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Invited Review Article

Antimicrobial activity of turmeric (*Curcuma longa*) extract and its potential use in fish preservation

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Abstract

Fish is one of the major sources of nutrients. However, because of its perishable nature, it begins to deteriorate as soon as they leave the water. So, preservation is required to extend its shelf life. The widely used chemical preservatives harm both human and fish. So, uses of natural, cheap, harmless, and efficient preservatives are in high demand nowadays. Turmeric (*Curcuma longa)* possesses excellent antibacterial, antifungal, immunostimulatory, and anti-insecticidal activities. It is found to have antibacterial activity against a wide range of bacteria causing spoilage to fish. It also inhibits the growth of some fungi associated with fish deterioration. Turmeric can boost the immunity of the fish, which makes them resistant towards spoilage microorganisms, and reducing the mortality rate efficiently. Insect manifestation, a big problem in the drying process, can be decreased with the use of turmeric. Turmeric has shown its activity while being applied as feed additive or by coating externally. The addition of turmeric during salt drying process also increases the shelf life of fish. Turmeric has a great potential to be used as a preservative in food science that need to be further explored in future.

Key words: Antimicrobial activity, Curcumin, Fish preservation, Turmeric

Highlights

- Turmeric is a natural antimicrobial compound which can be used either alone or in combination with mild physicochemical treatments and low concentrations of traditional chemical preservatives, to efficiently extend shelf life and food safety.
- Turmeric acts as a potential natural preservative for domestic purposes as well as commercial food industries and distribution chains.
- Turmeric (*Curcuma longa)* possesses excellent antibacterial, antifungal, immunostimulatory, and anti-insecticidal activities.

Introduction

India ranks second in aquaculture contributing 7% of global fish production with a fish diversity of 10% worldwide (Mukherjee *et al*., 2020). Fish is an excellent source of high nutritional value protein and contains omega-3 polyunsaturated fatty acids (PUFA), especially, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Mei *et al*., 2019), which are essential for normal growth and development and may prevent coronary artery disease, hypertension, diabetes, arthritis, inflammatory and autoimmune disorders, and cancer (Bakli *et al*., 2020). Fish is also a good source of vitamins like A, D, B_6 and B_{12}. Minerals such as iron, zinc, iodine, selenium, potassium, sodium, etc. are also present in fish (Bakli *et al*., 2020). Thus, fish can meet up the daily requirement of 200 to 500 mg of omega-3 PUFA as well as other vital nutrients as directed by World Health Organization (Mei *et al*., 2019).

Fish is perishable in nature due to its high-water content. The pH of fish is in the range of

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6.8 to 7 which is safe for human consumption (Farid *et al.*, 2014). Upon storage of fish, pH starts to increase due to the production of volatile amines and finally crosses the limit of acceptability of safe consumption of fish leading to spoilage. Due to the low acidic and highly perishable nature of fish, the food spoilage bacteria can grow easily which leads to spoilage. The extent of microbial spoilage depends on the microbial load, available metabolites in tissue and storage conditions, and species concern (Farid *et al.*, 2014). The pathogens associated with the fish during harvesting, handling, and processing lead to deterioration which is expressed by a strong odor, texture changes with slime production, and gross discoloration, thus fish being rejected by consumers (Farid *et al.*, 2014). One of the major concerns in food industries in tropical countries like India is the contamination by food spoilage and pathogenic bacteria causing foodborne diseases (Farid *et al.*, 2015). Moreover, higher temperature accelerates oxidation and hydrolysis of fats, protein denaturation and autolysis which are associated with microbial spoilage (Farid *et al.*, 2014). Among the changes of chemicals associated with fish deterioration, the low molecular weight nitrogenous biogenic amine (BA) compound such as histamine and tyramine, are produced due to the decarboxylation of the amino acids by decarboxylase enzyme of spoilage bacteria present in fish. The higher level of BA leads to several symptoms like nausea, vomiting, burning sensation in the mouth, respiratory disease, itching, headache, allergy, heart palpitation, hypertension, etc. (Chong *et al.*, 2011).

Present-day food preservation is viewed as a ‘convenience’ product as well as a key to ensure the availability of food as a vital benefit. Consumers, nowadays, demand natural but effective preservation of food free of potential health risks. This shift in consumer preference for minimally processed foods has led to the increasing consumption of precooked food, prone to temperature abuse, thus increasing the likelihood of food-related illness and product spoilage (Nath *et al.*, 2017). Therefore, to harmonize consumer demands with the necessary safety standards, traditional means of controlling microbial spoilage and hazards in foods are being replaced using biological, natural, and organic antimicrobial compounds such as turmeric, either alone or in combination with mild physicochemical treatments and low concentrations of traditional chemical preservatives. This approach of food preservation is an efficient way of extending shelf life and food safety through the inhibition of spoilage and pathogenic bacteria without altering the nutritional quality of raw materials and food products (Nath *et al.*, 2014).

Fish preservation

During storage, the freshness of fish gradually deteriorates with degradation of protein and fat content of the fish. Such changes are primarily accelerated due to the high moisture content in fish facilitating microbial growth and spoilage, enzymatic degradation, high ambient temperature, and unhygienic handling practices (Nwaigwe, 2017). Fish spoilage can be caused by three main mechanisms: enzymatic degradation, oxidative rancidity of fat and microbial spoilage. Implementation of food processing and microbiological food safety standards has diminished the likelihood of food-related illness and product spoilage, although complete elimination is not possible. The increasing consumption of precooked food especially seafood, prone to temperature abuse, and the import of raw seafood from developing countries, results in the outbreak of foodborne illness (Nath *et al*., 2014). In Europe, morbidity from foodborne illness is second only to respiratory diseases and an estimated 50,000 to 300,000 cases of acute gastroenteritis per million populations are encountered every year (Nath *et al.*, 2013). Bacterial pathogens including *Salmonella*, *Campylobacter jejuni*, *Escherichia coli* 0157:H7, *Listeria monocytogenes*, *Staphylococcus aureus*, and *Clostridium botulinum* are found associated with such outbreaks (Nath *et al.*, 2014).

Therefore, the preservation of food in sound and safe condition continues to be an ongoing challenge for human.

Drying, salting, and fermentation have long been adopted by human as a traditional method of food preservation. But the problem associated with the sun drying process is the infestation by insects followed by microbial spoilage of fish (Farid *et al.*, 2015). Low temperature such as chilling and icing are practiced for delaying the enzymatic degradation and bacterial spoilage, thus, retention of nutritional quality takes place (Nath *et al.*, 2019); but psychrotolerant Gram-negative *Pseudomonas* sp. and *Shewanella* sp. may survive to cause quality deterioration.

Preservation by modified atmospheric packaging (MAP) restricts the growth of aerobic bacteria but allows the growth of *Photobacterium phosphoreum* and lactic acid bacteria (LAB). Some Gram-negative fermentative bacteria like *P. phosphoreum* and psychrotolerant Enterobacteriaceae can grow in frozen product and under refrigeration storage, causing spoilage (Ghaly *et al.*, 2010). Even after acidification or addition of preservative, some lactobacilli and yeast can grow. Some halophilic and halotolerant bacteria and filamentous fungi cause spoilage in salt-cured and dried fish (Sivaraman *et al.*, 2015). Even after thermal sterilization or canning process, spores of *Bacillus stearothermophilus* can germinate and cause spoilage in canned fish and fishery products (Mohan, 2018). Recent advances to preserve fishes with antibiotics to reduce the chances of microbial spoilage are although effectively successful, but the development of antibiotic-resistant bacterial strains is of great concern and difficult to control.

Additives and preservatives with antimicrobial and antioxidant properties play an important role in ensuring food safety. Many antimicrobial agents such as sulfites, nitrites, organic acids, and several antioxidants (butylated hydroxyanisole, butylated hydroxytoluene, and butylhydroxyquinone) have been used since long to preserve fish from microbial spoilage and oxidative rancidity. Despite the high potential for preservation, some restrictions are there in the application of these synthetic preservatives due to potential toxicological effects (Viji *et al.*, 2017). Thus, the application of natural preservatives such as turmeric is a boon to the food industry.

Turmeric

Historical evidences and nomenclature: The earliest documentation of the use of the medicinal plant, turmeric, was in Rig-Veda, possibly written in between 4500-1600 BC (Krup *et al.*, 2013). The Atharvaveda of India along with other Sanskrit pieces of the literature revealed the use of turmeric in ancient India due to its nutritional value (Kumar *et al.*, 2011). At 700 AD turmeric reached China (Krup *et al.*, 2013) and Marco Polo mentioned, turmeric as Indian saffron (Bhowmik *et al.*, 2009) during his visit to India and China in 1280 (Rathaur *et al.*, 2012). Evidence of turmeric was found in East Africa and West Africa at around 800 AD and 1200 AD respectively, whereas turmeric was introduced in Arabian countries in the 10^{th} century (Kumar *et al.*, 2011). Although Arabian traders introduced turmeric in England around the 13^{th} century, after the voyage of a Portuguese sailor, Vasco da Gama in the 15^{th} century, turmeric was truly introduced to the west (Rathaur *et al.*, 2012).

Turmeric has a wide nomenclature in different regions. The recent name 'Curcuma' came from Arabic Kurkum and Hebrew Karkom, which stands for yellow; and the 'Longa' came due to the elongated shape of the rhizome. The botanist, Valeton, coined the term *Curcuma domestica* as it is referred to as domestic plant. Interestingly, the English term 'turmeric' came from Sanskrit, which means 'yellow' due to its yellow-colored rhizome (Kumar *et al.*, 2011).

Turmeric tree is 3 to 5 feet long having pointed, oblong leaves and funnel-shaped yellow flowers with a yellowish and thick rhizome (Kumar *et al.*, 2011; Sodamola *et al.*, 2016). The dried primary bulb and secondary lateral rhizomes are collected, cleaned, boiled, and finally dried to get commercial powder turmeric (Sodamola *et al.*, 2016). In subtropical regions and tropical countries like India, turmeric is widely cultivated.

Uses of turmeric: Turmeric is a popular folk medicine throughout the globe since the early days. In Uttar Pradesh, India, the rhizome of turmeric is widely used to treat cough and cold; the tribes of Jhalda, Purulia, West Bengal also apply the paste of rhizome of turmeric as skin fairness agent (Krup *et al.*, 2013).

Several beneficial attributes like antibacterial, antiviral, antifungal, antioxidant, anti-arthritic, anti-tumor, antithrombotic, nematocidal, antihepatotoxic, anti-mutagenic, anti-choleretic and even antivenom activities make turmeric indispensable in medicine, pharmaceutical, and food industry. Turmeric has a strong influence as antispasmodic, cardiovascular, diuretic, carminative, astringent, cholagogue, digestive, appetizer, stimulant, and vulnerary property (Bhowmik *et al.*, 2009). Lesser prevalence of Alzheimer's disease is documented in regions with high consumption of turmeric like India (Yadav *et al.*, 2017). Turmeric improves the function of the small intestine, digestion, and metabolism by stimulating the production of various digestive enzymes involving in the process (Sugiharto *et al.*, 2011). Arunkumar *et al.* (2016) reported that the hexane and ethanol extract of turmeric showed an inhibitory effect against 13 pathogenic bacteria. Gram-positive bacteria have enhanced interaction between the antimicrobial active compound of turmeric curcumin and the structural lipoproteins made them sensitive to turmeric than Gram-negative bacteria (Mukhtar and Ghori, 2012). Septiana *et al.* (2017) pointed out that endophytic symbiotic fungi of turmeric could inhibit histamine forming bacteria in fish; thus 5% of a turmeric extract has an inhibitory effect of histamine producing bacteria.

Chemical composition of turmeric: In 1815, curcumin was first isolated by Vogel and Pelletier as a 'yellow coloring matter' from rhizomes of *Curcuma longa* and named it curcumin and in 1973 chemical structure of turmeric was determined by Roughly and Whiting (Amalraj *et al.*, 2017). Curcumin exists in two tautomeric forms; keto and enol; the enol form is energetically more stable both in the solid phase and in solution than the keto form (Akram *et al.*, 2010). Due to hydrophobic nature, turmeric is soluble in non-polar solvent like oil, dimethylsulfoxide, acetone, and ethanol but partly soluble or insoluble in polar solvent like water (Amalraj *et al.*, 2017). The ethanolic extracts showed better results than the aqueous extract because organic solvent dissolves more organic molecules resulting in the release of higher active antimicrobial components (Mukhtar and Ghori, 2012).

Turmeric powder contains 6.3% protein, 69.4% carbohydrate, 5.1% lipid, 13.1% moisture, 3.5% mineral and 5% curcuminoids. Curcuminoids include curcumin (diferuloyl methane), demethoxycurcumin, and bisdemethoxycurcumin (Mooraki *et al.*, 2019). Curcumin (3 to 4%) is responsible for the yellow color of turmeric having maximum beneficial attributes (Akbik *et al.*, 2014). In India, mainly two types of turmeric are cultivated *viz.* 'Madras' (2% curcumin, 2% volatile oil, having bright, light, and intensified yellow color) and 'Alleppy' (4 to 7% curcumin, 3.5 to 5.5% volatile oil, with orange-yellow flesh color) (Gopinath and Karthikeyan, 2018).

There are several phenolic compounds present in turmeric such as 1-hydroxy-1, 7-bis (4-hydroxy-3-methoxyphenyl)-(6E)-6-heptene-3, 5-dione; 1, 7-bis (4-hydroxyphenyl)-1,4, 6-heptatrien-3-one; 1-(4- hydroxy-3, 5-dimethoxyphenyl)-7-(4-hydroxy-3-methoxyphenyl)-(1E, 6E)-1, 6-heptadiene-3, 4-dione; 1-(4 hydroxy-3-methoxyphenyl-5-(4-hydroxyphenyl)-penta-(1E, 4E)-1, 4-dien-3-one; 1-(4-hydroxy-3-methoxyphenyl)-7-(3, 4-dihydroxyphenyl)-1, 6-heptadiene-3, 5-dione and 1, 5-bis (4-hydroxy-3-methoxyphenyl)-penta-(1E, 4E)-1, 4-dien-3-one (Niranjan and Prakash, 2008).These phenolic compounds penetrate into the bacterial cell after destroying the cell wall and affect their metabolism (Antunes *et al*., 2012). Some other compounds are also found such as curlone, alpha-turmerone, beta-turmerone, terpinolene, alpha-phellandrene, curcumadiol, labda-8 (17)-diene-15, 16-dial and three acidic polysaccharides named Ukon A, B and C. They contain L-arabinose, D-xylose, D-galactose, D-glucose, L-rhamnose, D-galacturonic acid following ratios; Ukon A (12:4:12:1:4:10), Ukon B (12:4:12:1:2:4) and Ukon C (8:3:614:2:3). Whereas another polysaccharide Ukon D has different composition containing L-arabinose, D-galactose, D-glucose, and D-mannose (1:1:12:2). Turmerin (soluble peptide part) has amino acids aspartic acid/asparagine, glutamic acid/glutamine, serine, glycine, arginine, proline, alanine, tyrosine, valine, methionine, leucine, isoleucine, and phenylalanine in a ratio of 1:2:3:8:1:1:1:3:2:6:3:4:5:3 (Niranjan and Prakash, 2008). Ikpeama *et al*. (2014) reported that turmeric contains phytochemicals such as, 1.08% tannin, 0.76% alkaloid, 0.82% phytic acid, 0.45% saponin, 0.03% sterol, 0.08% phenol and 0.40% flavonoid. Saponin, flavonoid and tannin have antioxidant properties; flavonoid has anti-inflammatory, anti-allergic, antioxidant and health-promoting activities; tannin has antimicrobial, anti-secretolytic, anti-irritant, antiphlogistic, anti-parasitic, and anticancer properties; saponin has anti-inflammatory activity, cholesterol-lowering, and anti-fungal properties.

Antibacterial effects of turmeric in fish preservation: Turmeric has antibacterial properties that help to increase the shelf life of fish and fishery products by delaying the microbial spoilage and prevent diseases caused by infectious pathogens. The antibacterial study on aqueous extract of *C. longa* rhizome showed the MIC (minimum inhibitory concentration) values as 4-16 g/L and MBC (minimum bactericidal concentration) values as 16-32 g/L against *Klebsiella pneumoniae* ATCC 10031, *Staphylococcus epidermidis* ATCC 12228, *E. coli* ATCC 25922 and *S. aureus* ATCC 25923 (Moghadamtousi *et al*., 2014). The hexane and methanol extracts of *C. longa* have an antibacterial effect against 13 bacteria namely *Vibrio harveyi*, *V. alginolyticus*, *V. vulnificus*, *V. parahaemolyticus*, *V. cholerae*, *Bacillus subtilis*, *B. cereus*, *Aeromonas hydrophila*, *Streptococcus agalactiae*, *Staphylococcus aureus*, *S. intermedius*, *S. epidermidis*, and *Edwardsiella tarda* (Lawhavinit *et al*., 2010). Even, curcumin has inhibitory activity against methicillin-resistant *S. aureus* strains (MRSA) having MIC value of 125–250 μg/mL by inhibiting the transcription of the *mecA* gene, so that the expression of PBP 2α proteins get decreased (Mun *et al*., 2014); thus, MRSA becomes sensitive towards β-lactam antibiotics such as -penicillin and methicillin. The study on *S.aureus*, *E.coli*, and *B.subtilis* demonstrated that curcumin binds to *FtsZ* filament, decreasing the assembly of *FtsZ*, suppressing Z ring formation, hence prokaryotic cell division get disturbed (Kaur *et al*., 2010; Teow *et al*., 2016). Turmeric oil has inhibitory activity against *B. subtilis*, *B. coagulans*, *B. cereus*, *S. aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa* (Moghadamtousi *et al*., 2014). Moreover, Suvarna *et al.* (2014) reported that turmeric had significant antibacterial activity against *Enterococcus faecalis*. In fish and fishery products, enterotoxins produced by *S. aureus* causes gastroenteritis after consumption which may be inhibited by turmeric as binding of curcumin with the bacterial cell wall leads to the damage of cell wall and cell membrane causing cell lysis (Moghadamtousi *et al*., 2014). The microbial count, pH, and organoleptic evaluation revealed that 5% turmeric extract could extend the shelf life upto five days of Presto of Lalawak fish (*Barbodes balleroides*) when stored at room temperature (Aulia *et al*., 2019). While studying the rainbow trout fillets coated with turmeric, quinoa (*Chenopodium quinoa*), cardamom (*Elettaria cardamomum*) and chitosan separately, Korkmaz *et al.* (2019) reported the highest inhibition of microbial spoilage in turmeric coated fillet. The turmeric coat decreased lipid oxidation and protein denaturation with low pH value. This resulted in lowest increase in total volatile basic nitrogen (TVB-N) among all the samples. Pezeshk *et al.* (2011) reported that dip treatment in turmeric extract, shallot extract, and their combination separately of rainbow trout (*Oncorhynchus mykiss*) under vacuum-packaged condition showed retardation of chemical changes (TVB-N, PV, and TBA) with slowdown in microbial growth resulting in extended shelf life. Dip treatment in turmeric extract of cuttlefish (*Sepia brevimana*) stored at 4°C exhibited inhibitory activity against mesophilic, psychrophilic, *Pseudomonas* sp. and biogenic amine forming bacterial growth after 15 days of storage with 3 days more shelf life than the control (Arulkumar *et al.*, 2017).

According to Jana and Chakraborti (2016) the protein denaturation in fish can be minimized even upto 15 days by applying salt and turmeric together which is nowadays practiced in domestic households too. Nahid *et al.* (2016) reported that using salt and turmeric mixture followed by smoke-drying of fish shortened the drying time, maintained nutritional qualities with extended shelf life. Turmeric and salt-treated sun-dried Shoal (*Channa striatus)*, taki (*Channa punctatus*), and Tengra (*Mystus tenagra*) exhibited excellent sensory properties, less protein and fat deterioration with acceptable microbial load ($<10^5$ CFU g^{-1}) (Farid *et al.*, 2016). At the end of 12 months of storage of sun-dried tengra *(Mystus tengara*), both salt and turmeric treated fish remained in acceptable condition, whereas fish treated only with salt became spoiled based on the values of TVBN, pH and free fatty acid (Farid *et al.*, 2015).

Similarly, turmeric and salt-treated sun-dried shoal (*Channa striatus*) showed better nutrition profile, organoleptic properties, and higher shelf life than the fish undergoing the same treatment but without turmeric (Farid *et al.*, 2014). Ummul-Izzatul *et al.* (2020) reported that turmeric-salt marinated mackerel (*Rastrelliger brachysoma*) exhibited lowered growth of *L. monocytogenes* with a reduction of 0.07 log CFU/g from 2.81 log CFU/g under isothermal storage temperature. Imtiaz *et al.* (2017) reported that ribbon fish (*Trichiurus haumela*) treated with turmeric and dried in sun showed lower bacterial load than the salt-treated samples and control. Mosarrat *et al.* (2017) reported that salt and turmeric treated smoke-dried *Gudusia chapra*, *Xenentodon cancila*, and *Macrognathu spancalus* resulted in good sensory, proximate, chemical, and nutritional quality with lesser microbial load. On the other hand, Pankyamma *et al.* (2016) observed remarkably lesser values in FFA, peroxide value (PV) and thiobarbituric acid reactive substance (TBARS) in dip treated sutchi catfish fillets in 2% turmeric solution and smoked at 60°C for 2 hours than the control.

Handayani *et al.* (2018) reported the effectiveness of a combination of 3 to 6% of turmeric and 2 to 4% of tamarind in the preservation of yellow seasoned pindang fish by reducing microbial load. Chilek *et al.* (2017) found the best preservative effect of a combination of salt, and turmeric and sodium acetate applied to preserve refrigerated tilapia fish. Patin fillets coated with Cassava starch, enriched with Javanese turmeric and red ginger essential oil showed retardation in microbial growth, inhibited protein deterioration, and slowed down lipid oxidation while storing under the frozen condition for four months (Utami, 2016). Fish treated with salt, pepper, turmeric, and ajwain sample conferred best nutritional profile, better organoleptic properties, delaying in microbial spoilage, and enzymatic activity with extended shelf life (Alex, 2016). Treatment with 0.3% of salt and 0.15% of curcumin with a soaking time of 20 minutes followed by drying at 40°C for 20 h of snake head (*Channa striata*) exhibited nice physicochemical, microbiological, and organoleptic characteristics (Minh *et al.*, 2019).

Antifungal activity of turmeric in fish: Curcumin, the most important component of turmeric showed anti-fungal activity against various fungi. The most possible mechanism may be due to decrease in ergosterol content in fungal cell in presence of curcumin. Curcumin reduces the ergosterol production and leads to accumulations of biosynthetic precursors of ergosterol. This eventually results in cell death due to the production of reactive oxygen spices (Sharma *et al*., 2010). The fungal inhibition may also be due to a decrease in the proteinase secretion as well as alteration of the membrane-associated properties of ATPase activity (Neelofar *et al*., 2011).

Curcumin has antifungal activities against 38 different strains of genus *Candida* including *C. albicans*, *C. glabrata*, *C. krusei*, *C. tropicalis*, and *C. guilliermondii* causing fish disease; the mechanism may be due to intracellular acidification through H^+/ extrusion inhibition (Moghadamtousi *et al*., 2014). Turmeric oil is found to have significant antifungal activity against *Aspergillus flavus* (Kumar *et al*., 2011) that produces aflatoxin causing harmful effects to fish culture (Sivaraman *et al*., 2016; Mohamed *et al*., 2017).

Antioxidant activity of turmeric in fish: The presence of antioxidants significantly retards the rate of oxidation by protecting cells from damage caused due to unstable free radicals (Asimi *et al.,* 2013). The curcumin can scavenge oxygen from these free radicals. This property increases when phenolic and methoxy groups are present in the ortho position of curcumin (Niranjan and Prakash, 2008). The lipid peroxidation product, thiobarbituric acid reactive substances (TBARS) content either reduced or remains unaltered in *Anabas testudineus* fed with turmeric supplemented diet as reported by Manju *et al*. (2012). Turmeric decreased the enhanced frequency of micronuclei induction in peripheral erythrocytes induced by chromium trioxide in *Channa punctatus* (Prasad *et al*., 2017).

Insecticidal activity of turmeric in fish: Blowflies and insect infestation are one of the major problem associated with fish drying. Turmeric powder showed inhibition against *Necrobia rufipes* in dried punti fish (Ahmed *et al*., 2013).

Conclusions

Recently there is a high demand among the consumers for fish having great quality and safety, presence of a minimal amount of less harmful preservatives, low cost, and the absence of pollutants, antibiotics, and carcinogens. In order to achieve improved food safety and to harmonize consumer demands with the necessary safety standards, traditional means of controlling microbial spoilage and hazards in foods, as well as the use of harmful chemical preservatives, are being replaced by combinations of innovative technologies that include natural antimicrobial substance, free of potential health hazards; such as turmeric. Turmeric has a magnificent history of use in Ayurveda, Unani, and Siddha system. Literature survey shows that turmeric possesses excellent antimicrobial, immunostimulatory, antioxidant, anti-fungal properties, and flavor-enhancing attribute, thus increasing its potential to be used in fish preservation providing low cost and nutritious fish and fishery products with extended shelf life and minimal toxicity. Turmeric-preservation may be effectively used in combination with other preservative factors (hurdles) to inhibit microbial growth and achieve food safety. Using an adequate mix of hurdles is not only economically attractive; it also serves to improve microbial stability and safety, as well as the sensory and nutritional qualities of a food, which are required to be duly investigated.

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Author's contribution: SN and PC: Collected the literatures cited here and wrote the first draft, arranged the final manuscript, and refined at per the journal guidelines; SC: Helped in collection of literatures; NR and SM: Helped in final refinement of the manuscript.

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