



Review

Marine foods as functional ingredients in bakery and pasta products

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ABSTRACT

Marine food, due to its phenomenal biodiversity is a treasure house of many novel healthy food ingredients and biologically active compounds as fish oils, fish proteins, bioactive peptides, seaweeds, macroalgae and microalgae. Despite having so much health benefits, marine functional ingredients have been under exploited for food purposes. Bakery and pasta products, being most widely consumed food products all over the world are the best sources of incorporating marine functional ingredient and reaching the targeted population. Current status and future projections of marine functional ingredients in bakery and pasta products are reviewed in this communication.

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1. Introduction

Diet and health relationship was initially proposed in fourth century B.C. by Hippocrates. In 1999, a European Community (EC) Concerted Action on Functional Foods Science in Europe (FUFOSE)

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tightened the definition of “functional food”. It declared a food as “functional” if – “it is satisfactorily demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects, in a way that is relevant to either an improved state of health and well-being and/or reduction in risk of disease” (Ross, 2000).

Marine foods contain many chemical compounds with nutraceutical potential

- 1) Particular components are directly connected with well-defined physiological effects and the health benefit is linked to a single product, thus it is expensive affair.
- 2) It creates novelty in food without necessarily changing the sensory properties of food.
- 3) As the manufacture of functional food, this component needs to be added, removed or modified it is perceived as less natural product to consumer (Urala, & Lahteenmaki, 2004).

2. Marine food: current status

As people become increasingly aware of the relation between diet and good health, the consumption of fishery products will most likely increase. The consumer recognizes that fish and shellfish are nutritious and wholesome foods. They are perceived as an excellent source of high-quality protein, containing lipids with high levels of unsaturated fatty acids, and perhaps contributing to the enhancement of human health by reducing the risk of cardiovascular disease. Likewise, seafood is characteristically tender, easily digested, and a good source of many important minerals. Marine food sources have found enormous compounds, which are good for health and are having nutraceutical value. These include omega-3 oils, chitin and chitosan, fish protein hydrolysates, algal constituents, carotenoids, antioxidants, fish processing by-products such as fish bone, shark cartilage, taurine and bioactive compounds. Omega-3 oils are much popular and extensively used than any other ingredients of marine source. Chitin and chitosan are polysaccharides, which are gaining much attention. Fish protein hydrolysates are enzyme hydrolysis products of fish proteins. Algae and seaweed have been found to be good source of dietary fibre and antioxidants and carotenoids on other hand fish bone and shark cartilage are extensively used as source of calcium.

3. Obstacles and challenges in food application

There are various challenges ahead for use of marine functional ingredients in daily diet. These include low consumer awareness among people about potential health benefits at grass roots level, pollution of seafood with various hazardous components as industrial waste, metals etc., sensory changes in the product with incorporation of marine food and changes in physicochemical properties of food.

4. Pasta and bakery industry

Pasta is an Italian word to describe a cooked, extruded and dried wheat product. The usual basic ingredients are wheat flour or semolina and water. Alternatives include potato flour and maize flour. Italy consumes the most at about 28.5 kg/person/year and regionally it may range as high as 48 kg in Sicily. Italian domestic pasta consumption is flat and a proportion of the production is aimed at the export market. On the other hand, consumption is growing in other countries around the world. For example, in the United States, pasta consumption rose from about 3 kg/person/year in 1965 to a level of 9 kg in 1999. The nearly ubiquitous consumption of cereals all over the world gives cereals an important position in international nutrition. Besides the high starch content as energy source, cereals provide dietary fibre, nutritious protein and lipids rich in essential fatty acids. Important micronutrients present in cereals are vitamins,

especially many B vitamins, minerals, antioxidants and phytochemicals. In general, cereals provide important amounts of most nutrients.

5. Nature of marine functional ingredients

In the above context potential exists for exploitation of marine foods as functional ingredients such as chitin, chitosan, omega-3 oils, seaweed, algae and microalgae, carotenoids, vitamins and minerals, shark cartilage and calcium in fish bone, bioactive peptides, fish protein hydrolysates and taurine, a brief about these is given below. Table 1 summarizes marine functional ingredients, sources and potential health benefits.

5.1. Chitin

Chitin and chitosan polymers have unique structures properties, highly sophisticated functions and wide ranging applications in variety of fields such as agricultural, chemistry, medicine, biotechnology, the pulp and paper industry, cosmetics, water treatment and foods (Chandy & Sharma, 1990). Chitosan is approved for use as a food additive or dietary supplement in countries such as Japan, England, USA, Italy, Portugal, and Finland. In 1992, chitosan was accepted as a functional food ingredient by Japan's health department. The main producers of chitosan are Japan and the United states with smaller operations in India, Italy and Poland (Chen & Subirade, 2005). Chitin and chitosan have a variety of nutraceutical applications, including immune-enhancement, disease recovery, and use as dietary fibre. Their ability to be useful in these areas is largely dependent on factors such as molecular weight and degree of N-acetylation, which can greatly influence solubility and interactions with other biomolecules.

5.2. Omega-3 fatty acids

Lipids contribute to food quality by providing flavor, aroma, colour, texture, taste, and nutritive value. From the nutritional point of view, lipids function as sources of metabolic energy, carrier of fat-soluble vitamins (e.g., A, D, E, and K), and contribute to the formation of cell and tissue membranes (Dyerberg et al., 1975).

The ratio of fatty acids namely linoleic acid (LA, 18:2, n–6) and alpha linolenic acid (ALA, 18:3, n–3) in the diet plays an important role in enrichment of ALA in tissues and further conversion to long-chain polyunsaturated fatty acids (LC-PUFA) like eicosapentaenoic acid (EPA) and docosaheptaenoic acid (DHA) (Lokesh, Diwakar, Dutta, & Naidu, 2008).

Table 1
Marine functional ingredients and potential health benefits.

Ingredient	Sources/component	Potential health benefit
Chitin chitosan	Crab, shrimp	Prevention of inflammatory disorders Antibacterial activity
Omega-3 oils	Salmon oil, cod Liver oil	Prevention of cardio vascular diseases Brain function in children
Seaweed	Wakame	Antioxidant and antitumor agent
Polysaccharides	Carrageenan	Anti-carcinogenic, antiviral
Carotenoids	Astaxanthin Fucoxanthin	Antioxidants, prevent neurodegenerative diseases
Vitamins and minerals	Marine fish	Growth and physiology of body
Shark cartilage	Shark	Anti-carcinogenic agent
Calcium	Fish bone	Teeth and bones strength and antitumor agent
Bioactive peptides	Fish protein	Obesity control and Ca-binding activity
Fish protein hydrolysates	Fish protein	Protein supplement
Taurine	Cod, mackerel	Prevent CVDs, Alzheimer's disease and cystic fibrosis.

Omega-3 oils are incorporated in bakery products, pastas, dairy products such as milk, yogurt and juice as well as nutrition bars. Novel microencapsulated oil prepared by Ocean Nutrition Canada, known as MEG 3 remains protected from environment until it reaches the gastrointestinal tract (Young & Conquer, 2008). A study by Conquer and Holub (1998) showed that DHA supplementation in humans increased serum DHA as non-esterified fatty acid at levels that were potentially antithrombotic. Liu, Wallin, and Saldeen (2001) found a significant increase in plasma omega-3 fatty acids and in HDL-cholesterol in 36 hyperlipidemic patients fed with bread containing fish oil. Park, Choi, and Kim (2000) reported that fish oil had a protective effect against cardiovascular disease by inhibiting hepatic HMG CoA reductase activity and increasing hepatic microsomal fluidity, leading to a reduction in plasma lipids. The ability of ω -3 polyunsaturated fatty acids to modulate tumor-cell growth was demonstrated for EPA by Chiu and Wan (1999). They showed EPA arrested cell-cycle progression at G₀/G₁ phase, inducing necrosis in human leukemic HL-60 and K-562 cells *in vitro*. EPA, however, only induced apoptosis in HL-60 cells by down-regulation of Bcl-2. Consequently, PUFAs (Poly Unsaturated Fatty Acids) and their derivatives and analogues are important nutraceutical and pharmaceutical targets (Ward & Singh, 2005).

Omega fatty acids have potential application in health promotion; prevention from atherosclerosis, protection against arrhythmias, reduce blood pressure, beneficial for diabetic patients, fight against manic-depressive illness, reduce symptoms in asthma patients, protection against chronic obstructive pulmonary diseases, alleviation of symptoms of cystic fibrosis, prevent various cancers, provide bone health, and improve brain functions in children.

5.3. Seaweed

Seaweed contains a significant amount of soluble polysaccharides, and has potential function as dietary fibre. The seaweed polysaccharides possess a higher Water Holding Capacity (WHC) than cellulosic fibres. There is an interest in seaweed hydrocolloids for human nutrition as they can act as dietary fibre, their physiological effects being closely related to their physicochemical properties such as solubility, viscosity, hydration, and ion-exchange capacities in the digestive tract (Lahaye & Kaeffer, 1997). Seaweed is a source of biologically active phytochemicals, which include carotenoids, phycobilins, fatty acids, polysaccharides, vitamins, sterols, tocopherol, phycocyanins among others. Many of these compounds have been recognized to possess biological activity and hence beneficial for use in human and animal healthcare. Some of the potential benefits included control of hyperlipidemia, thrombosis, tumor, and obesity (Plaza, Cifuentes, & Ibanez, 2008). Seaweed as a source of bioactive compounds is helpful as; antioxidant activity – carotenoids, antibacterial and antiviral activities of dietary polysaccharides – carrageenan, platelet aggregation, antitumor activity, hyperoxaluria, HIV inhibition, hyaluronidase inhibition. *Sargassum marginatum*, *Padina tetrastomatica* and *Turbinaria conoides* are Indian seaweeds having good amount of antioxidant activity. *In vitro* antioxidant activity of methanolic extracts from all the three seaweeds showed an increase with increasing concentration indicating the dose dependency of these properties (Bhaskar, Ganesan, & Kumar, 2008).

5.4. Microalgae

Microalgae can be used to enhance the nutritional value of food and animal feed, they play a crucial role in aquaculture and they can be incorporated into cosmetics (Spolaore, Joannis-Cassan, Duran, & Isambert, 2006). Microalgae are also rich in pigments like chlorophyll (0.5% to 1% of dry weight), carotenoids (0.1% to 0.2% of dry weight on average and up to 14% of dry weight for β -carotene of *Dunaliella*) and phycobiliproteins. These molecules have a wide range of commercial applications (Becker, 1988). However, prior to commercialization,

algal material must be analyzed for the presence of toxic compounds to prove their harmlessness (Metting, 1996).

5.5. Polysaccharides

Algae have mainly been used in western countries as raw material to extract alginates (from brown algae) and carragenates (from red algae). Algae also contain multitude of bioactive compounds that might have antioxidant, antibacterial, antiviral and anticarcinogenic properties. Some of them are outlined later due to their special interest as possible functional ingredients.

Consumption of dietary fibre has a positive influence on several aspects related to health such as reducing the risk of suffering from colon cancer, constipation, hypercholesterolemia, obesity and diabetes. Besides, many constituents of dietary fibre show antioxidant activity as well as immunological activity (Suzuki et al., 2004). In this sense, *U. pinnatifida* (wakame) showed some positive effect on cardiovascular diseases (hypertension and hypercholesterolemia) (Ikeda et al., 2003); this alga contains basically dietetic fibre, being its principal component alginate. This alginic acid has demonstrated to reduce hypertension in hypertensive rates (Ikeda et al., 2003).

5.6. Carotenoids

The carotenoids, found in nature, can be classified into two: hydrocarbons, such as β -carotene, xanthophylls, and the oxygenated derivatives of carotenes such as astaxene, astaxanthin, canthaxanthin, cryptoxanthin, echionine, lutein, neoxanthin, violaxanthin, and zeaxanthin. Originally of interest for their use as a food colouring agent, and still used as such, these compounds give some fish and shellfish their reddish pink colour. The two main carotenoids, astaxanthin and canthaxanthin are extracted from crab and shrimp processing. Newer uses for both these compounds have been identified. Their highly antioxidative properties make them candidates as functional food ingredients. Astaxanthin may have a use as an anti-aging compound, whilst canthaxanthin could contribute to treatments for Alzheimer's and Parkinson's disease, high cholesterol, strokes and cancer (Miyashita & Hosokawa, 2008).

Crabs are important crustaceans, in which carotenoids occur. Astaxanthin and its esters were found to be the major carotenoids in red kelp crab, *Taliepes nuttalli*, snow crab *Chinocetes opilio*, hermit crab, *Paralithodes brevipes*, and blue crab (Sachindra, Bhaskar, & Mahendrakar, 2005).

Astaxanthin is a very potent antioxidant. Several studies have shown that its activity can be several folds higher than that of other antioxidants, for example β -carotene and Vitamin E. The powerful antioxidant activity also can play a role in astaxanthin's enhancement of immune responses, liver function and eye, joint, prostate, and heart health. It can also be used in cardiovascular health, neurodegenerative diseases and anticancer activity (Olaizola, 2008). Wakame (*Undaria pinnatifida*) is one of the most popular edible seaweed in Japan and has been found to contain 5–10% fucoxanthin apart from containing polar lipids such as glycolipids. Health benefits of fucoxanthin are anticancer effect – it is evaluated that neoxanthin and fucoxanthin were reported to cause a remarkable reduction in growth of prostate cancer cells, and also demonstrated antiobesity activity and anti-inflammatory activity (Miyashita & Hosokawa, 2008). Fucoxanthin is other major biofunctional pigment of brown seaweeds and the content in various edible seaweeds including *U. pinnatifida* has been reviewed by Hosakawa, Bhaskar, Sashima, and Miyashita (2006).

5.7. Vitamins and minerals

Marine fish oils are rich sources of vitamins A, D, and E. Vitamin A is concentrated mostly in fish liver oils. Halibut and cod liver oils are rich sources of vitamins A and D. Sardine fish contains up to 4500 IU of

vitamin A and up to 500 IU of vitamin D per 100 g of meat, with an average of 125 µg/g of oil. The vitamin A found in small fish species is particularly bio-available (Mansour, 1999). A 3.5 oz portion provides 90% of the daily need of vitamin D. Herring, mackerel, salmon, and lake trout contain varying amounts of vitamin D in their tissues. Patients who consumed more amount of vitamin D and calcium contained in daily servings of dairy products and fish were 40% less likely to develop polyps than those who got little or no vitamin D (Volkman, 1999).

5.8. Calcium and fish bone

Fish bone is considered as a potential source of calcium. Fish bone material derived from processing of large fish is a useful calcium source. To use fish bone as a calcium fortificant, the bone should be converted into an edible form by softening its structure. Fish bone powder is a potential value-added by-product of the tuna processing industry. The calcium containing powder from fish bone could be used for the fortification of fish products such as surimi (Shungan, 1996).

5.9. Bio-active peptides

Fish and other foods are known to contain anti-hypertensive peptides known as angiotensin I converting enzyme (ACE) inhibitors (Ono, 2003). These bioactive components are found in the muscle flesh of various species (Matsumoto, 1994).

5.10. Fish protein hydrolyzate

Hydrolyzates are defined as proteins that are chemically or biologically broken down to peptides of varying sizes. Fish protein hydrolyzates (FPH) are prepared by digestion of fish meat by proteolytic enzymes and have been considered as an alternative approach for converting underutilized fish biomass into edible protein products, instead of animal feed or fertilizer. The process of preparation of FPH consists of proteolytic digestion of fish and fish waste at optimal conditions of pH and temperature required by the enzymes. The enzymes can be from plant (papain and ficin), animal (trypsin and pancreatin), or microbial (pronase and alcalase) sources (Löffler, 1986).

Currently it has been used as milk replacement in young animal feeding, fermented fish sauces, the production of fish peptone broth as a microbiological growth media, and as food binding and gelling agents. The main obstacle for commercial development of FPH into human food products has been process economics, non-uniformity of final product, functional problems and off-odors/flavors that can commonly develop during this process (Kristinsson & Rasco, 2000).

5.11. Taurine

Fish is a good source of taurine a conditionally essential amino acid that has been shown to be involved in certain aspects of mammalian development. The molecule contains a sulfonic-acid group, rather than the carboxylic acid moiety, that is not incorporated into proteins and is one of the most abundant free amino acids in many tissues, including skeletal and cardiac muscle and the brain. Taurine is present in cod, mackerel, farmed and wild salmon, albacore tuna, ray, siki shark, whiting and several other species. Taurine, hypotaurine, and thiotaurine have been identified and assayed in several deep sea organisms including bivalves and tube worms living close to hydrothermal vent sites. The potential use of taurine to reduce blood pressure, improve cardiac performance and reduce blood cholesterol levels (Gormley, 2006).

6. Application in bakery products

6.1. Marine fatty acids in bakery products

Currently, the terms 'functional foods' and 'nutraceuticals' seem to be dominating the food market. Bread is an excellent product in which incorporation of 'nutraceuticals' or 'pharmafoods' is attempted. One of the latest enrichments has been the addition of omega-3 PUFA to improve essential fatty acid intake. In Europe, consumption of bread enriched with omega-3 PUFA is steadily increasing because Europeans recognize the healthy component of such products. Therefore, the near future for nutrition could include extending the use of breads as vehicles for different micronutrients.

Yan (2003) patented an encapsulation method that could be used to enhance the stability of omega-3 lipids. In this method, a multi-core approach was taken by first encapsulating the omega-3 lipids and then applying a second shell over the agglomerated encapsulated lipids. This approach provides a product that has multi-layers of protection. Currently, Ocean Nutrition Canada uses this technology under the Powder-loc trademark to produce stable omega-3 encapsulated powders. The powder that results from this process can deliver 500–800 mg oil per gram of dry powder. In contrast, 200–350 mg oil per gram of dried powder is typically delivered for conventional spray-dried encapsulated powders. The Wright Group (Crowley, LA) uses a proprietary technology called Super Micro Atomization Retention Technology (SMART) to produce SuperCoat omega-3 products. The application of specific fatty acids to bread may also be a new approach to incorporate more omega-3 into the diet. Yep, Li, Mann, Bode, and Sinclair (2002) have shown that bread enriched with microencapsulated tuna oil (MTO) increases DHA and determined the acute and chronic effects of low doses of long chain (LC) n–3 PUFA (<100 mg per day) on plasma LC n–3 PUFA levels using a novel delivery form. Their study was concentrated on determining whether the consumption of bread enriched with a low dose of MTO would improve LC n–3 PUFA status in healthy individuals, as measured by plasma levels of these PUFA. To achieve this, an acute study (single dose ingestion with 4 h follow up) was conducted to establish the feasibility of the use of a low intake of LC n–3 PUFA, delivered as MTO-enriched bread. This was followed by a 3 week chronic study using commercial MTO bread as the LC n–3 PUFA source. They found that low dose MTO-enriched bread did improve plasma LC n–3 PUFA status in both the acute and the chronic study. In other words, the LC n–3 PUFA in the MTO-enriched bread was bio-available. Liu et al. (2001) studied the effects of daily intake of a small amount of fish oil in bread, 36 subjects with hyperlipidemia were randomly divided into three groups: stable fish oil with oat fibre, control with oat fibre and control with wheat fibre. Phospholipid fatty acids, triglycerides, cholesterol and malondialdehyde (MDA) were measured. Plasma levels of EPA and DHA and total omega-3 fatty acids were increased after 2 and 4 weeks of daily intake of 93 g bread containing 1.3 g stable fish oil. Triglycerides were decreased and HDL-cholesterol increased after intake of the bread containing stable fish oil. No significant changes occurred in the control groups. Intake of the bread containing stable fish oil did not induce any signs of lipid peroxidation; on the contrary, plasma MDA values were slightly decreased after intake of all types of bread. This study showed that in subjects with hyperlipidemia intake of bread containing a small amount of fish oil results in a significant increase in omega-3 fatty acids, an increase in HDL-cholesterol, and a decrease in triglycerides and MDA, which may reduce the risk of ischemic heart disease. Neilsen (1992) studied the effect of white bread enriched with n–3 fatty acids in the form of gelatine-coated fish oil and marketed in Denmark since 1990 under the name of 'Omega Bread'. This bread was found to be a reliable and significant source of higher n–3 PUFA (with 20 and 22 C atoms). Saldeen, Wallin, and Marklinder (1998) showed that fish oil concentrate fluid or in capsule, has shown beneficial

effects on several risk factors for cardiovascular disease, but their use implies addition of fat to the diet. Table 2 summarizes different marine functional ingredients and marine hydrocolloids incorporated in bakery products.

Harrison et al. (2004) developed functional foods which are capable of reducing key risk factors for coronary heart disease populations at risk of developing. The specific hypothesis tested was that providing bread, cracker biscuits and snack bars fortified with DHA (long-chain omega 3) would have a positive impact on cholesterol level and blood pressure.

6.2. Marine hydrocolloids in bakery products

Supplementation of several hydrocolloids with different chemical structure and from diverse origin to the bread making process is presented. The effect of marine based hydrocolloids (sodium alginate, κ -carrageenan) on fresh bread quality and its influence on bread staling were studied by Guarda, Rosell, Benedito, and Galotto (2004). Physical properties (moisture, hardness, and volume) and sensory properties of fresh bread and after storage of 24 h were assessed. Both sodium alginate and κ -carrageenan affected in different extent to the fresh bread quality, and concentration of 0.1% (w/w, flour basis) was sufficient for obtaining the observed effects. Marine based hydrocolloids were also able to reduce the loss of moisture content during bread storage, and dehydration rate of crumb. In addition, during storage, alginate showed an anti-staling effect retarding the crumb hardening.

7. Application in pasta products

Pasta is a complex multi component system consisting of bio-macromolecules such as proteins, carbohydrates and lipids (Kill, 2001). Pasta is a source of carbohydrates (74–77%, db) whose interest is increasing due to its nutritional properties, in particular due to its low glycemic index (GI). Wakame (*U. pinnatifida*), one of the widely consumed brown seaweed is rich in fucoxanthin (Miyashita, & Hosokawa, 2008). Fucoxanthin is a xanthophyll characteristic of brown seaweed and is the most abundant among aquatic carotenoids accounting for more than 10% of estimated total natural production of carotenoids.

Prabhasankar, Ganesan, and Bhaskar (2009a) developed pasta with Indian brown seaweed (*S. marginatum*) as an ingredient to improve the biofunctional and nutritional qualities. Different levels of seaweed (1.0, 2.5, and 5.0%; w/w) were substituted to obtain seaweed-incorporated pasta and pasta without seaweed was used as control. Microstructure studies revealed that the incorporation of seaweed up to 2.5% enhanced gluten network of pasta. Indian brown seaweed (*S. marginatum*) can be incorporated up to 2.5% (w/w) to get pasta with better biofunctionality/quality and also better utility value for seaweeds as food products. But it was also found that antioxidant property of pasta did not increase with increase in seaweed concentration beyond 2.5%.

Different levels of brown seaweed, *U. pinnatifida*, when incorporated in semolina for pasta preparation, have shown effect on the sensory, cooking, nutritional and biofunctional quality of pasta. Replacing pasta ingredients with wakame powder considerably improved the protein and fat contents ($p < 0.05$). Likewise, increased levels of wakame

powder significantly increased the ash and fibre contents of pasta ($p < 0.05$). Control pasta had no fucoxanthin or fucosterol contents for obvious reasons. Increased levels of seaweed incorporations increased the fucosterol (0.51–2.55 mg/g) and fucoxanthin (0.02–0.23 mg/g) contents in seaweed pasta samples. Sensory analysis of different pasta samples revealed that pasta samples containing seaweed powder up to 10% had higher acceptance rating by the panelists. There was no significant difference ($p > 0.05$) in sensory scores of control and 5% seaweed containing pasta as well as 5% and 10% seaweed containing pasta. In case of pasta samples containing 20% and 30% wakame powder, panelists complained of saltiness as well as they feel similar to that of eating wakame. Also, 30% seaweed containing pasta was not preferred sensorily as indicated by the lower scores for appearance and mouth feel. Hence, it was concluded that wakame powder up to 10% is better both in terms of sensory characteristics and additional nutritional value (Prabhasankar et al., 2009b).

Pasta and other cereal products serve as a staple food and could be a good opportunity to achieve the recommended daily intake of LC n–3 PUFA. Pasta is excellent choice for incorporating microencapsulated nutraceuticals such as powder encapsulated refined marine oil (ROPUFA 10 n–3 food powder) because it is popular with consumers due to it is easy handling, storage and preparation. It was also found that microencapsulated integrator allows the preparation of spaghetti characterized by added nutritional value maintaining a high sensory acceptability. Microencapsulated integrator is a powder that contains LC n–3 PUFA, is stabilized with tocopherols, ascorbyl palmitate, and rosemary extract. Spaghetti with intermediate levels of integrator (RP-1.2 – sample containing 1.2% of ROPUFA powder) provided the best sensorial acceptability and lowest LC n–3 PUFA cooking loss. Thus spaghetti fortified with EPA + DHA could be used to increase consumption of LC n–3 PUFA and to decrease dietary n–6/n–3 ratio (Iafelice et al., 2008).

Lipid oxidation studies were done in spaghetti enriched with LC n–3 PUFA by the addition to semolina of 1.2% ROPUFA 10 n–3 refined marine oil powder containing EPA and DHA. Two oxidative parameters were evaluated: peroxide value (PV), to assess primary oxidation and oxidised fatty acids to quantify secondary oxidation products. Functional spaghetti had a shelf life comparable to control pasta. LC n–3 PUFA were not significantly implicated in the onset of oxidation in spaghetti stored under daylight and accelerated oxidation in a laboratory heater. Storage decidedly affected shelf life: PV in functional spaghetti increased from 7.1 to 43.4 meq O_2 /kg of fat under light exposure over 12 months, and from 7.1 to 16.2 meq O_2 /kg under accelerated aging at 55 °C for 27 days, equivalent to 18 months at room temperature. Oxidised fatty acids increased in fortified spaghetti from 4.8 to 13.8 cc of fat under light exposure over 12 months and from 4.8 to 7.8 g/100 g of fat at 55 °C in 27 days. The high sensitivity of spectrophotometric and chromatographic analytical methods permitted the evaluation of primary and secondary oxidative derivatives in small amounts of fat (Verardo et al., 2009).

The physical, chemical, sensory and nutritional qualities of pasta were altered with incorporation of surimi in semolina. They determined the concentration of surimi to be incorporated so that product becomes more consumers acceptable. They used formulations of pasta with 0, 10, 20 and 30% levels of surimi. Table 3 summarizes different marine functional ingredients incorporated in pasta products (Huang & Resurreccion, 1988).

Table 2
Marine functional ingredients in bakery products.

Ingredient	Product	Reference
Microencapsulated tuna oil (MTO)	Bread	Yep et al. (2002)
Marine hydrocolloids	Bread	Guarda et al. (2004)
Fish oil concentrates	Bread	Saldeen et al. (1998)
Fish oil	Bread	Liu et al. (2001)
n–3 PUFA	Bread	Neilsen (1992)
DHA	Biscuit, cracker	Harrison et al. (2004)

Table 3
Marine functional ingredients and their use in pasta products.

Ingredient	Product	Reference
Encapsulated fish oil	Spaghetti	Iafelice et al. (2008)
1.2% encapsulated fish oil	Spaghetti	Verardo et al. (2009)
Indian brown seaweed	Pasta	Prabhasankar et al. (2009a)
Wakame	Pasta	Prabhasankar et al. (2009b)
Surimi	Pasta	Huang and Resurreccion (1988)

8. Conclusions

Marine food, due to its phenomenal biodiversity, is treasure house of many novel healthy food ingredients and biologically active compounds such as fish oils, fish proteins, and seaweeds. Marine functional ingredients such as fish oils, seaweeds and fish proteins have found application in bakery, dairy, confectionary and pasta products. These are added in the form of fortificants and nutritional enrichments in food. As bakery industry has come out of its image as wheat based product industry, fish oils which are rich in omega-3 oils are widely and extensively used in bread and other products. These products have shown considerable improvement in EPA and DHA contents of breads and other bakery products leading to reduction of cardiovascular diseases which is major health concern of 21st century. Recent advances and research have shown that seaweed can be used as a rich source of carotenoids such as astaxanthin, fucoxanthin and dietary fibre and can be incorporated in pasta products without much intervention in sensory quality. Incorporation of Wakame (*U. pinnatifida*) seaweed in pasta has shown great potential to improve fucoxanthin content. Also surimi is accepted by consumers at moderate concentrations in pasta products. Thus, constant efforts in research and development in the field of marine functional food ingredients is needed for the future diet which will help in reducing all health problems of human beings.

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