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Research Article

Quality Boost and Shelf-Life Prolongation of African Catfish Fillet Using *Lepidium sativum* Mucilage Extract and Selenium Nanoparticles

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Aiming to boost the catfish fillet quality, the consequences of their treatment with *Lepidium sativum* seeds mucilage (LSSM) and with LSSM-mediated selenium nanoparticles (LSSM-Se NPs) were investigated. The LSSM assessment for phenolic acids contents emphasized higher concentrations. Green-synthesized Se NPs were conjugated with LSSM to form LSSM-Se NPs and characterized; the NPs had spherical shapes, negatively charged with 15.47 nm mean diameters. Fish fillets were immersed in coating solutions for 2 min, drained, and stored for 25 days at 4°C. The fish groups (C: untreated samples, M: LSSM-treated, and G: LSSM-Se NPs treated) were assessed for their physicochemical, bacteriological, and sensorial attributes. On the 25th day, the samples' pH values were 6.96, 6.6, and 6.3; TVB-N values were 38.8, 28.4, and 16.4 mg/100 g; TBARS values were 1.7, 0.97, and 0.68 malondialdehyde/kg; and overall acceptability scores were 3.9, 5.6, and 8.3, for C, M and G groups, respectively. At day 16, the psychrophilic bacterial count was 6.2, 4.0, and 3.6 log CFU/g for C, M, and G groups, respectively. The application of LSSM and LSSM-Se NPs is recommended to compose active coatings for quality boost and shelf-life extension of stored catfish fillet.

1. Introduction

Fish farming is the most important economic input in Egypt due to its geographical location and its various possessions of water bodies, especially after digging the new branch of the Suez Canal and establishing the famous fish production station, Ghalyoun pond, which makes it a pioneer in this field. Egypt is the leading African country in aquaculture, with high production of African catfish (*Clarias gariepinus*), but the optimal utilization of this species is still limited, either by exporting or processing [1, 2].

Regarding fish meat, they are principal and cheap sources of animal proteins, which increase the importance for their processing and preservation; African catfish are particularly positioned as ideal species for additional utilization due to their great endurance to various environmental effects and their high growth rate [3].

The meat of African catfish has high total protein content (16.91–17.90%) and relatively low-fat content (3.95–7.57%), and they are considered a medium-fat fish. Due to the low percentage of fat in the fillet of catfish, oxidative rancidity is delayed and shelf life is extended compared to other species [3, 4].

The catfish could be commonly subjected to many pathogenic and spoilage microorganisms, which increase the public concerns about their processed products, and need more verifications for their safety and potential usages [5].

The preservation of seafood products and elimination of spoilage/pathogenic contaminants are conducted using different processing technologies and food-grade additives that have both antimicrobial and antioxidative effects. Lowering the temperature is from the principal technologies that increase the storage time of fish fillet up to several months, including freezing and chilling. The chilling of African catfish fillet could lead to higher protein, fat, ash, energy content, tenderness, and water holding capacity with lower moisture content and cooking loss in comparison with frozen fillets [3].

Lepidium sativum seeds mucilage (LSSM) has many pharmaceutical and therapeutic uses; it can also be used as food-grade additive as it has hydrocolloid characteristics and antimicrobial and antioxidative effects in addition to its cost-effectiveness and wide usages in homemade remedies [6].

Selenium (Se) is the essential trace element for the human body, with strong antimicrobial and antioxidant effects. The Se deficiency in human increases the tendency of cardiovascular diseases, arthritis, and age-related immunosuppression [7]. These great effects of Se are boosted when it is transformed into Se nanoparticles (Se NPs) with additional anticarcinogenic effects, so food treated with Se NPs could have additional health importance [7, 8].

Nowadays, nanotechnology applications are widely used in the food industry to increase shelf life, enhance sensory characters, and maintain the nutritional and microbial qualities; the green (bio) synthesis and stabilization of nanometals (e.g., Se NPs) provided elevated safety, biocompatibility, and functionality to biosynthesized NPs [9].

In this study, LSSM was evaluated as food-grade additive to preserve chilled African catfish fillet. The fabrication of Se NPs with LSSM and their combined assessment as potent preservatives and quality enhancers of catfish fillets were also intended.

2. Materials and Methods

2.1. Preparation of LSSM Extract. Garden cress seeds (*Lepidium sativum*) were attained from ARC "Agricultural Research Center—Giza, Egypt." Each 100 g of seeds was soaked in distilled water (1000 ml) for 12 h, and then, the gel was separated by passing through a vacuum pump. The attained gel was filtered through muslin cloth, and then, the extracted material was soaked in acetone for precipitation. The precipitated materials were collected by centrifugation (4500× g) and dried at 45°C for 6 h to achieve the dried garden cress seeds extract (LSSM) [10]. For LSSM solution preparation, 2 g of the dry powder was dissolved in 100 ml distilled water.

2.2. LSSM Phenolic and Flavonoid Contents Determination. It was determined by HPLC analysis "High-performance liquid chromatography" using Agilent 1260 series (Waldbronn, Germany); the separation was carried out using Eclipse C18 column (4.6 mm × 250 mm i.d., 5 μm). The mobile phase comprised water (A) and 0.05% trifluoroacetic acid in acetonitrile (B) at a flow rate of 1 mL/min. The mobile phase was consecutively programmed in a linear gradient as follows: 0 min (82% A), 0–5 min (80% A), 5–8 min (60% A), 8–12 min (60% A), 12–15 min (82% A), 15–16 min (82% A), and 16–20 (82% A). The multiwavelength detector was monitored at 280 nm. The injection volume was 5 μl for each of the sample solutions. The column temperature was maintained at 40°C.

2.3. Preparation of LSSM-Se NPs. The decorated Se NPs with LSSM were synthesized via reduction of sodium selenite by ascorbic acid in the presence of LSSM as stabilizing/capping agent. An aqueous solution (10 mM) of $Na_2SeO_3.5\ H_2O$ was prepared, and 90 mL of this solution was mixed with equal volume of LSSM solution (0.1%, w/v) and vigorously stirred (730× g) for 90 min. Subsequently, while stirring, 10 mL of ascorbic acid solution (56.7 mM) was dropped slowly into the matrix, and the stirring was continued for further 60 min in dark. The appearance of deep orange color solution indicated the Se NPs formation, which was collected via centrifugation (10500× g, 25 min), reconstituted in Milli-Q water, freeze-dried, and kept at room temperature (25 ± 2°C).

2.4. Characterization of LSSM-Mediated Se NPs

2.4.1. Se NPs Optical Analysis. For validating the Se NPs formation, through detection of their SPR "surface plasmon resonance" associated with liberated electrons on NPs surfaces, the LSSM-Se NPs spectrum was screened via UV-vis spectrophotometer "model UV-2450, Shimadzu, Japan," at wavelength range of 200 to 600 nm.

2.4.2. NPs Size and Charge. The appraising of LSSM-Se NPs size and zeta (ζ) potential was conducted via DLS "dynamic light scattering" technique, applying zeta-sizer "Zeta plus, Brookhaven, USA."

2.4.3. NPs Ultrastructure. TEM imaging "Transmission electron microscopy, Leica, Leo 0430; Cambridge, UK" was performed to determine structural features "size, shape, morphology, and distribution" of LSSM-Se NPs.

2.4.4. FTIR Analysis. For identifying the characteristic biochemical bonding/interactions in produced composites, the spectra of LSSM and LSSM-Se NPs were spectrophotometrically investigated by running FTIR "Fourier transform infrared spectroscopy, JASCO FT-IR-360, Tokyo, Japan" at 450–4000 cm^{-1} wavenumber range.

2.5. Fish Preparation. Alive African catfish (*Clarias gariepinus*, Burchell), ~450 g weight/fish, were purchased from the local market at Desouk city, Kafrelsheikh governorate, Egypt. The samples were wrapped in a separate, sterile, and labelled polyethylene bags and transferred directly to the laboratory, Faculty of Aquatic and Fishery Science, Kafrelsheikh University, in a sterile icebox for further preparation within 2 h from purchasing. Fish samples were

washed thoroughly with potable water, and then, each sample was gutted, beheaded, skinned off, cleaned, and filleted into pieces of about 40 g for each piece and measured ($5 \times 7 \times 1$ cm). Then, the fillet was divided into three groups: the first is called control group and referred to as C group, and the second is mucilage-treated group and referred to as M group while the third is LSSM-mediated Se NPs-treated group and referred to as G group.

Group C was soaked into sterile distilled water for 2 min, then left to dry for another 2 min, then packed in polyethylene bags, and kept in the refrigerator for 25 days. M group was treated by dipping in LSSM solution (2% concentration, w/v) for 2 min, was left to dry for another 2 min, then packed in polyethylene bags, and stored in the refrigerator (at 4 ± 1C) for 25 days. The G group was treated by dipping in LSSM-Se NPs (2%, w/v) for 2 min and left to dry for another 2 min, then packed in polyethylene bags and stored in the refrigerator for 25 days as well [10,11].

All the experiments for the fillet were performed for each group every 8 days (12 pieces from each group were experimented each time) until the 25th day.

The study design and conducting were authenticated and approved by the "Committee of Aquatic Animal Care and Use in Research, Faculty of Aquatic and Fisheries Sciences, Kafrelsheikh University, Egypt," approval No. IAACUC-KSU-30-2019.

2.6. Organoleptic Examination. A panel of seven trained panelists was chosen from the Department of Fish Processing and Biotechnology, Faculty of Aquatic and Fishery Science, Kafrelsheikh University. They were served samples that were cut into cubes and cooked in an oven for 5 minutes to evaluate different organoleptic attributes, i.e., color, odor, flavor, texture, and overall acceptability. On a scale from 1 to 10, the samples were scored, and the samples with scores below 4 were rejected [12].

2.7. Physicochemical Analysis

2.7.1. Measuring PH. A homogenized sample was prepared by adding 10 times of potassium chloride solution, and then, pH value was read using pH meter after the value has reached constant number [13].

2.7.2. Measuring Total Volatile Basic Nitrogen (TVB-N) and Thiobarbituric Acid Reactive Substances (TBARS). The determination of the TVB-N value followed the hydrodistillation method as illustrated in the official method [14]; the method was used based on the extraction of TVB with alkaline solution and titration of recovered ammonia. Homogenized 10 g of fish meat with 20 ml of 7.5% tricholoroacetic acid was filtered over Whatman no 1 paper, then the filtrate was hydrodistilled (VELP, UDK-6, Milan, Italy), with the addition of 3 mL of NaOH (10%). The steam distillates were collected in a flask containing boric acid (4%) that was amended with 1 mL of mixed indicator (methylene blue/methyl red 1 : 2). The attained basic solution was titrated with 0.025 N H_2SO_4.

For the determination of TBARS, the spectrophotometer was used to measure photometric absorption strength (optical density) at 532 nm wavelength [15]. Fillet sample (5 g) was homogenized with 11% trichloroacetic acid (TCA) for 60 s at 11100 rpm (IKA Homogenizer, Wilmington, USA), then placed in the ice bath for 60 s, and then homogenized for further 1.0 min. The homogenates were filtered through Whatman No.1, and then, 1.0 mL of 20 mM thiobarbituric acid solution was added to 1.0 mL of filtrate and incubated for 20 h in dark conditions at 25°C. The absorbance value was assessed at 532 nm via a UV-1800 spectrophotometer (Shimadzu, Kyoto, Japan). The results were calculated as μg of MDA (Malondialdehyde)/g.

2.8. Psychrophilic Bacterial Count. About 225 ml of sterile buffered peptone water was blended for 1 minute with 25 g of fish flesh sample, and then, a 10-fold serial dilution was prepared [16].

One milliliter of the prepared dilution was aseptically inoculated into 2 sterile Petri dishes to which about 15 ml of sterile-melted and tempered Plate Count Agar (Difco Lab., Detroit, MI) was added, then left to solidify, and then kept in the refrigerator at 7°C for 10 days after their ending, and the psychrophilic bacterial count was performed [17].

2.9. Statistical Analysis. Data had undergone two-way ANOVA when $n = 3$, with expressing results in the form of mean and standard error of mean (SEM). The post hoc test of choice was Tukey's test using GraphPad Prism 8.0.2 software. The significance was calculated at P value <0.01.

3. Results and Discussion

3.1. LSSM Phenolic and Flavonoid Content. The extract of LSSM has antioxidant activity due to the presence of phenolic phytochemicals that act as scavengers of free radicals to interfere with lipid peroxidation and antimicrobial action on spoilage and pathogenic microorganisms [18–20].

The detailed inspection of the phenolic and flavonoid contents of LSSM is shown in (Table 1), which clarified the role of four phenolic acids in the process of oxidation reaction inhibition and antibacterial effect due to their elevated level [21, 22]. For example, aside from the flavoring effect of gallic acid (3,4,5-trihydroxybenzoic acid), it also has the ability to inhibit the bioactivity of several bacteria. In addition, it can damage Gram-negative and Gram-positive bacterial cell membrane via interference with the membrane permeability, increase the accumulation of antibiotic in bacterial cell, and at the same time play an important role in the antioxidant scavenging process and metals chelation [23, 24]. The same as for caffeic acid (3,4-dihydroxycinnamic), chlorogenic acid (hydroxycinnamic esters with quinic acid), and ferulic acid ([E]-3-[4-hydroxy-3-methoxyphenyl] prop-2-enoic acid) [21–25]. The LSSM components and their phytochemical constituents were illustrated to possess potent bioactivities, e.g., antioxidant and antimicrobial potentialities [19], which enabled their former usages for foodstuffs preservations [18], and capability for

Table 1: The concentrations of phenolic and flavonoids (μg/g) in extracted *Lepidium sativum* seeds mucilage (LSSM).

Phenolic and flavonoid compounds	Concentration in LSSM (μg/g)
Gallic acid	164.98
Chlorogenic acid	98.02
Caffeic acid	125.05
Ferulic acid	205.60
Coumarin	0.52
Catechin	1.09
Pyrogallol	0.95
Rutin	1.42
Benzoic acid	0.24
Hesperidin	5.02
Ellagic acid	1.52
Coumaric acid	0.04
Rosmarinic acid	0.52
Vanillic acid	0.42
Naringenin	0.93
Cinnamic acid	0.12
Quercitrin	1.48
Kaempferol	0.06
Hesperetin	0.14

incorporation in functional foods due to LSSM biosafe nature and human-friendly attributes [26, 27]. Although some researches suggested that LSSM might lead to abortion [28], it was proven that it has a role in milk production, increases postpartum, enhances blood flow in the uterus, and improves natural parturition as a result, so it is preferable to be ingested at the last third of pregnancy. There is a problem in its ingestion in the first two-thirds of pregnancy [27, 29].

By a close look at the permissible limit of LSSM intake to avoid induction of abortion, it was found that there was no toxicity limit to be set [26, 27]. Other research studies proved that garden cress is safe for use whatever the concentration used is; the LSSM concentration of 2% was used to obtain the best results as a food additive with the lowest chances for triggering health toxicological hazard [26–29]. However, more research studies are needed to confirm the biosafety of LSSM at extreme doses, especially for immune-compromised and pregnant women.

3.2. Characterization of LSSM-Mediated Se NPs

3.2.1. Optical and Structural Analysis of NPs. The visual observation of Se NPs formation indicated that the clear sodium selenite solution turned into deep orange color after the reduction of Se to Se NPs and their interaction with LSSM (Figure 1(a)). This was also verified with the spectroscopic analysis of Se NPs solution, which indicated the highest color absorbance (λ_{max}) at a wavelength of 278 nm (Figure 1(a)).

The DLS analysis of LSSM-Se NPs indicated that the NPs had diameters size range of 7.17 to 45.46 nm, mean diameter of 15.47 nm, and negative zeta potentiality of −32.4 mV.

The TEM investigation of Se NPs size and shape emphasized the well-dispersion of Se NPs microspheres in the matrix of LSSM (Figure 1(b)). The NPs size was estimated via TEM analysis to have 7.63–43.84 nm particle size range and 15.89 nm mean diameter, which matched the acquired sizes from DLS analysis.

The visual validation of LSSM-Se NPs formation was acknowledged via changing of the composite solution color into orange-red due to the designative SPR for Se NPs in wavelength range of 270 to 400 nm, which was stated in former investigations [30, 31]. The Se NPs reduction mechanism was stated to correlate with their SPR excitation, which could be responsible for the absorbance λ max and NPs solution color change; these are strong indications for such NPs formation [30–33].

The ζ potential frequently presents indications for surface charge of individual molecular and the potential generated electric layer from the surrounding ions; characteristically, NPs with lower ζ than −30 mV or higher than +30 mV values exhibit elevated stability degrees due to interparticle repulsion electrostatically [32]. The obtained ζ potential here for LSSM-Se NPs (−32.4 mV) indicates their advanced stability after capping/stabilization with LSSM, which was stated formerly for the stabilization of Se NPs using different biopolymers, polysaccharides, and phytoconstituents [31, 33].

The detected sizes for decorated LSSM-Se NPs revealed the successfulness of the synthesis process to generate minute NPs with well-dispersion and stability attributes; this was assumingly attributed to the higher reducing/capping potentialities of LSSM and its contents from bioactive phytochemicals that interacted with Se NPs and prevented their aggregation [33, 34].

3.2.2. Biochemical Bonding Analysis via FTIR. The FTIR spectra of LSSM and LSSM-Se NPs were provided to emphasize the main biochemical bonds/groups in LSSM and their potential interactions with Se NPs (Figure 2).

The key designative peaks in the LSSM spectrum indicated the weak stretching of C–O (at 1089 cm^{-1}) and the symmetric/asymmetric carboxylate groups (at 1424 and 1621 cm^{-1}). The appeared band around 2900 cm^{-1} (exactly at 2925 cm^{-1}) is generally referred to bending and stretching vibrations of C–H (including CH, CH2, and CH3), with occasional doubles overlapping with O–H bonds [34–36]. The peak at 1143 denotes the monosaccharides presence (e.g., glucose and mannose) [37, 38].

For the LMMS-Se NPs spectrum, new emerging bands were appeared at 788 and 1332 cm^{-1}, assumingly due to the interaction between Se NPs and LSSM and the formation of new active bonds between them. The bands at 708 and 1511 cm^{-1} in the LSSM spectrum were disappeared from the spectrum of LSSM-Se NPs, and the band at 1198 cm^{-1} (in LSSM spectra) was shifted to 1148 cm^{-1}, which indicated the breakage/desaturation of these bonds after formation and interaction with Se NPs [34, 36].

3.3. Organoleptic Examination. By observing the changes in sensory attributes as shown (Figure 3) and analyzing the results statistically, it was found that there was significant

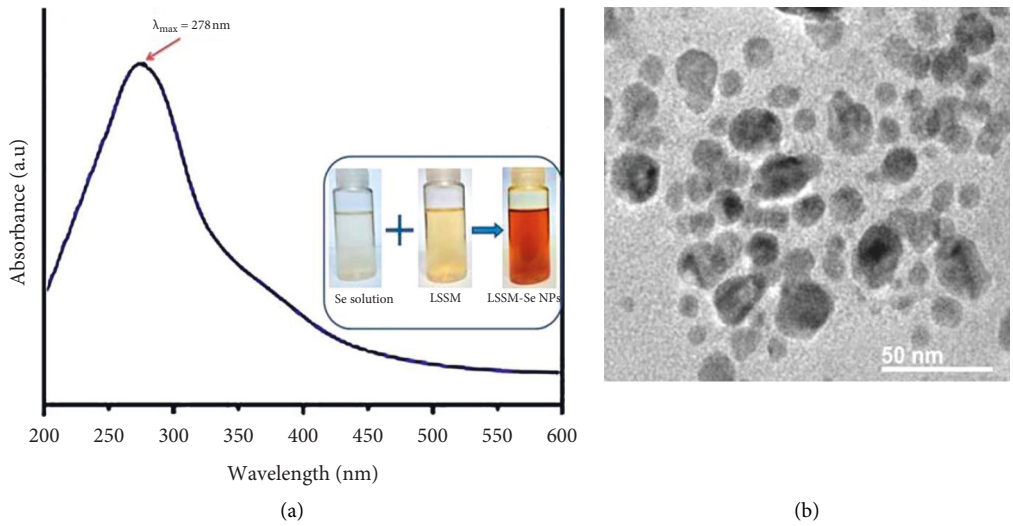


Figure 1: Color indicators and UV-vis spectrum (a) and TEM physiognomy (b) of mediated Se NPs with *Lepidium sativum* mucilage (LSSM).

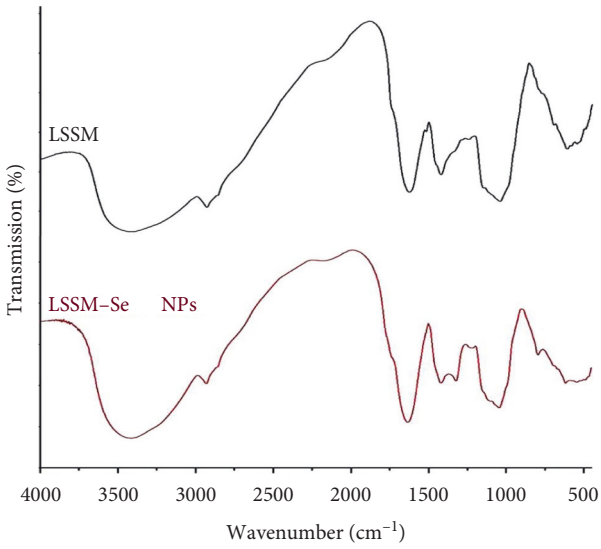


Figure 2: FTIR spectra for LSSM and LSSM-Se NPs.

difference among scores due to the effect of treatment, storage time, and the interaction of both.

After performing Tukey multiple comparison test, it showed that for overall acceptability, the highest score was recorded at zero day (>9), then it decreased with time till the 25th day in C, M, and G groups, while there was a difference between the groups at the same days. The score inclined more in the C group than in the M group, and the decrease was at its minimum level in the G group, but the scores stayed within the acceptable limit till the 16th day and exceeded the permissible limit on the 25th day for the C group. The M and G groups stayed within the limit of acceptability until the end of the experiment with higher score in the case of the G group.

The same as for color and texture where the highest scores were at the zero day (>8), and then, the inclination happened in all groups with time, but the difference was that all groups stayed within the range of acceptability till the end of the experiment with the highest score in G group.

Applying the same analysis to odor and flavor with the highest scores at zero day (>8 and >9), respectively, it gave results that resembled that of overall acceptability where odor and flavor development happened with the continuation of the deterioration process. Therefore, the C group was refused on the 25th day due to the putrid odor, but M and G were acceptable; the scores in the G group remained near the highest levels until the end of the experiment.

As the regular shelf life for refrigerated fish and fish products could not generally exceed the limit of 21 days [39, 40], the current samples' storage period was set to 25 days for assessing the potential spoilage/decomposition parameters that can appear within this period, with taking 4 indicating samples (at 8 days intervals) to trace these changes during storage.

The coated groups (M and G) upheld ~10 mL from coating solutions (10% concentration) per kg of treated fillets; this amount could contain ~250–300 μg of Se NPs for each kg of fillet, which still remain at the safe levels of human daily intake from Se element (required daily intake for human = 40–300 μg and the toxicity could occur at high dosages ≥3,200 μg/day) [41, 42].

The bioavailability, bioactivity, and toxicity of Se elements depend predominantly on their chemical and structural form; the Se NPs possess much lower toxicity and increased bioavailability, compared to organic and inorganic bulk Se species [43]. Additionally, the administered Se NPs via oral routes were demonstrated to efficiently increase the selenoenzymes bioactivities, but with significant diminished toxicities than other Se forms (e.g., selenomethionine, methylselenocysteine, or sodium selenite), in animal experiments [44]. These validated results could change the supposed dogma regarding elemental Se bioactivities and suggest Se NPs as effectual, low-risk, and biosafe sources for Se supplementations with minimal toxicity [43, 44].

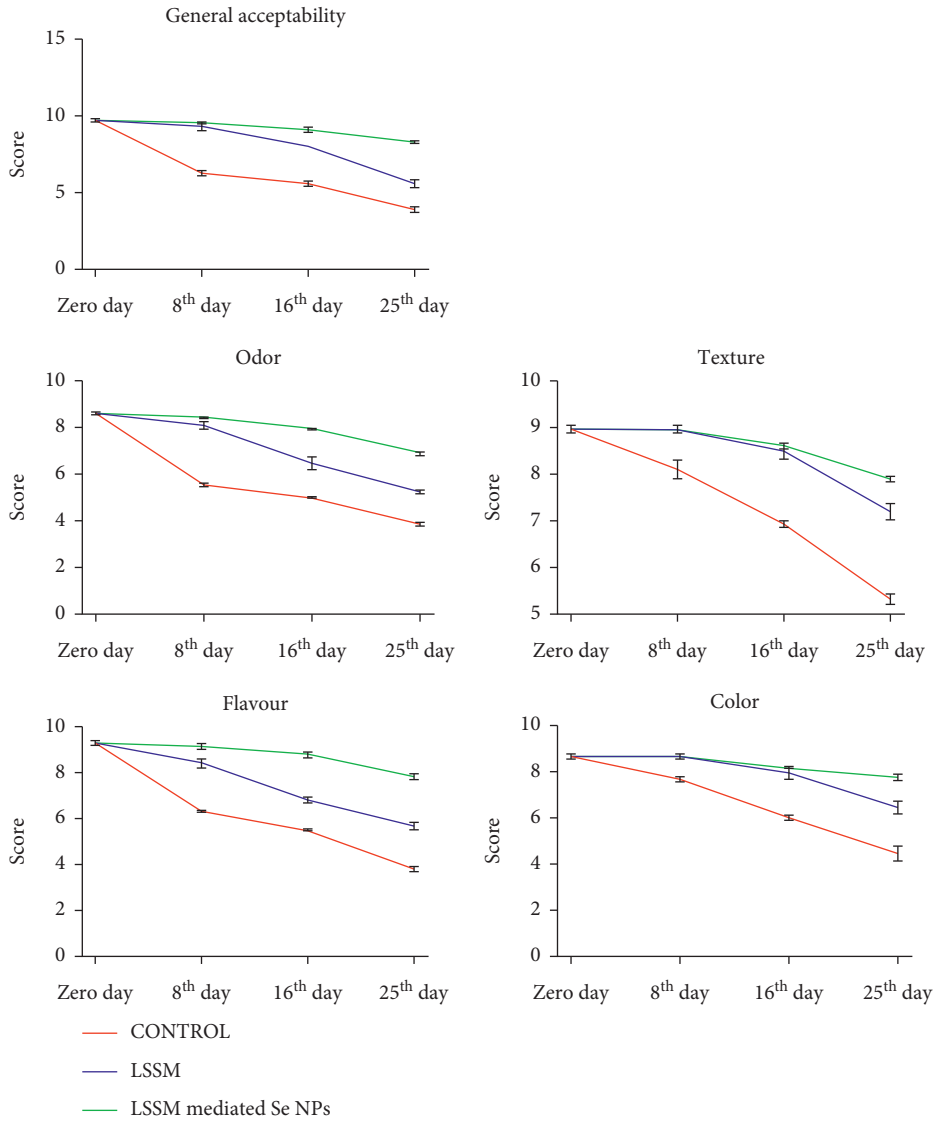


Figure 3: Mean scores of organoleptic characteristics of treated catfish fillets with *Lepidium sativum* mucilage (LSSM) and LSSM-mediated Se NPs during storage at refrigeration temperature.

The frequent applications of Se NPs in food processing, packaging, and cold preservation warrant their elevated biosafety and diminished toxicity; Se NPs were demonstrated as highly applicable and biosafe nanometals for direct intake and contact with human and animals [41, 42, 45]. As the usage of biological macromolecules (e.g., biopolymers, polysaccharides, phytocompounds) in Se NPs synthesis, capping, and stabilizing, provides more biosafety attributes for the synthesized NPs [43, 45], it could be expected that LSSM-mediated Se NPs will have elevated biosafety and compatibility and minimal potential toxicity.

From these results, whereas control samples were rejected by the panelists in terms of odor, flavor, and overall acceptability, the LSSM- and LSSM-Se NPs-treated groups retained good sensory characteristics for a longer time with a higher grade sensory quality compared to the control group. The G group scores stayed close to normal until the storage end, which may suggest more extension of fillet shelf life if the experiment continued more than 25 days. The cost-effectiveness of used agents in the current investigation (sodium selenite and *L. sativum* seeds) could be claimed; their average commercial prices are 2–15 USD/kg and 1–4 USD/kg, respectively. However, 1 kg from Na_2SeO_3 could give ~300 – 450 g of Se NPs, and 1 kg from *L. sativum* seeds could give 300 – 400 g of LSSM [10, 11, 27].

3.4. pH. Mostly, the general pH of postmortem fish is 6.0 – 6.8, and some papers stated that this value around 7.0 is the standard for fresh fish [39, 40], so the results in (Figure 4) were all within permissible limits [12, 46].

The pH value on the 8th day increased in the C group while it remained the same in M and G groups. On the 16th day, there was a slight increase in pH of both C and M groups while it was unnoticeable in the G group. On the 25th day, there was an increase in pH of the first two groups, which

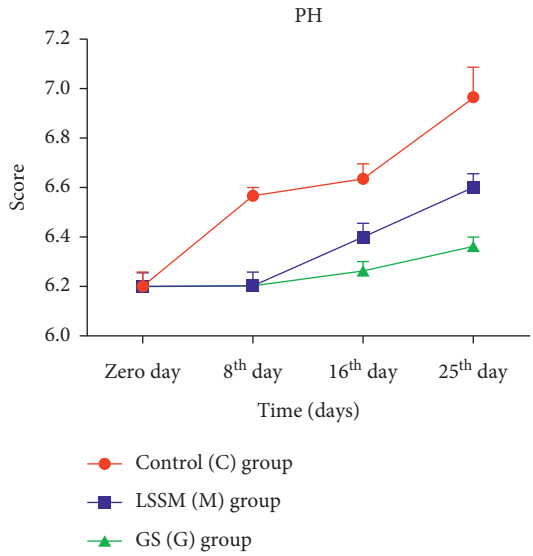


Figure 4: The means of pH values of treated catfish fillets with *Lepidium sativum* mucilage (LSSM) and LSSM-mediated Se NPs during storage at refrigeration temperature.

was more remarkable in the C group than in the M group, while in the G group, the level was barely increased. The pH value elevation is mainly due to the increase in basic substances level like ammonia, which may be due to microbial activity or autolytic enzymes that occur with the progress of fish spoilage [46, 47].

Although all the results of coated groups were within the permissible limits for fish acceptance, but by comparing groups, it was found that the pH level was the lowest in the G group followed by the M group, which means a lower level of basic substances released. This means that LSSM extract and LSSM-Se NPs have a delaying effect for pH elevation whether by microbial inhibition or enzymatic activity suppression. However, reliance on pH alone is unreliable because there are many factors that affect the change of pH rather than microbial effect and enzymatic action [48].

3.5. Chemical Analysis. The acceptable limit of TVB-N in fish flesh was stated to be 35 mg/100 g, and it resulted from protein degradation whether by the action of bacteria or autolytic enzymes [49–51].

Table 2 shows raised TVB-N level in the C group with a significant difference starting from the 8th day until the end of the experiment. The values still rely under the acceptable limit until the 16th day, although it was close to the unacceptable limit. On the 25th day, it exceeded the limit and the product was unfit for consumption, while in the M group, the significant difference started to appear from day 16 until the end of the experiment with complete agreeability for product consumption until the end of the experiment; all values in this group remained at the permissible limits. In the G group, a significant difference was shown on the 25th day but stayed away from the acceptable limit. Thus, the results can indicate that LSSM extract had a direct or indirect role in retarding the elevation rate of TVB-N levels while LSSM-Se NPs have a more powerful effect in retarding the elevated TVB-N, which persisted close to fresh values [39, 40].

Fish lipids have high tendency for oxidation due to the presence of polyunsaturated fatty acids with the production of thiobarbituric acid reactive substances (TBARS) [52, 53]. The limit for acceptability was set to be <3 mg malondialdehyde/kg where other researches stated that rancidity starts when TBARS value exceeds 4 mg malondialdehyde/kg [46, 54].

The level of TBARS increased with time until the end of the experiment, but when comparing C, M, and G groups, it was found that the elevation of values was much lower in the M group than in the C group, and its lowest level was recorded in G group. This means that the process of lipid peroxidation has a lower tendency in LSSM and LSSM-Se NPs-treated groups. The cause can be attributed to the presence of phenolic acids in LSSM extracts and their antioxidant activity, which can also explain the boosted antioxidant activity of LSSM-Se NPs (Table 2).

In order to achieve a rational way from a panelist perspective and guarantee a safe product to the consumer, the results should be compared to those of sensory attributes and TVB-N values. In both cases, the product was unsuitable for human consumption on the 25th day in the C group where they stayed acceptable for consumption until the end of the experiment in the M and G groups. Depending on this outcome and with a close look at TBARS value table, the acceptable limit would be set equal to 1 malondialdehyde/kg.

3.6. Psychrophilic Bacterial Count. This type of bacteria is important, especially in preserved products in cold temperatures. It can cause many negative changes in sensory attributes via the production of different compounds throughout their metabolism like biogenic amines, volatile sulfides, ketones, and aldehydes [55, 56].

The maximum limit for psychrophilic bacteria was suggested to be 4 log CFU/g [57]. The results in terms of log CFU/g (Table 3) show that the product in the C group was unaccepted in the time between day 0 and day 8, while in the M group, the refusal occurred on the 16th day, which means that the LSSM-treated group had longer storage period due to the antimicrobial effect of LSSM extract phenolic acids. However, the G group stayed acceptable up to the end of the experiment due to the boosted antibacterial effect of LSSM-Se NPs.

The psychrophilic bacteria possess lipolytic and proteolytic activity that both have a direct effect on the increase in TVB-N and TBARS levels. Thus, the resultant judgement in terms of TVB-N and TBARS previously mentioned is related to these activities.

It was formerly mentioned that LSSM extract and LSSM-Se NPs have an effect on several bacteria such as *Pseudomonas*, *Streptococcus*, *Listeria*, *Chromobacterium*, and *Staphylococcus* spp. in addition to other Gram-negative, Gram-positive, and *Campylobacter* spp.; most of them are suggested to be members of the psychrophilic family [18, 20, 24, 58, 59]. The dependency on the psychrophilic

Table 2: The TVB-N and TBARS values of treated catfish fillet groups with LSSM (*M*) and LSSM-Se NPs (*G*) compared to control (*C*) during storage at refrigeration temperature*.

Days of storage	TVB-N (mg/100 g)			TBARS (malondialdehyde/kg)		
	C	*M*	*G*	*C*	*M*	*G*
Zero	15.507 ± 0.058^{Aa}	ND	ND	0.410 ± 0.006^{Aa}	ND	ND
8^{th}	16.567 ± 0.120^{Ba}	15.507 ± 0.116^{Ab}	15.507 ± 0.058^{Ab}	1.343 ± 0.015^{Ba}	0.657 ± 0.049^{Bb}	0.480 ± 0.017^{Ac}
16^{th}	30.150 ± 1.565^{Ca}	16.333 ± 0.328^{Ab}	15.700 ± 0.058^{Ab}	1.697 ± 0.039^{Ca}	0.810 ± 0.035^{Cb}	0.570 ± 0.017^{Ac}
25^{th}	38.770 ± 0.301^{Da}	28.440 ± 0.411^{Bb}	16.400 ± 0.265^{Ac}	1.700 ± 0.058^{Ca}	0.970 ± 0.006^{Db}	0.677 ± 0.009^{Ac}

Note. *Different capital letters in the same column indicate there is a significant difference while different small letters in the same row indicate a significant difference is present where P value <0.01.

Table 3: The psychrophilic bacterial count (log CFU/g) in treated catfish fillet groups with LSSM (*M*) and LSSM-Se NPs (*G*) compared to control (*C*) after storage at refrigeration temperature*.

Days of storage	Log CFU/g		
	C	*M*	*G*
Zero day	3.500 ± 0.000^{Aa}	ND	ND
8th day	4.500 ± 0.058^{Ba}	3.467 ± 0.145^{Ab}	3.533 ± 0.033^{Ab}
16th day	6.200 ± 0.351^{Ca}	4.000 ± 0.289^{Ab}	3.600 ± 0.058^{Ab}
25th day	7.633 ± 0.120^{Da}	5.033 ± 0.145^{Bb}	4.000 ± 0.289^{Ac}

Note. *Different capital letters in the same column indicate there is a significant difference while different small letters in the same row indicate a significant difference is present where P value <0.01.

count for final judgement not only relies on their importance in the spoilage process but also these bacterial species may have further public health importance because they include numerous pathogenic bacterial species [20, 24, 59].

The garden cress and LSSM, because of their containment of numerous bioactive compounds, were reported to possess strong antimicrobial potentialities toward several screened bacteria and fungi, especially those belonging to food-borne pathogens [27, 29]. The ability of lepidine and many other alkaloids from LSSM was proved to inhibit bacterial and fungal development through diverse routes of physiological and molecular routes [6, 10, 29], which support our findings here for inhibiting fish contaminating bacteria.

The fisheries products' biopreservation, using natural derivatives from plant, biopolymers, and biosynthesized nanoparticles, was proved as effectual techniques/agents to extend the shelf lives and augment the overall qualities of stored seafoods [7, 14, 32, 53, 60]; this supported the current targets of our study and their applicability in fisheries processing/preservation.

4. Conclusion

The shelf life and quality of catfish fillet treated with LSSM extract and LSSM-mediated Se NPs were enhanced compared to the nontreated fillet. Regarding the overall acceptability, TVB-N values, TBARS values, and bacterial count, it could be claimed that the coated products' suitability for consumption was extended more than 16 days at chilling temperature in LSSM-coated group with a higher quality, compared to nontreated group, whereas the shelf life was extended to ≥25 days with LSSM-Se NPs treatment. This recommended the application of *L. sativum* seeds mucilage and LSSM-Se NPs as effective agents for the preservation of seafood product in particular catfish fillet.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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