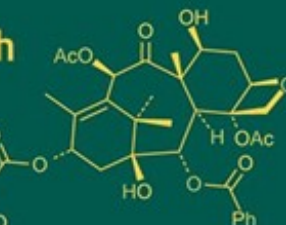


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Scope for value addition of oyster species in India

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ABSTRACT

Oysters are renowned for their exceptional nutritional value, serving as a vital source of high-quality protein, essential vitamins, minerals, and omega-3 fatty acids. Particularly rich in zinc, iron, calcium, and vitamin B12, their consumption supports immune function, cardiovascular health, and cognitive development. Found abundantly across global coastal regions—with major production hubs in the US, France, China, Japan, and India—oysters have seen a surge in demand driven by their unique flavor and health benefits. To meet this need, year-round sustainable oyster farming has become essential. The market potential for oysters is substantial, propelled by growing consumer awareness regarding healthy diets and sustainable protein sources. Compared to traditional livestock, oyster farming has a minimal environmental footprint, appealing to eco-conscious consumers. Furthermore, their culinary versatility ranges from raw consumption to gourmet processed dishes, expanding their global appeal. Looking ahead, the oyster industry's future is highly promising. Continued focus on health, wellness, and sustainable aquaculture is expected to drive market expansion. Advancements in selective breeding, modern farming techniques, and innovative packaging and distribution are crucial for enhancing yields, product quality, and shelf-life, thereby opening new export avenues. However, sustaining this growth requires addressing critical challenges such as fluctuating environmental conditions, disease management, and regulatory frameworks. Ensuring water quality and implementing efficient disease control are vital to balancing rising production with ecological preservation. Despite being a globally cherished delicacy, oysters remain underutilized in many regions. While traditionally eaten raw, processing techniques like canning, freezing, marinating, and smoke-drying offer significant scope for value addition and extended shelf-life. Ultimately, this study aims to highlight the immense nutritional significance of oysters and explore their vast potential for sustainable commercial utilization and value addition.

Keywords: Molluscs, Oyster, Canned product, Vitamin B12, Marketing, Crustaceans

Introduction

Molluscs make up the majority of the four main kinds of aquaculture products in the world, followed by fin-fish, crustaceans, and seaweeds. Two-thirds of all aquaculture products are molluscs, and Asia produces two-thirds of the world's mollusc production (Nair, 1999) [1]. Since oysters, mussels, clams, and other molluscs are exported as well as consumed both live and processed, bivalves are the most significant of all molluscs (Samuel, 1988) [2].

A sedentary species is the edible oyster. Two shell valves—a lower cupped valve (left valve) and an upper flat right valve—enclose the animal's soft body. While the upper valve functions as a lid and is connected to the lower valve by a hinge mechanism, the lower valve is anchored to the substrate. By contracting and relaxing the adductor muscle, the valve can be moved. The adductor scar is sub-central, reniform, and dark purple in colour; the adductor scar has an irregular shape, and the inner surface of the valves is smooth, glossy, and white. The hinge is narrow and elongated. There are three layers to the shell. The middle layer is dense and chalky and made of calcium carbonate, while the outermost layer is known as the periostracum and is thin, hard, and typically lustrous (Xia et al., 2008) [3].

Oysters are a great source of zinc, iron, calcium, selenium, vitamin A, and vitamin B12. Oysters are poor in food energy; a dozen raw oysters only have 460 kilojoules (110 kilocalories). They contain a lot of protein (approximately 9 g in 100 g of Pacific oysters). The Recommended Daily Intakes of zinc and vitamin B12 are met by two oysters (28 gm or 1 ounce) (Dauphin et al., 2013) [4].

The current state of oyster processing uses traditional and modern techniques. Manual shucking is a traditional technique in which skilled personnel crack open the oyster shells and remove the meat. On the other hand, modern methods use automated machinery to shuck oysters, increasing efficiency and lowering expenses. To suit market demands, oyster meat can be shucked and then put through procedures like washing, grading, and packaging, either in whole form or as shucked meats (Patosa et al., 2014) [5].

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However, oyster processing faces several limitations. Oysters' susceptibility to contamination, especially from dangerous bacteria like *Vibrio vulnificus*, is a significant problem. To maintain consumer safety, proper handling, storage, and sanitation procedures are essential. Oysters are also extremely perishable and need precise temperature control to avoid spoiling. Processing facilities have logistical difficulties as a result of this restriction, particularly when shipping oysters over long distances (Patosa et al., 2014) [5].

Another limitation is the seasonal availability of oysters. Oysters are frequently harvested in particular months, which can cause swings in supply and demand all year long. Processing activities are impacted by this seasonality since facilities may need to adapt their capacity or rely on frozen or canned oysters during off-peak times (Patosa et al., 2014) [5].

Resource availability of oyster in India

A clear pattern may be seen in the occurrence of oysters along the Indian coastline. Except for West Bengal, the main oyster species along the east coast, from Orissa to Tamil Nadu, is *C. madrasensis* (Mahadevan, 1987; Das, 1993; Narasimham et al., 1993; Rao et al., 1996) [7, 6, 8, 9]. It predominates more in the south than the north along the west coast (Mahadevan, 1987) [7]. The dominant species of oyster in the northwest, particularly in the Gulf of Kutch, is *C. gryphoides*. Around the northwestern shore, *C. gryphoides* and *C. rivularis* mixed populations can be detected (Chhaya et al., 1993) [10]. It has been noted that populations of various oyster species in an estuary divide horizontally. *Saccostrea cucullata* is more prevalent in the marine environment of most estuaries (Rao et al., 1987) [11]. Near the barmouth of Kerala's Ashtamudi Lake, *S. cucullata* is found in high concentrations, accounting for 81.7% of the lake's total oyster density with the remaining *C. madrasensis*. The number of this species decreases as it approaches the estuary, making up just 15 to 19% of the entire oyster population. In the estuarine area, *C. madrasensis* predominates, whereas on the riverside, *S. cucullata* is totally absent (Kripa, 1998) [12]. Owing to the variation in the lower threshold of their salinity tolerance, *C. madrasensis* may have a better capacity to adapt to low saline conditions than *S. cucullata*, which may account for the zonation pattern from marine to brackish water.

Global scenario

Around the Chinese shore, *Crassostrea gigas* grows naturally, and it has also been introduced from Japan. It produces between 10 and 20 percent of China's oysters. The culture is done in 10-100 m³ concrete tanks inside the hatchery and only relies on seed raised there (Guo et al., 1999) [13]. Antibiotics and vitamin supplements are frequently utilised.

In 2003, Japan harvested 260,644 tonnes of oysters, placing second overall with a 5.8% share of the world's total production. Bardach et al. (1972) [14], Imai (1977) [15], Kafuku et al. (1983) [16], and Korringa (1976a) [17] all discussed aquaculture in Japan, which included oyster culture. Korringa (1976a) [17] also provided information on *C. gigas* culture in the Japanese bay of Hiroshima. The most significant oyster species raised in Japan is *C. gigas*. It is primarily developed in two areas: the Seto Inland Sea, which is centred in Hiroshima Prefecture, and the Tohoku region, which is along the Pacific coast and has Miyagi Prefecture as its focus.

In 2003, France yielded 117,000 tonnes of oysters through aquaculture, including 115,000 tonnes of *Crassostrea gigas* and 2,000 tonnes of flat oyster, *Ostrea edulis*. According to Pillay (1990) [18], some people believe that the Portuguese oyster *C. angulata* and *C. gigas* are genetically related or the same species. Although uniform oysters are produced with this technique to meet the demands of the half-shell oyster trade, oysters are primarily grown on the bottom. In France, the half-shell of the flat oyster, *Ostrea edulis*, is the preferred option for gourmets. Few bodies of water are ideal for this species' culture. On the bottom is also how the Portuguese oyster *Crassostrea angulata* is typically cultivated.

Nutritional aspects of oyster

It is possible to evaluate a species' nutritional and digestible value in terms of energy units by looking at its biochemical composition. According to chemical analysis, *C. madrasensis* is composed primarily of water (82%), protein (10%), fat (3.25%), carbohydrates (3.2%), and ash (1.01%). The primary component of oyster meat is water, which is an indicator of freshness and is strongly bonded to the proteins in the structure so that it cannot be easily evacuated even under high pressure (Murray et al., 2001) [19]. The protein content and below-average fat levels are comparable to those of several fish species. The amount of carbohydrates in oyster meat is higher than that in finfish, which has a much lower amount. The presence of glycogen in oysters has been noted in many papers (Berthelin et al., 2000; Bacca et al., 2005) [20], as it is crucial for spawning. Oysters have a slightly lower ash level than other fish species.

Both macro and trace metals are abundant in oyster meat. Conventionally, foods high in potassium are regarded as being healthful (USDA, 2010); oysters contain relatively high amounts of potassium. In intermediary metabolism, trace metals including Se, Cu, Zn, Mn, and Fe serve as cofactors for enzyme activities, and Fe is a component of haemoglobin (Hb), which is necessary for the oxygenation-deoxygenation cycle of Hb.

Lysine (14.3 g%) and threonine (12.3 g%) were the two essential amino acids with the highest content, respectively. Aspartic acid (11.8 g%) and histidine (7.7 g%) were the two non-essential amino acids with the highest concentration. The outcomes are comparable to those discovered in finfish by other writers (Murray et al., 1969; Chukwuemeka, 2008) [22, 21]. Oyster protein contains 14.3 g of lysine per 100 g of crude protein, which is much more than the FAO/WHO-recommended reference lysine basic value of 5.8 g per 100 g of dietary protein for a child between the ages of 2 and 5.

Oysters have twice as much cholesterol as fish at 106 mg/100 g of oyster meat. Oysters' high taurine content, which is known to have a strong hypocholesterolemic effect, balances out their high cholesterol concentration.

Present status of utilisation of oyster

Oysters may have a significant impact on heart health in a variety of ways, but cholesterol is extraordinary because it contains much more omega-3 unsaturated fat than omega-6 unsaturated fat. Omega-3 unsaturated fats play a significant role in lowering the level of bad cholesterol in the blood and preventing it from being responsible for vein and coronary diseases due to their role as healthy forms of cholesterol (HDL cholesterol) and improving the proportion of good to "bad" (LDL cholesterol) (omega-6 unsaturated fat) (DiNicolantonio et al., 2018) [23]. Moreover, clams and oysters' high potassium and magnesium content can loosen blood vessels, lower blood pressure, promote blood flow and oxygenation, and lessen the stress on the heart. The next stage of defence against serious heart disease is the cell layers' stability and flexibility, which is increased by the vitamin E in shellfish (Lehman et al., 2020) [24].

The fisheries and aquaculture sectors are increasingly focusing on circular economy principles and value addition to utilize discarded parts and generate alternative revenue streams. For instance, recent studies have demonstrated the viability and positive consumer perception of developing leather from discarded fish skins (Soni et al., 2026) [25]. A similar approach to waste utilization is highly relevant to the oyster industry. Oyster shells are appropriate raw materials for the manufacture of calcium carbide, lime, fertiliser, cement, and other products since they make up around 90% of the overall mass and contain 52-55% calcium oxide. The oyster shells are also perfect for use as spat collectors to gather oyster spat. The shells can also be broken down into usable pieces and used as grit for poultry. When 100 kg of oyster shells were broken down, four different grades of shell grit—5 mm, 2 mm, 1 mm, and < 1 mm—were recovered. The 2-3 mm size grit was confirmed to be suitable as an element in poultry feed after being tested in a nearby poultry farm. The majority of the oyster shells were

supplied to the calcium carbide business since they could be discarded without being processed as in the case of shell grit (Lehman *et al.*, 2020) [24].

Oyster powder is used to prepare keratin, collagen, and elastin for fair skin, hair, and nails. Chemicals, cancer preventive agents, and necessary proteins like keratin—which is found in thin, brittle skin, dull hair, and broken nails—are needed to cure the obstructive structure of collagen and free amino acids (Aguirre-Cruz *et al.*, 2020) [26]. Scientific research has demonstrated that an oyster powder diet improves the body's production of glutathione and SOD.

A single oyster costs between 20 and 30 rupees at the lower end. A single oyster pearl measuring 1 to 20 mm can cost anywhere from Rs 300 to Rs 1500. Pearls are highly sought-after for use in jewellery, cosmetics, paint formulas, and clothing embellishment. The start-up cost for pearl farming would be in the range of 20,000 to 25,000. With this much money invested, you could make up to Rs 300,000. The initial investment would yield a return of between 50% and 60% (Aguirre-Cruz *et al.*, 2020) [26].

Processing

Freezing

Whole oysters (shell on) can be successfully frozen after purification when spread out in single layers in an air blast freezer. Moreover, frozen oysters in the shell are an option. To preserve the open surfaces of the oyster meat, they should be placed on trays in an air blast freezer. Polypropylene film should be stretched over each tray. For six months in a cold storage at -30 °C, frozen whole oysters packaged in polythene bags can be preserved in good condition. As a glaze, the liquid inside the shell prevents the meat from drying out. The flesh of frozen entire oysters can be used to make food (Patosa *et al.*, 2014) [5].

Canning

Oyster in brine: Oyster meat is cooled, cleaned, and blanched for 4-5 minutes in 3% brine that contains 0.1% citric acid. 90 gm of blanched beef (112 gm net weight) are packaged in cans with a hot 2% brine that contains 0.1% citric acid. The packed cans are sealed and sterilised for 25 minutes at 115 °C. The cans are then promptly refrigerated, cleaned to remove any exterior water, and stored (Patosa *et al.*, 2014) [5].

Smoked Oyster: To prepare smoked oyster meat, the meat must first be cleaned, treated with 5% brine for 5 minutes, drained, then dipped in edible oil and spread in a single layer on nylon wire mesh. After this, the meat must be drained once more and loaded into the smoking chamber. The meat is kept in dense smoke and kept at 40 °C for 30 minutes before being raised to 70 °C for 80–90 minutes. To maintain uniform smoking of the meat, the materials in the smoking chamber are flipped around once every 15 minutes. The smoked oysters are placed in cans together with an adequate amount of heated, refined edible oil. The cans are then sealed, sterilised for 25 minutes at 115 °C, and then promptly chilled and stored for marketing (Patosa *et al.*, 2014) [5].

Effect of high pressure on proximate composition of oyster

Compared to untreated or constant pressure (CP) oysters, the proximal composition of oysters underwent changes with high pressure (HP) and thermal pressure (TP) treatment. Oysters that had not been treated initially had a moisture percentage of 84.7%; those that had been treated with HP, TP, or CP had moisture contents of 86.5%, 83.5%, and 84.9%, respectively. Oysters treated with HP showed a significant ($P < 0.05$) rise in moisture content compared to untreated oysters (Cioni *et al.*, 1994; Silva *et al.*, 2001; Vidugiris *et al.*, 1995) [27, 28, 29].

Parallel to this, the ash content of HP- or TP-treated oysters was lower compared to CP or control oysters but was not significantly different. In contrast, the protein content was significantly ($P < 0.05$)

lower in HP-treated oysters than in controls or heat-treated oysters. The leaching of oyster components by the intervalval fluid may be the cause of the lower ash content.

When compared to CP or untreated oysters, the pH of HP-treated and TP oyster tissue was considerably higher ($P < 0.05$); however, CP processing had no significant impact on the pH when compared to untreated oysters. The average water activity levels for untreated oysters were 0.988, whereas they were 0.989 for oysters that had undergone HP or heat treatment. These differences were not statistically significant. Prior to treatment, oysters had a 0.99% salt content (Kramer *et al.*, 1962; Cook *et al.*, 1988) [31, 30].

Oyster salt content was unaffected by CP or HP treatment. However, Hoover *et al.* (1989) [32] found that oyster flavour was improved by HP treatment as a result of uptake of the salty fluid in which oysters were treated. The yield, content, and quality of oyster tissue were modified by the HP and thermal treatment processes. With less adverse effects on the quality features and a noticeably larger yield than untreated samples, HP processing of oysters may be a more acceptable post-harvest procedure than heat treatment (Hoover *et al.*, 1989) [32].

Conclusion

Oysters are a traditional food for some coastal communities in states like Kerala, Karnataka, Goa, and Maharashtra, as well as for some urban residents. Organizing oyster producers and promoting value-added practices can significantly uplift the socio-economic status of coastal populations, a benefit that has been similarly observed among organized fish farmer producer organizations in other aquaculture sectors (Rathod *et al.*, 2026) [33]. Commodities, which include oysters, are highly perishable but are regarded as inexpensive providers of vital nutrients. These bivalves can be processed into goods with additional value to increase product quality, marketability, storage stability, and consumer acceptance.

Oysters are primarily consumed as a raw or cooked seafood item, valued for their unique flavor and texture. They can be served on their own, used in various recipes, or incorporated into dishes such as soups, stews, and seafood salads. Value is added to oysters by preparing them in different culinary styles, offering diverse flavor profiles and catering to consumer preferences.

All these products are healthy for eating by humans and are a good source of necessary nutrients. Oysters can be processed into fried, dried, and canned products to increase their storage life from one to three days in raw form to two weeks, four weeks, and even more than a year at ambient temperatures.

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Conflict of interest

There is no conflict of interest among the authors.

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