Chapter 11

# Chemical Ecology of Biocompounds in Molluscs

Nooshin Sadjadi

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.72741

**Abstract**

Among aquatic creatures, molluscs are one of the main phylums of marine organisms because of their vast biodiversity, nutrition advantages and their natural compounds. Chemical ecology discusses study of natural compounds in organisms, analyzes their structures and tracing their production and variation in response to environmental parameters. There are about 600 natural compounds identified, in which their metabolism are studied more in four classes of molluscs: polyplacophora, gastropoda, cephalopoda and bivalves. The main identified compounds are amino acids, lipids and fatty acids, terpens and steroids. Fatty acids and lipids are the main pre-structures for biological membranes, and their physical characteristics create membrane structure and its activities. Therefore, many cell functions depend on membrane activity and chemical composition of membrane lipids and environmental parameters as follows. Normally, the omega 6 to omega 3 ratio has moderate amounts in natural food sources. The more the ratio closer to 1, the more body metabolism could be sensitive for absorption. Environmental parameters, such as temperature, salinity, pH and food type source, could change the amount and structure of natural compounds. Biological factors such as sex type, reproduction and breeding cycles, different tissues and their activities could receive different types of natural compounds.

**Keywords:** mollusc, chemical ecology, biocompounds, environmental parameters

## 1. Introduction

The name mollusc (mollusk) was derived from Latin word mollus meaning soft. This term was first used by Cuvier in 1798 to describe squids, cuttlefish and animals whose shells is reduced. After the arthropods the molluscs are the most successful of the animal phyla in terms of numbers of species. Considering the vast species of molluscs and the large number of fossil species, they are the largest marine phylum, comprising about 23% of all the named marine organisms [1].

Molluscs live in very different habitats and are highly diverse especially in their ecological behaviors. The phylum consist 10 taxonomic classes, which two are entirely extinct. Among the existing classes, Cephalopods such as squid, cuttlefish and octopus, are among the most neurologically advanced of all invertebrates, and gastropods (snails and slugs) are the most numerous classes in this phylum [2].

Molluscs are highly successful animal group in terms of ecology and adaptation and they are found in all habitats ranging from deepest ocean to intertidal zone, freshwater and terrestrial lands where they occupy a wide range of habitats, but the highest diversity could be found in the sea in comparison with freshwater and terrestrial habitats. Between all classes in the phylum Mollusca, the most important class is gastropoda comprising more than 80% of all living Mollusca species. The species belonging to this class occurs in marine, freshwater and terrestrial habitats. Whereas bivalves occurs both in freshwater and marine environments, but there is not any species in terrestrial habitats. In the all classes of molluscs, 6 classes are exclusively marine species [3, 4].

Molluscs are consumed as a food source for humans, birds, fish, mammals and other invertebrates, and also play a key role in the recycling of nutrients, soil-generation and water filtration. They are good bio-indicators too, for environmental quality in all types of aquatic habitats [4, 5].

Molluscs have very different forms among the other animal phylums. Snails, slugs and other gastropods; clams, oysters, scallops and other bivalves; squid, cuttlefish, octopus and other cephalopods; and also lesser known subgroups have interesting diversities in structure, color and size [6]. The giant squid, which had not been observed alive in its adult form recently, is one of the largest invertebrates, with 10 m (33 ft.) long and 500 kg (1100 lb.) weighed [7].

Molluscs are an important food source for humans as mentioned earlier, but there is a risk about poisoning from toxins which can accumulate in certain molluscs under specific conditions. Besides, they are a good source of many luxury goods, such as pearls, mother of pearl, Tyrian purple dye, and sea silk. Also, in ancient periods, their shells have also been used as money [4].

Mollusca are very abundant and form an important trophic level in the aquatic food chain. A large number are filter feeders and hence, are important in nutrient recycling along with the other soil invertebrates. Numerous molluscs are important food source for humans such as Clams and Snails. Some gastropods are pest and damage crops or others hosts for some disease causing parasites such as lung worm which causes schistosomiasis and liver worm for fascioliasis in humans [3, 5].

In addition to the wide usages of molluscs in food industry, shell decorations, dyes and medicines; determination, identification and extraction of their bioactive compounds and secondary metabolites have been an important scientific field of research recently. For instance, isolated natural products from molluscs and their structural analogues are particularly well represented in the anticancer compounds in clinical trials. These compounds and their different chemical structures could be change in each species [8–10].

The marine environment is highly competitive and being able to produce fundamental compounds which have both industrial and medical applications. Based on the species number, molluscs are the second largest phylum in the marine environment. Their morphological and physiological features attract many investigators [11]. Among molluscs, gastropods have a particular role in commercial shell craft industry. A wide variety of species exists on land, fresh water and the sea. Marine gastropods form only a minor component of marine fishery resources. Many species are exported for the purposes of manufacturing ornaments, curious and various other artifacts of commercial value. Women and children collect this gastropods and bivalves from shallow estuaries for nutritional food. Shells and shell crafts of gastropods are the major economy for the local peoples in marine coasts. Marine bivalves and gastropods are also rich source of many biologically active compounds. Owing to their medicinal and industrial properties, several species are traditionally fished for food and shell [2].

Mollusc species could be hazardous or pests. For example, blue-ringed octopus which is often fatal, and Octopus apollyon causes inflammations which can last for over a month. Toxic cone shells could kill or cause inflammations, while some times their venoms could become important tools in neurological research. Also, some snails and slugs are serious agricultural pests or dangerous vectors for transition parasitic diseases [10, 11].

## 2. Concept of chemical ecology

The different species from molluscs probably utilizes the neutral and total lipids during cold seasons in order to survive and stores them for hot seasons. The importance of stored lipids is for reproductive purposes. However, they have also been shown to provide energy during winter, when carbohydrate reserves are depleted. This indicates that the fatty acid compositions of animals, neutral lipids in particular, are dictated by their metabolic activities and components of their dietary lipids [12].

The feeding habitats and diet composition are important factors that cause changes in the levels or type of the fatty acids in the different groups of molluscs. There are different feeding habits (such as filter feeder and detritus feeder) in the different groups of this phylum. Most of the lipids and considerable amounts of C20:5ω3 and C22:6ω3 acids are provided by diatoms and dinoflagellates, respectively. For example, diet composition of bivalves which are filter feeders, consist of dinoflagellates, bacteria and particulate organic material. It is found that diatoms have high levels of C20:5ω3 acid and low C22:6ω3 acid, but dinoflagellates have high concentrations of C22:6ω3 acid. Some species of molluscs are detritus feeder, and amounts of lipids, SFAs and MUFAs of 14–18 carbons are provided by detritus. Therefore, diet composition has the important role in the variation in the level and type of the fatty acids between different groups during four seasons of the year [13–15].

The different metabolic processes play an important role in the changes of levels and type of the fatty acids, because there are significant differences in amount of consumed energy between different metabolic processes. Between all metabolic processes, reproductive cycles is the main process for consume of energy, and this process need high levels of energy (fatty acid). Therefore, there is probably an apparent relation between reproduction cycles and fatty acid profiles. In between all fatty acids same as C20:4ω6, is mostly associated with the reproductive enzymes and highest levels of this compound is consumed in spawning times and reproductive processes.

Growth is one of the processes which needs high levels of energy too, and the energy levels (fatty acid) change in the different stages of the growth. The growth ratio is not similar for different organs and species, and different types of organs need different fatty acids level for growth. Among different organs, sexual organs such as gonads need high levels of fatty acids for growth, and the highest levels of energy are consumed for gonad growth. Therefore, metabolic ratio and followed energy level are varied in different processes, and it could be found that metabolic ratios are key roles in fatty acid amounts and their profiles [4, 5, 14].

The decrease in the ∑PUFA level of neutral lipids of mollusks may probably due to transport of fatty acids to the reproductive organs responsible for gonad maturation. In the different species of mollusks, which the winter is reproductive time, the level of fatty acids in the winter is low, in comparison with other seasons [6, 7].

Many studies indicate that there are a positive correlation between fatty acids and temperature in the tissues of mollusks. Accumulation and increase in the amount of lipids especially PUFAs during summer and decrease in winter may be related to the adaptable regulation of the melting point of cellular lipids. Therefore, many researches are indicated that the amount of lipids in summer is higher than the winter, which returns to; (1) consume of lipid in the reproductive organs for gonad maturation and (2) the adaptable regulation of the melting point of cellular lipids. Finally, variations in the lipid levels in their tissues are related to environmental parameters (such as temperature, light and salinity), seasonal variations, feeding habitats, spawning time and reproductive processes, sexual development and growth metabolisms of molluscs [15–17].

In the total body lipids analyses of molluscs, fatty acids, phospholipids and neutral lipid fractions identified from different tissues. These fatty acids are mostly common in marine and freshwater mollusks. Also, odd-numbered fatty acids, such as C13:0, C15:0, C17:0, and C20 polyunsaturated fatty acids in body lipids of different species, were identified. As mentioned, temperature, food availability, metabolic and physiological activities can affect the lipid and fatty acids compositions of molluscs [6, 8].

## 3. Chemical ecology of natural compounds in molluscs

Marine molluscs have become the focus of many chemical studies aimed at isolating and identifying novel natural products and secondary metabolites. As scant information is available on the chemistry of terrestrial and freshwater species, this review focuses on marines. Considering the chemical redundancy between species, at least 977 distinct compounds have been isolated from about 251 species in the annual reviews of marine natural products [6], which indicates different chemical diversities and related compounds derived from their biochemical pathways. These compounds could be isolated from a single species merely, or from the same family or genus [9].

Distribution histogram of species diversity reveals multiple metabolites, with a median number of two and a maximum of 58 compounds isolated from a single species [18, 19].

Search results typically show small groups of structurally related compounds (analogues), regarding that the compounds vary in different habitats for the same species. For example, 25 compounds such as terpenes, nitrogenous aliphatic compounds, macrolides and fatty acid derivatives have been isolated from the sea hare *Aplysia kurodai*. Eight novel metabolites were isolated from this species in new environment, further [20].

Its close related species *Aplysia dactylomela*, had 58 compounds which were primarily terpenes derived probably from algal diets of these cosmopolitan grazing sea hares. The *Patinopectin yessoensis* bivalve contained second highest number of sterols and algal toxins. Hence, it could be found that dietary sources contribute significantly to the chemical diversities in molluscs. Evidence for the biogenesis of secondary metabolites mostly stems from feeding experiments, which demonstrate the incorporation of radio-labeled precursors in certain groups of heterobranch molluscs. The secondary metabolites isolated, fall into a wide range of structural classes, with some compounds being more dominant in certain taxa [21, 22].

Clearly, all the secondary metabolite types are present in both gastropods and bivalves. Terpenes are dominated In Gastropods, while only three terpenes were identified in bivalves. Terpenes have been an important field of research in soft-bodied grazing gastropods, which they might gain these compounds from their diet for their own defense [5]. Sterols are dominated in bivalves partly because of their role in reproduction cycles, while they are rare in gastropods, taking into account that the large number of researches in bivalves is probably due to their importance in fisheries and aquaculture. Polyproprionates and alkaloids have been isolated from both classes, whereas aliphatic nitrogenous compounds are relatively uncommon in both [8].

There are an extraordinary series of unusual compounds in marine invertebrates, many of them cause interesting biological properties. For instance, opisthobranchs and pulmonates, particularly are important due to their secondary metabolites, and the ecological role and biosynthesis of these compounds could be related to their diet such as microalgae and diatoms. Opisthobranchs which are unprotected with reduced or completely absent shells, have defensive strategies using different chemicals [12]. The selected sampling stations were along different ecosystems such as Indian, Chinese, Mediterranean, Australian and Atlantic coasts of Spain, and strongly indicate that the metabolism of the opisthobranchs is influenced by geographical location, ecosystem type and habitats. The feeding ecology and habitats of all molluscs species are very selective, so feeding metabolites possessed by related species are more similar, while those de novo biosynthesized are most identical in species belonging to the same family but with different geographically habitat. Also, some recent biosynthetic experiments possessed had been discussed [23, 24].

Natural products research aimed at the isolation and identification of novel secondary metabolites, has only been undertaken on a small proportion of molluscan species to date. The bioactivity of many molluscan traditional medicines is yet to be substantiated, but preliminary data available from bivalves, cephalpods and caenogastropods suggests that there is likely to be some chemical basis to their medical applications.

All compounds which are produced by molluscs are varied because of environmental factors such as temperature, salinity and seasonally variations. Therefore, changes in environmental factors could cause variations in the chemical components. Therefore differences in chemical components need different conditions for production, for example fatty acids and amino acids are related to specific temperature and salinity. In conclusion, environmental factor changes in different seasons could be caused in decrease or increase level of compounds. Also, other biological factors such as food availability, metabolic and physiological activities can affect the compounds such as lipid and fatty acids composition of molluscs [13–15].

## 4. Different types of natural compounds in molluscs

Amino acids are classified into essential amino acids (EAA) (cannot synthesized by humans) and non-essential amino acids (NEAA). In addition to oils and other hydrocarbon derivatives in the marine environment, the hydrocarbons synthesized by organisms occur normally in this environment. Aliphatic hydrocarbons are the principal group, and can occur in several species of marine as well as terrestrial plants and animals.

There are different type of fatty acids such as ∑SFA, ∑MUFA, and ∑PUFA in the whole body of molluscs. There could be changes or variations in their levels of different groups in the different seasons. These differences might be based on temperature, feeding habitats, or metabolic demands [24–26].

The triacylglycerol compounds store SFAs for energy purposes in different processes in body and they also may be interim PUFAs reservoir, which could be transferred to the structural lipids or directed to specific metabolic routes for function of different organs. In contrast, phospholipid compounds fractions of mollusks show considerably less seasonal variations to maintain structural exactness of the cell as compared to the store of saturated fatty acids to be used as a source of energy and store of PUFAs required for phospholipid synthesis to multiple membrane structures or to be integrated in several metabolic processes [25, 26].

Molluscs are sources of many important and different natural compounds such as amino acids, fatty acids, lipids, terpenes and steroids. Different types of fatty acids such as lipids, ∑SFA, ∑MUFA, and ∑PUFA, omega 6 to omega 3 and other compounds are produced by different classes of molluscs specially polyplacophora, gastropoda, cephalopoda and bivalves. Four classes are important, that they could produce about 600 natural compounds. The level of natural compounds between different species, organ and sexes are different, and many of biotic and abiotic factors can cause variations in those levels. Also, the process and metabolism are different for all compounds. Finally, amino acids, lipids and fatty acids, terpenes and steroids are important natural compounds that they could be produced [27–29].

## 5. The role and importance of fatty acids in molluscs

Lipids are major sources of metabolic energy and of essential materials for the formation of cell and tissue membranes, and they are important in the processes of egg productions.

They are very important in the physiology and reproductive processes of marine animals and reflect the special biochemical and ecological conditions of the marine environment. Lipids also provide energy for growth during conditions of limited food supply, when carbohydrate levels (the main energetic reserve in molluscs) are low.

The lipid composition can be affected by external (exogenous) factors, such as fluctuations in the environmental conditions and qualitative and/or quantitative changes in food availability, or by internal (endogenous) factors such as sexual maturation [28–30].

Accumulation and depletion of stored reserves in molluscs depends mainly on the stage of gonad development, environmental factors affecting metabolic activities and on the quantity and nutritional value of the food supply. Usually, the glycogen compound is the major energy source in species, while lipids are considered as the nutritive store source of the gonad organs. A high correlation between the gonad lipid content and the phase of the reproductive process cycle has been established in different species of bivalves and also prosobranch species.

Seasonal variations in lipid and fatty acid compositions have been reported for several marine molluscs and are generally related to the growth process and the maturation cycle: in the summer season and in the high temperature when the growth process takes place, receptacles of lipid compounds are build up and stored, and these are later consume for gametogenesis in the maturation cycle (often autumn or winter), normally are decreased during spawning process. However, the majority of these publications have focused on the class bivalve class, probably because of their major commercial importance and influence on the public health of people. Studies about biochemical compounds and their chemical structures, particularly fatty acid compounds in prosobranch gastropods, are strait [30].

Limpets are herbivore grazers which remove large quantities of unicellular microbes, algal germ lings and detritus, apparently unselectively, during feeding excursions around the home scar. As a consequence, there are considerable variations in their diets. There is a large amount of literature detailing about fatty acid compositions of a large number of species of marine algae. Availability and quality of algal lipids are very important in the nutrition, growth and development of aquatic animals such as marine fish larvae, shrimps and molluscs [28, 31, 32].

Molluscs phylum are of important aquatic invertebrates that the levels of the chemical compounds such as fatty acid components are higher in their tissues in comparison with other animals. They exhibit a range of lipid and fatty acid components in both freshwater and marine species and therefore fatty acid contents in mollusks are studied in many habitats, because of their importance in human's life. Among the marine invertebrates, the molluscs are the potential source of bioactive substances. The bioactive compounds isolated from the gastropods are considered to have a role in the chemical defense of the animals against their predators. Molluscs in the oceans are common sight and are virtually untapped resource for the discovery of novel compounds [27, 29].

Marine molluscs are excellent sources of nutritionally important compounds, such as fatty acids, amino acids and sterols. Fatty acids are essential for life, due to their key role as a good source of energy, membrane constituents, as well as metabolic and signaling mediators. In recent years, poly unsaturated fatty acids (PUFAs) have been recognized as a good remedy for cardiovascular diseases. Marine organisms consume diets rich in n-3 PUFAs and the lipids of the animals can contain up to 50% unsaturated fatty acids, with five or six double bonds, including 22:6 n-3 and 20:5 n-3 [18, 19].

The term sterol refers to a compound with a fused cyclopentano phenanthrene ring with a 3-hydroxyl moiety. Early studies of gastropod sterols indicated cholesterol as the principal sterol of all species. Most species only one or two types of sterols present. Amino acids are the building blocks of protein molecules. They cause metabolites in the homeostasis of an organisms, due to their role as the regulation of several cellular processes and also as precursors of other molecules, such as hormones and nitrogenous bases. Lipid compositions and storage strategy in molluscs, particularly of bivalves and gastropods, have been studied since lipids constitute a major fraction of molluscan tissues. Almost all the data included in their lipid studies, concern the entire organism and only a few reports on the tissue distribution of fatty acids are available [24, 26, 28, 29].

The lipid in the gill tissue in the marine molluscs has important role for regulate of ions such as Na. In the marine animals, the primary site of Na uptake is gills. In addition to being the initially site of an ion transport, gills also captive food, have roles in gas exchanges and act as a brooding chamber for the larval glochidia in females species. Thus, gills activate in many different functions, regarding that their related importance may vary during the year. From the lipids, C20:4ω6 acid is an active substrate for prostaglandin productions involved in regulating Na uptake and it has relatively high contents in gill lipids. Therefore, high level of C20:4ω6 acid in the gill is probably related to prostaglandin synthesizing in the gills to regulate Na uptake. Finally the accumulation of C20:4ω6 acid in the gills was related to physiological activities in the organs [22, 30–33].

Fatty acids are organic compounds consist of hydrocarbon chains with terminal carboxyl groups. The fatty acid chains in sea foods differ from vegetables in length. In the presence of Omega-3 fatty acids, prostaglandins actions on epinephrine is diminished and thus constriction or narrowing of blood vessels is prevented. Therefore, marine Mollusca have been regarded as a good source of lipid compounds, and lipids are proper energy sources for animals and nutritive foodstuff for human diets [34].

## 6. Omega 6 to omega 3 ratio and its related effects

Normally, the omega 6 to omega 3 ratio has moderate amounts in natural food sources, especially in marine foods. In aquatic creatures, omega 6 to omega 3 ratio in the tissues of molluscs is significantly higher in comparison with others. Also, the omega 6 to omega 3 ratio vary between different organs and different species, as well as marine and freshwater species. There are significant differences in the omega 6 to omega 3 ratio in the gills, foot, mantle and whole body tissues of molluscs species, respectively [12, 14, 35].

Different species of the marine molluscs are generally rich in fatty acid compounds of ω3 (especially C18:3ω3, C20:5ω3 and C22:6ω3). The mussels species in freshwater, however, include a greater proportion of fatty acids compounds of ω6 (especially C18:2ω6 and C20:4ω6). The $\Sigma\omega6/\Sigma\omega3$ ratios is 2:4 in freshwater mussels, but the marine species have ratios of 0.1:1.0 [12].

Obesity disease which is a complex condition along with organs dysregulations and molecular pathways, such as adipose organ, liver, gastrointestinal tract, pancreas, central nervous system (CNS), and genetics. The role of the CNS in this disease needs more attention as obesity rates rise and relating treatments might fail. Since hypothalamus system has long been recognized in the regulation of appetite and food intake, the role of the CNS systems were examined as well as environmental impacts on energy balance. Furthermore, the omega-3 fatty acids have an important role in this disease and in the prevention and management of obesity [3, 4, 6].

The omega-6 and omega-3 polyunsaturated fatty acids (PUFAs) compounds are very important and essential fatty acids that must be derived from the diet compositions. Since omega-6 and omega-3 polyunsaturated fatty acids (PUFAs) compounds need endogenous enzymes for omega desaturation and there are no endogenous enzymes for omega desaturation in human and other mammals, these compounds cannot be made by man or other mammals and could be made particularly by Mollusca species. Modern agricultural western diets contain excessive concentrations of omega-6 PUFAs but very low concentrations of omega-3 PUFAs, leading to an unhealthy omega-6/omega-3 ratio of 20:1, instead of 1:1 proper for evolution process in the humans [9, 10].

Thus, an unbalanced omega-6/omega-3 ratio in favor of omega-6 PUFAs is highly prothrombotic and proinflammatory, which contributes to the prevalence of atherosclerosis, obesity, and diabetes. In fact, regular and balance of the omega-6/omega-3 ratio have positive effects for of these diseases and is the important factor for improve of these diseases (obesity, diabetes, atherosclerosis and cancer) [23, 24, 26, 30].

As mentioned earlier, omega-6 to omega-3 fatty acids compounds cannot be made and convert in humans and other mammalian cells, therefore, they cannot made enzyme for omega-3 desaturase and so they lack converting enzyme, omega-3 desaturase. Omega-6 and omega-3 fatty acids compounds are not interconvertible, and they are metabolically compounds and functionally distinct. Also they have important opposing physiological influences, therefore, omega-6 to omega-3 fatty acids balance in the diet is very important for better function and body protection [6, 7]. When fish consume by humans or predators, the EPA and DHA from the diet composition partially replace the omega-6 fatty acids, especially AA, in the skin and membranes of almost all body cells, but specifically in the membranes of platelets, erythrocytes, neutrophils, monocytes, and liver cells. The parent compounds for eicosanoid formation, are AA and EPA fatty acids. Because of high levels of omega-6 in the diet, the eicosanoid metabolic products from AA, especially prostaglandins, thromboxane, leukotriene, hydroxyl fatty acids, and lipoids, are formed in larger amounts than those derived from omega-3 fatty acids, especially EPA [32]. The eicosanoids from AA are biologically active in very small concentrations and, if they are formed in high levels, they contribute to the formation of thrombus and atheroma; allergic and inflammatory disorders, particularly in susceptible people; and proliferation of cells. Thus, a diet composition rich in omega-6 fatty acids shifts the physiological state to prothrombotic, proinflammatory, and proaggregatory effects with increases in blood viscosity, vasospasm, and vasoconstriction and cell proliferation. Omega-6 and omega-3 fatty acids balance is a physiological state that is less inflammatory in terms of prostaglandin, gene expression and leukotriene metabolism activity, and interleukin-1 (IL-1) production [28–31].

Novel agricultural technologies, by changing animal feeds for better and short term productions, have decreased the omega-3 fatty acid contents in many foods such as meats, eggs, and even fish. Foods from edible wild plants contain a good balance of omega-6 and omega-3 fatty acids. For instance, *Purslane*, a wild plant, in comparison to *Spinach*, red leaf lettuce, butter crunch lettuce and mustard greens, has eight times more ALA than the cultivated plants [30]. New aquaculture technologies produce fish with less omega-3 fatty acids than naturally grown fish in the ocean or freshwaters. The fatty acid composition in egg yolk from free-ranging chicken has an omega-6: omega-3 ratio of 1.3 whereas egg production supervising by the United States Department of Agriculture (USDA) conclude ratio of 19.9. By enriching the chicken feed with fishmeal or flaxseed, the ratio of omega-6: omega-3 decreased to 6.6 and 1.6 respectively [33].

High omega-6/omega-3 ratios cause some disorders such as increasing in the end cannabinoid signaling and related mediators, which could lead to change inflammatory state, energy homeostasis, and mood. In animal experiments a high omega-6 acid intake leads to decreased insulin sensitivity in muscle and promotes fat accumulation in adipose tissues. Nutritional approaches with dietary omega-3 fatty acids reverse the dysregulation of this system, improve insulin sensitivity and control body fat [5, 7].

End cannabinoids are lipids, derived from the omega-6 AA. Their concentrations are regulated by (1) dietary intake of omega-6 and omega-3 fatty acids; and (2) by the activity of biosynthetic and catabolic enzymes involved in the end cannabinoid pathway, which is an important parameter in regulation of appetite and metabolism. The end cannabinoid system is involved in preservation of energy balance and sustained hyperactivity of the end cannabinoid system which result obesity. Finally, omega 6 to omega 3 ratio is important factor in regulation metabolism and enzyme activities, and is important factor in control and improve of the nervous system diseases and genetics [9, 10, 13, 14].

## 7. Environmental parameters and nutrition effects on biocompounds variations

Environmental and biological parameters could change the amount and structure of natural compounds (fatty acids, amino acids and steroids). The environmental and biological factors could change in the different seasons, therefore, seasonal changes have the main role in the variations in the amount and structure of natural compounds. Studies of seasonal variations in biochemical contents of organisms explain how environment, biology, ecology and physiology can affect the compositions. As such, seasonal variations in the biochemistry of phylum Mollusca are known to be related to the complex interaction of both biological parameters (reproduction, growth, food type, food bioavailability, sex, tissue variance), and environmental parameters (temperature, salinity of water and pH) [21, 23, 24].

Observations the close correlations between temperature in the aquatic environment and different compounds in the tissues of Mollusca, could be explained by varying the level of metabolisms in different temperatures, which could change in the amount of biocompounds in the tissues of animals. Also, salinity of water and pH has effect on the variations in the compounds such as fatty acids. The accumulation of fatty acids in the different tissues of organisms vary in different salinity and pH. Also, the accumulation of fatty acids in the different level of salinity and pH are not similar for different organs, and fatty acid profiles and their amounts in gill tissue for example, has more variations in the different salinities [4, 6].

Levels of proteins, lipids and carbohydrates (glycogen) have been shown to fluctuate with food availability. Food abundance allows for the accumulation of proteins and lipids in the tissues of the different species such as bivalves and gastropods. There are correlations between food type source and biocompounds structure, which increase in the food availability in the aquatic environment could result increasing the amount of the biocompounds in the tissues of the different species of Mollusca. When food availability levels are high in the environment the level of biocompounds are higher in comparison with other situations [17, 20]. The reproductive cycle and time spawning have the key role in the variation of chemistry compounds especially fatty acids, because of the high levels of energy needs for spawning processes and the high level of fatty acids consumed in this process [31, 32].

Lipids generally increase during the course of gametogenesis and decrease upon release of gametes. For proteins, diverging trends have been observed throughout gametogenesis and spawning. During gametogenesis, protein content was found to increase, decrease or even remain stable. During spawning, levels of protein were found to increase or decrease. Differences in food availability and water temperature conditions may partially explain the observed discrepancies since these factors are known to influence protein accumulation [1, 2].

Focusing on proteins and lipids, compounds involved in most biochemical and physiological processes of any organism is therefore useful for the recognition of ecological and physiological changes. Indeed, differences in seasonal trends have been observed among both AAs and FAs. More commonly reported, is the different behavior exhibited among free AAs in relation to salinity and that exhibited among FAs in relation to temperature. The biochemical composition of an organism is determined by endogenous (e.g., gametogenesis, maturation, spawning) and exogenous (e.g., food availability, salinity, temperature) processes. The temporal tests in the field of biochemical compounds permit intercrossing along with chronological and other variables allowing researchers to gain knowledge about ecology and physiology of an organism and also understanding how the surrounding ecosystem may affect [8, 9, 12].

There are significant differences between tissues and their activities for accumulation of amount and structure of natural compounds, and different tissues based on their activities can be accumulated fatty acids, amino acids and other compounds. Therefore, the level of compounds in the tissues are related to their activities. Some tissues such as gonad have highest level of biocompounds in comparison with the other tissues, due to this fact that gonad must have high level of energy for reproductive and spawning process. Since, gonad consume high amount of energy for this process, reproductive and spawning processes need high levels of energy. Also, gills need high energy levels for their metabolism, and so the high levels of fatty acids can be accumulate in this tissue [15, 16].

Sex types in the mollusca could affect variations in the concentrations and structures of natural compounds, because the biological factors are different between male and female animals and therefore changes in biological factors could cause variations in the compounds. One of the important factors in female animals is reproductive or spawning process, which could result variations during consuming of compounds. Since this process needs high energy, almost more energy levels are consumed in the reproductive cycles. Therefore, decreasing in energy levels of female species are observed. Also, other factors such as metabolism ratio vary between different sexes, therefore, level of compounds change between sex types [17].

Finally, according to many studies conclusions biotic and abiotic factors have effective results on variations of natural compounds. Throughout abiotic and environmental factors; temperature, salinity and pH, and in biotic factors; growth, reproduction cycle, food availability, sex type, tissue variances and functions, have the most important effects on the variations of natural compounds concentration and structure of lipids, fatty acids, amino acids and steroids.

## Author details

Nooshin Sadjadi

Address all correspondence to: nooshinsadjadi@yahoo.com

Environmental Science and Technology Department, Marine Science and Technology Faculty, North Tehran Branch, Islamic Azad University, Tehran, Iran

## References

[1] Amsler CD, Iken KB, McClintock JB, Baker BJ. Secondary metabolites from Antarctic marine organisms and their ecological implications. In: McClintock JB, Baker BJ, editors. Marine Chemical Ecology. Boca Raton: CRC Press; 2001. pp. 267-300

[2] Amsler CD, McClintock JB, Baker BJ. Secondary metabolites as mediators of trophic interactions among Antarctic marine organisms. American Zoologist. 2001;**41**:17-26

[3] Anil MK. Laboratory rearing and breeding of spineless cuttlefish Sepiella inermis Orbigny (Mollusca: Cephalopoda). Journal of Aquaculture in the Tropics. 2003;**18**:35-44

[4] Avila C, Iken K, Fontana A, Cimino G. Chemical ecology of the Antarctic nudibranch Bathydoris hodgsoni Eliot, 1907: Defensive role and origin of its natural products. Journal of Experimental Marine Biology and Ecology. 2000;**252**(1):27-44

[5] Avila C, Fontana A, Esposito M, Ciavatta ML, Cimino G. Fatty acids of Antarctic gastropods: Distribution and comparison with Mediterranean species. Iberus. 2004;**22**:34-44

[6] Bachère E. Anti-infectious immune effectors in marine invertebrates: Potential tools for disease control in larviculture. Aquaculture. 2003;**227**:427-438

[7] Bahamondes-Rojas I, Bretos M. Induction of spawning and early development in *Fissurella picta* (Mollusca: Archaeogastropoda) from Southern Chile. Journal of Shellfish Research. 2002;**21**:185-191

[8] Benkendorff K, Davis AR, Rogers CN, Bremner JB. Free fatty acids and sterols in the benthic spawn of aquatic molluscs, and their associated antimicrobial properties. Journal of Experimental Marine Biology and Ecology. 2005;**316**:29-44

[9] Blunt JW, Copp BR, Munro MHG, Northcote PT, Prinsep MR. Marine natural products. Natural Product Reports. 2005;**22**:15-61

[10] Cohan CS, Karnes JL, Zhou FQ. Culturing neurons from the snail Helisoma. Methods in Cell Biology. 2003;**71**:157-170

[11] Constantino V, Fattorusso E, Menna M, Taglialatela-Scafati O. Chemical diversity of bioactive marine natural products: An illustrative case study. Current Medicinal Chemistry. 2004;**11**:1671-1692

[12] Hadfield MG, Paul VJ. Natural chemical cues for settlement and metamorphosis of marine invertebrate larvae. In: McClintock JB, Baker BJ, editors. Marine Chemical Ecology. Boca Raton: CRC; 2001. pp. 431-461

[13] Iijima R, Kisugi J, Yamazaki M. L-Amino acid oxidase activity of an antineoplastic factor of a marine mollusk and its relationship to cytotoxicity. Developmental and Comparative Immunology. 2003;**27**:505-512

[14] Ishikura M, Hagiwara K, Takishita K, Haga M, Iwai K, Maruyama T. Isolation of new Symbiodinium strains from tridacnid giant clam (*Tridachna crocea*) and sea slug (*Pteraeolidia ianthina*) using culture medium containing giant clam tissue homogenate. Marine Biotechnology. 2004;**6**:378-385

[15] Jansen BJM, de Groot A. Occurrence, biological activity and synthesis of drimane sesquiterpenoids. Natural Product Reports. 2004;**21**:449-477

[16] Jimeno JM. A clinical armamentarium of marine-derived anti-cancer compounds. Anti-Cancer Drugs. 2002;**13**(Suppl 1):15-11

[17] Koueta N, Boucaud-Camou E. Combined effects of photoperiod and feeding frequency on survival and growth of juvenile cuttlefish *Sepia officinalis* L. in experimental rearing. Journal of Experimental Marine Biology and Ecology. 2003;**296**:215-226

[18] Gannefors C, Boer M, Kattner G, Graeve M, Eiane K, Gulliksen B, Hop H, Falk-Petersen S. The Arctic sea butterfly *Limacina helicina*: Lipids and life strategy. Marine Biology. 2005;**147**:169-177. DOI: 10.1007/s00227-004-1544-y

[19] Hanuš LO, Levitsky DO, Shkrob I, Dembitsky VM. Plasmalogens, fatty acids and alkyl glyceryl ethers of marine and freshwater clams and mussels. Food Chemistry. 2009;**116**: 491-498. DOI: 10.1016/j.foodchem.2009.03.004

[20] Kirsten B. Molluscan biological and chemical diversity: Secondary metabolites and medicinal resources produced by marine molluscs. Biological Reviews. 2010. DOI: 10.1111/j.1469-185X.2010.00124

[21] Magnusson CD, Haraldsson GG. Ether lipids. Chemistry and Physics of Lipids. 2011; **164**:315-340

[22] Dembitsky VM, Rezanka T, Kashin AG. Fatty acid and phospholipid composition of freshwater molluscs *Anodonta piscinalis* and *Limnaea fragilis* from the river Volga. Comparative Biochemistry and Physiology. 1993;**105**:597-601

[23] Kraffe E, Sounant P, Marty A. Fatty acids of serine, ethanolamine, and choline plasmalogens in some marine bivalves. Lipids. 2004;**39**:59-66. DOI: 10.1007/s11745-004-1202-x

[24] Brosche T, Brueckmann M, Haase KK, Sieber C, Bertsch T. Decreased plasmalogen concentration as a surrogate marker of oxidative stress in patients presenting with acute coronary syndromes or supraventricular tachycardias. Clinical Chemistry and Laboratory Medicine. 2007;**45**:689-691

[25] Latorre E, Collado MP, Fernandez I, Aragones MD, Catalan RE. Signaling events mediating activation of brain ethanolamine plasmalogen hydrolysis by ceramide. European Journal of Biochemistry. 2003;**270**:36-46

[26] Hartmann T, Kuchenbecker J, Grimm MO. Alzheimer's disease: The lipid connection. Journal of Neurochemistry. 2007;**103**:159-170. DOI: 10.1111/j.1471-4159.2007.04715.x

[27] Carballeira NM. New advances in fatty acids as antimalarial, antimycobacterial and antifungal agents. Progress in Lipid Research. 2008;**47**:50-61. DOI: 10.1016/j.plipres.2007.10.002

[28] Proksch P, Edrada RA, Ebel R. Drugs from the seas—Current status and microbiological implications. Applied Microbiology and Biotechnology. 2002;**59**:125-134. DOI: 10.1007/s00253-002-1006-8

[29] Schmidt EW, Donia MS. Life in cellulose houses: Symbiotic bacterial biosynthesis of ascidian drugs and drug leads. Current Opinion in Biotechnology. 2010;**21**:827-833. DOI: 10.1016/j.copbio.2010.10.006

[30] Lindquist N, Barber PH, Weisz JB. Episymbiotic microbes as food and defence for marine isopods, unique symbioses in a hostile environment. Proceedings of the Biological Sciences. 2005;**272**:1209-1216. DOI: 10.1098/rspb.2005.3082

[31] Haine ER. Symbiont-mediated protection. Proceedings of the Biological Sciences. 2008; **275**:353-361. DOI: 10.1098/rspb.2007.1211

[32] Wagele H, Ballesteros M, Avila C. Defensive glandular structures in Opisthobranch mollusks—From histology to ecology. Oceanography and Marine Biology. 2006;**44**:197-276

[33] Schuett C, Doepke H. Endobacterial morphotypes in nudibranch cerata tips: A SEM analysis. Helgoland Marine Research. 2013;**67**:219-227. DOI: 10.1007/s10152-012-0317-0

[34] Zhukova NV, Eliseikina MG, Balakirev ES, Ayala FJ. A Novel Symbiotic Association of the Nudibranch Mollusk Rostanga Alisae with Bacteria. 2014. Unpublished work

[35] Sajjadi N et al. Seasonal variations of n-6: N-3 ratios and fatty acid compositions in foot and tissue of *Chiton Lamyi* in a high primary productivity area. American Journal of Environmental Sciences. 2009;**5**(3):278-284