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Review

Bioactive compounds from marine mussels and their effects on human health

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ABSTRACT

The consumption of marine mussels as popular seafood has increased steadily over the past decades. Awareness of mussel derived molecules, that promote health, has contributed to extensive research efforts in that field. This review highlights the bioactive potential of mussel components from species of the genus *Mytilus* (*e.g. M. edulis*) and *Perna* (*e.g. P. canaliculus*). In particular, the bioactivity related to three major chemical classes of mussel primary metabolites, *i.e.* proteins, lipids, and carbohydrates, is evaluated. Within the group of proteins the focus is mainly on mussel peptides *e.g.* those obtained by bio-transformation processes, such as fermentation. In addition, mussel lipids, comprising polyunsaturated fatty acids (PUFAs), are discussed as compounds that are well known for prevention and treatment of rheumatoid arthritis (RA). Within the third group of carbohydrates, mussel polysaccharides are investigated. Furthermore, the importance of monitoring the mussel as food material in respect to contaminations with natural toxins produced by microalgae is discussed.

Contents

Abbreviations: AA, amino acid; AMP, antimicrobial peptide; ASP, amnesic shellfish poisoning; AZP, azaspiracid shellfish poisoning; CFP, ciguatera fish poisoning; COX, cyclooxygenase; DHA, docosapentaenoic acid; DSP, diarrhetic shellfish poisoning; EPA, eicosapentaenoic acid; HAB, harmful algal bloom; LO, lipoxygenase; NSP, neurotoxic shellfish poisoning; PSP, paralytic shellfish poisoning; PUFA, polyunsaturated fatty acid.

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1. Introduction

It is predicted that, approximately 2,210,000 distinct life forms exist in the ocean, from which only around 190,000 species have been catalogued so far (Mora, Tittensor, Adl, Simpson, & Worm, 2011). The phylum Mollusca represents one of the largest and most diverse groups of marine animals. The Bivalvia, a large class with around 20,000 species (Chapman, 2009) within Mollusca, includes some of the best known invertebrates such as clams, oysters, scallops, and mussels and is represented at all depths and in all marine environments. Molluscan shells, including those from bivalves, have been used as tools, containers, religious symbols, and decorations since ancient times. Large populations, particularly those living in coastal areas, *e.g.* aboriginal groups, have relied on these animals for a substantial portion of their diet (Brusca & Brusca, 1990). Apart from the New Zealand green-lipped mussel, few reports available in the public domain deal with the traditional use of mussels against diseases. The sauce from a decoction of *Mytilus edulis*, for instance, is traditionally used in China for its immune strengthening properties and to treat liver and kidney dysfunctions, as well as impotence and menoxenia (Li & Ding, 2006). Nowadays, molluscan shellfish, including bivalves, are harvested commercially and are of considerable relevance for aquaculture industries worldwide. Farmed marine mussels from the *Mytilidae* family, comprising genera, such as *Mytilus* and *Perna*, are popular in human diet, providing high levels of proteins, omega-3 polyunsaturated fatty acids (PUFAs), iodine, and carbohydrates.

Considering the close relation between food and health, bioactive mussel components have proven to play a vital role for the development of functional foods, defined as food with specific beneficial health effect beyond simple nutrition, or nutraceuticals, describing a union between nutrition and pharmaceutics (Bernal, Mendiola, Ibanez, & Cifuentes, 2011; Haller, 2010; Lordan, Ross, & Stanton, 2011). Moreover, relatively high volumes of mussel wastes in aquaculture and processing, prompted researchers to focus on this underexplored source for bioactives (Harnedy & FitzGerald, 2012; Kim & Mendis, 2006). Over the past decades, bioactive properties of mussel components have been investigated by many researchers and several dietary supplements, containing mussel extracts, have been brought to the market. For example Lyprinol®, a dietary supplement product containing the lipid extract of the green-lipped mussel, *Perna canaliculus*, is sold almost worldwide as an anti-inflammatory and anti-arthritic remedy. Hence, the importance of marine mussels as source for bioactive substances, such as *e.g.* antimicrobial, anti-inflammatory, as well as anti-cancer agents, is increasing rapidly. In this review article, we focus on mussel primary metabolites comprising peptides, lipids, and carbohydrates considering their bioactive properties, as well as different classes of shellfish toxins and their impact on human health.

1.1. Literature search and data evaluation concerning mussel bioactives

This review covers literature up to January 2013 and is based on the combination of surveys in three scientific databases, *i.e.* SciFinder Scholar (Chemical Abstracts Service-http://www.cas.org/products/sfacad/index.html), ISI Web of Knowledge (Thomson Reuters-http://www.webofknowledge.com), and Scopus (Reed Elsevier-http://www.scopus.com). The two most abundant mussel genera, *i.e. Mytilus* and *Perna,* were applied as keywords and the retrieved references were further refined focusing on reported bioactivity. Fig. 1 gives an overview on the number of publications dealing with mussel bioactives corresponding to three major primary metabolite classes, *i.e.* proteins/peptides/amino acids, lipids, and carbohydrates, as well as miscellaneous metabolites. Furthermore, selected publications were evaluated according to the type of bioactivity in relation to metabolite classes, revealing that most studies deal with antimicrobial mussel peptides or anti-inflammatory mussel lipids (Fig. 2).

1.2. Marine mussel species of interest: morphology, geographical distribution, and habitat

Marketed worldwide as live, frozen or processed seafood, marine mussels are native to both, northern and southern hemispheres. The mussel industry is split into two production techniques, *i.e.* bottom mussels, naturally grown on the seabed and harvested by specialised dredging equipment, and rope mussels, cultivated on rope structures in aquaculture (Gosling, 1992). In their natural environment mussels have to adapt to parameters, such as salinity, wave exposure, substrate, zone, height, temperature, and water quality. Most species tolerate a wide range of salinity. However, at very low salinities the mussel growth is limited, which leads to smaller sizes (Almada-Villela, 1984). Mussels, occurring in low and mid intertidal areas, prefer sheltered places where individuals are usually attached to hard surfaces, such as rocky substrates. In order to adhere to boulders, cobbles, or pebbles they use their byssal threads which are proteinaceous silk-like fibres, also known as the mussel's beard (Lee, Messersmith, Israelachvili, & Waite, 2011). The most limiting parameter for the distribution of marine mussels is the temperature, as some species prefer colder while some prefer warmer waters. Furthermore, the content of active metabolites varies with season, life cycle, and habitat (Freites, Fernandez-Reiriz, & Labarta, 2002).

Commercially most relevant marine mussel species belong to the two genera of *Mytilus* and *Perna*. *Mytilus* species occur in temperate waters of Europe, Asia, and America, whereas *Perna* species are cultured in warmer waters such as Thailand, the Philippines, China, and New Zealand (Gosling, 1992). Within the genus *Mytilus*, the marine mollusc *M. edulis* is commonly known as blue or black mussel (Fig. 3A and B) due to the colour of its shell (size up to

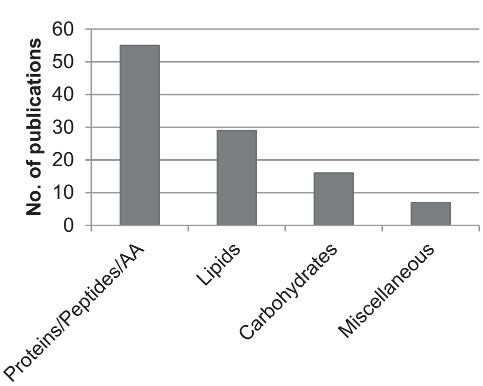

Fig. 1. Comparison of number of selected publications dealing with bioactives from marine mussels categorised in four classes, *i.e.* proteins/peptides/amino acids (AA), lipids, carbohydrates, and miscellaneous.