway from α-linolenic acid (Domenichiello et al., 2015). DPA supplementation has demonstrated positive effects on cognition and brain health, making it a noteworthy player in maintaining cognitive function as we age (Taoro-González et al., 2022). The n-3 LCPUFAs can be esterified in nature, either in triacylglyceride (TAG), or in phospholipid (PL) form (Ahmmed, Ahmmed, et al., 2021; Ahmmed et al., 2020; Zhang et al., 2019). Different forms of n-3 fatty acids have different bioavailability and stability (Burri et al., 2012). Notably, n-3 LCPUFAs in the PL form are more stable, bioavailable, and capable of crossing the blood–brain barrier, making them particularly valuable for enriching brain DHA levels and optimizing health benefits (Ahmmed et al., 2020; Zhang et al., 2019).

In this special issue on “Marine Lipids”, five insightful studies contribute new information to our understanding of marine lipids in various ways:

Studies published in this issue

2.1. Protease-mediated lipid extraction: enhancing efficiency and quality

The use of protease preparations was explored for optimizing lipid extraction from hoki roe (Ahmmed et al., 2022b). Three commercial proteases, Alcalase, FP-II, and HT were characterized and used at the same hydrolytic activity to determine their effectiveness in breaking down the protein matrix present in hoki roe.

The use of proteases was found to substantially increase lipid yields, compared to control treatment without proteases. Hydrolysis with Alcalase generated the most promising results, in enhancing lipid yield by approximately 40 %. Both the FP-II and HT proteases exhibited lower extracted lipid yield increases of around 20 % and 15 %, respectively. Based on the degree of hydrolysis and SDS-PAGE analysis, it is evident that Alcalase achieved a more effective hydrolytic performance compared to HT and FPII. Additionally, Alcalase yielded a higher total extracted lipid percentage at 19.29 %, surpassing the results obtained with HT at 18.29 % and FPII at 18.33 %. The HT hydrolyzed hoki roe homogenate demonstrated superior results in terms of both total phospholipid (PL) and n-3 fatty acid yields, with values of 30.7 μmol/g for PL and 10.5 % for n-3, in comparison to Alcalase, which yielded 22 μmol/g for PL and 5.95 % for n-3. Alcalase hydrolysis yielded less oxidised lipid, suggesting that hydrolysis with Alcalase provides antioxidant protection to the lipids, potentially contributing to enhanced stability and healthiness.

The research is of practical value since it offers a more efficient utilization of marine resources such as hoki roe.

2.2. Metabolomics and diabetes

Zhang et al. (2023) reported a comprehensive investigation of the impact of *Holothuria leucospilota* polysaccharides (HLP) which were found to improve metabolism disorders in the liver of Goto-Kakizaki (GK) rats with spontaneous type 2 diabetes. The study employs advanced metabolomic techniques and gene expression analysis to unravel the underlying mechanisms of the therapeutic action of HLP.

The global surge in type 2 diabetes mellitus (T2DM) prevalence has reached alarming levels, posing significant health challenges worldwide (Tinajero & Malik, 2021). Lifestyle effects, including poor dietary choices and sedentary habits, have fueled this epidemic. Consequently, there is an urgent need for innovative approaches to combat T2DM and its debilitating complications.

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HLP, derived from the edible sea cucumber *Holothuria leucospilota*, emerges as a promising natural intervention (Sanjeewa & Herath, 2023). Previous research has already hinted at its multifaceted benefits, such as reducing glycosylated proteins, TAG, and cholesterol levels in diabetic rats, while also mitigating oxidative stress and inflammation (El Barky et al., 2016; El Kareh, 2014; Ganesan & Xu, 2019; Jin et al., 2014; Liu et al., 2022). This study takes a deeper dive into the mechanisms behind these effects. Metabolomics, a powerful tool for profiling changes in endogenous substances, unveils the metabolic alterations associated with T2DM and HLP intervention. Indole acrylic acid and various bile acids emerge as critical biomarkers, shedding light on their roles in cholesterol metabolism, liver damage, and overall metabolic health.

The exploration of gene expression patterns in this study further enriches our understanding. Notably, the farnesoid X receptor-small heterodimer partner (FXR-SHP) signaling pathway takes center stage. HLP appears to modulate this pathway, influencing bile acid synthesis, glycination, excretion, and reabsorption. These regulatory actions contribute to improved bile acid balance, accelerated cholesterol metabolism, and relief from liver damage in diabetic rats.

This comprehensive research paints a compelling picture of HLP as a multifunctional agent in managing T2DM and promoting liver health. By regulating bile acid metabolism and cholesterol consumption, HLP offers potential avenues for preventing and treating T2DM and its complications. The study's integration of advanced analytical techniques and molecular insights paves the way for future investigations and therapeutic developments.

Overall, this study marks an important step in the pursuit of natural remedies for T2DM and liver-related complications. HLP, with its intriguing metabolic effects, holds great potential as a complementary approach to combat this global health crisis.

2.3. Flavour formation analysis

Xu et al. (2023) investigated flavour formation based on sensory profiles and lipidomics of un-rinsed mixed sturgeon surimi gels. This research provides valuable insights into the sensory aspects of lipid-containing food products. This study identified 72 volatile compounds, analyzed 1594 lipid molecules, and uncovered the flavour-enhancing role of glycerol phospholipid oxidation. By doing so, the authors provided insights into creating high-quality and cost-effective sturgeon surimi products.

Sturgeon surimi, a protein-rich product, has gained popularity due to its low-fat content. With marine fish production declining, sturgeon meat is being explored as a suitable alternative. However, traditional surimi processing involves rinsing, which removes pigments, enzymes, and lipids but also essential nutrients. Un-rinsed surimi, while rich in lipids, is prone to oxidation, leading to a fishy smell. To address this, chicken breast, with similar whiteness and desirable properties, was incorporated into surimi products. The addition of chicken breast has shown promise in improving sturgeon surimi's texture, reducing its fishy odour, and maintaining quality. Chicken breast myofibrillar proteins create a stable gel structure, while the amino acids and nucleotides present enhance umami and sweetness. The study also found that the addition of chicken breast reduced bitterness and astringency, further enhancing the overall taste of surimi.

Gas chromatography and mass spectrometry revealed 72 volatile compounds in the surimi samples (Xu et al., 2023). Notably, the addition of chicken breast led to the emergence of desirable fruity and creamy aromas while reducing fishy odours. A comprehensive lipid analysis identified 1594 lipids in the samples. Glycerophospholipids, a vital component of cell membranes, played a crucial role in flavour development. They produced aldehydes and ketones, key contributors to the aroma of surimi (Shahidi & Hossain, 2022). This lipid-focused perspective has shed light on how lipid oxidation impacts flavour formation.

Overall, the integration of chicken breast into sturgeon surimi represents a promising avenue for enhancing flavour and quality while reducing fishy odours. This thorough analysis of volatile compounds and lipids presented in this study, provides valuable insights into creating superior sturgeon surimi products.

2.4. Metabolomics investigation

Liu et al. (2022) report a metabolomics investigation of the volatile and non-volatile metabolites that contribute to the distinctive taste of the Pacific oyster (*Crassostrea gigas*).

The study focused on identifying the volatile compounds responsible for these odours, including unsaturated aldehydes, ketones, and alcohols. The researchers discovered that the enzymatic hydrolysis process generated distinctive key odorants, such as hexanal, (E)-4-heptenal, and (E)-2-pentenal, which are linked to off-putting aromas.

Moreover, the study explored non-volatile metabolites, revealing changes in the flavour profile resulting from alterations in amino acid composition and fatty acid content. Notably, amino acids such as aspartate, glutamine, alanine, and arginine were identified as crucial precursors affecting the flavour. Understanding these relationships between sensory attributes, odorants, and non-volatile metabolites could pave the way for better flavour control and product enhancement in oyster processing.

The findings of this study indicate that enzymatic hydrolysis alters the sensory profile of oysters, intensifying off-odours while preserving pleasant sensory attributes, in contrast to traditional high-temperature boiling, which maintains the pleasant odour profile. This knowledge is instrumental for evaluating product quality and optimizing processing methods. Furthermore, the study sheds light on the impact of fatty acids, especially unsaturated fatty acids, in flavour formation. The oxidation of these fatty acids during enzymatic hydrolysis was found to contribute significantly to the development of off odours.

2.5. Impact of oral processing on sensory perception

A comprehensive investigation of oral processing effects on flavour release and composition changes in steamed sturgeon meat is reported by Qian et al. (2023). This research is of particular relevance given the growth of sturgeon farming, especially in China, where sturgeon products are in high demand.

The authors employed a multifaceted approach, incorporating various analytical techniques and sensory evaluations, to provide a thorough understanding of the complex interplay between oral processing, sensory perception, and the biochemical composition of sturgeon meat.

The research characterized taste and texture perceptions evolving during oral processing. The study reveals that umami and saltiness are the predominant tastes, with bitterness at a low level throughout the process. The concentrations of free amino acids, 5′-nucleotides, organic acids, and sodium ions in steamed sturgeon meat during oral processing appeared to manipulate the perceptions. Notably, umami-contributing compounds such as glutamic acid and inosine monophosphate (IMP), play an important role in the taste profile (Dermiki et al., 2013; Duppeti et al., 2022).

This research identified 42 volatile compounds in sturgeon meat during oral processing. The changes in the concentrations of these volatile compounds over time provide insights into the aroma development of sturgeon meat. The study highlights the importance of alcohols, aldehydes, and esters in shaping the flavour of meat.

The researchers employed a lipidomic approach to analyze the composition and changes in lipids during oral processing. The study identifies substantial variations in lipid profiles, shedding light on the role of lipids in flavour perception and retention. Furthermore, the study investigated the role of proteins during oral processing and identified 589 proteins that could be involved in flavour release and perception.

This special issue on Marine Lipids has taken us on a captivating voyage through the intricate world of marine lipids. These five studies contribute substantially to our comprehension of marine lipids and their impacts. Marine lipids, sourced from the diverse ecosystems of our oceans, hold a unique status due to their essential long-chain omega-3 fatty acids, particularly EPA, DPA, and DHA (Ahmmed et al., 2020). These compounds are pivotal for various biological processes and possess vital functions both in marine organisms and in human health (Burri et al., 2012; Zhang et al., 2019). The composition of brain, with its significant DHA content, underscores the critical role of these lipids in neurological development and health (Ahmmed et al., 2020; Burri et al., 2012; Zhang et al., 2019).

There is limited information available on biochemical pathways investigating absorption of marine lipids, in particular DHA, and delivery of DHA to targeted organs such as heart, brain, kidney and eyes. Further, the bioavailability of marine lipids and their interactions with other food components and matrices remain to be investigated.

There are numerous research areas in marine lipids that require special attention in the future, ranging from improving health to enhancing the taste of seafood. The studies published in this special issue (Marine Lipids, Food-Chemistry-X) is a positive step towards better utilization of marine-derived fats.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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