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Original Article

Effect of amla and ginger powders on quality criteria of African catfish (*Clarias gariepinus*) fingers

Efeito da amla e do gengibre em pó nos critérios de qualidade dos palitos de bagre-africano (*Clarias gariepinus*)

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Abstract

Catfish (*Clarias gariepinus*) meat isn't preferred by consumers in compared to other fish species meat, thus to enhance the use of catfish meat, ready to eat catfish fingers were prepared with some plants additives (amla and ginger powder). The mean objective of this study was to assess the impact of amla and ginger powder on catfish finger qualities in terms of physical, chemical, microbiological, and sensorial parameters under stored at a low temperature (5 ± 1 °C). The obtained results were compared with those of a control sample (basic formula) and a sample containing the synthetic antioxidant. During the storage period, the levels of pH, thiobarbituric acid, total volatile basic nitrogen, trimethylamine, total bacteria count, psychrophilic bacteria, molds and yeasts counts increased dramatically, although the values remained within acceptable ranges. The findings also revealed, that amla and ginger powder considerably ($p < 0.05$) reduced the changes in quality parameters, as well as there was a considerable increase in the quality parameter in all treated samples than in the control. Finally, amla and ginger powder can be a substitute for synthetic antioxidants and antimicrobials. These findings suggest that the powder of amla and ginger are suitable for use as a natural antioxidants and antimicrobials to extend the shelf-life of animal products.

Keywords: quality parameters, catfish finger, amla, ginger, antioxidants, antimicrobial.

Resumo

A carne de bagre-africano (*Clarias gariepinus*) não é preferida pelos consumidores em comparação à carne de outras espécies de peixes, portanto, para aumentar o uso da carne de bagre, foram preparados palitos de bagre-africano prontos para consumo com alguns aditivos vegetais (amla e gengibre em pó). O objetivo médio deste estudo foi avaliar o impacto da amla e do pó de gengibre nas qualidades dos palitos de bagre-africano em termos de parâmetros físicos, químicos, microbiológicos e sensoriais armazenados em baixa temperatura (5 ± 1 °C). Os resultados obtidos foram comparados com os de uma amostra controle (fórmula básica) e uma amostra contendo o antioxidante sintético. Durante o período de armazenamento, os níveis de pH, ácido tiobarbitúrico, nitrogênio básico volátil total, trimetilamina, contagem de bactérias totais, contagem de bactérias psicrófilas, bolores e leveduras aumentaram drasticamente, embora os valores tenham permanecido dentro dos limites aceitáveis. Os achados também revelaram que amla e gengibre em pó reduziram consideravelmente ($p < 0,05$) as mudanças nos parâmetros de qualidade, assim como houve um aumento considerável no parâmetro de qualidade em todas as amostras tratadas do que no controle. Por fim, a amla e o pó de gengibre podem substituir os antioxidantes e antimicrobianos sintéticos. Essas descobertas sugerem que o pó de amla e gengibre são adequados para uso como antioxidantes naturais e antimicrobianos para prolongar a vida útil de produtos de origem animal.

Palavras-chave: parâmetros de qualidade, palito de bagre-africano, amla, ruivo, antioxidantes, antimicrobiano.

1. Introduction

Fish and fishery products are considered as a great source of nutritionally important proteins that are rich in essential amino acids, contributing by 20% of the per capita animal proteins consumption (FAO, 2014a). Numerous fish include

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fat that is high in n-3 polyunsaturated fatty acids, which are linked to a decreased risk of heart disease. Additionally, fish contains a number of macro-and micronutrients, that influence health promotion. It is advised by the World Health Organization to eat 1-2 servings of fish each week.

To maintain a balanced dietary pattern, for normal and pregnant women the American Dietary Guidelines advise 8 to 12 ounces of fish per week (USDA, 2020). Due to the changes in global eating habits that place an emphasis on foods that are rich in nutrients, fish and their products intake has increased from 9.9 kg in 1960 to 20 kg in 2015 per capita (FAO, 2016a). Consumption of fish has increased due to its great nutritional value, numerous health benefits, accessibility to the general population, and dominance in the world's food trade (Rathod et al., 2021). Rapid urbanization has resulted in a change in eating patterns, with an increasing number of people choosing "Ready-To-Cook and Ready-To-Eat" snack food, as their preferred option (Xavier et al., 2018).

Catfish, carp and salmon are the most prevalent fish species, and African catfish (*Clarias gariepinus*) is the most extensively cultivated fish species (FAO, 2014b). Aquaculture of African catfishes are an important aquaculture species that is raised throughout the world. The Nigeria, Brazil, Netherlands, Kenya, Hungary, Egypt, Syrian, Cameroon, South Africa, and Mali are the largest producers of African catfish (FAO, 2016b). In 2019, about 1,245.3 tonnes of African catfish were produced overall, according to FAO (2020). About 39,507 tonnes of African catfish were produced overall through wild fisheries (lakes and the Nile River), while 8454 tonnes were produced through fish farming (GAFRD, 2019). A native fish species in African countries, the African catfish is a member of the Clariidae family.

African catfish are raised in a number of African countries as well as in Asia, Europe, and South America (Opiyo et al., 2017); nonetheless, their contribution to global aquaculture production (89.1%) is quite little and only accounts for 0.33% of total production (Dauda et al., 2018; FAO, 2020). On the other hand, tilapia and African catfish account for the majority (99%) of the continent's contribution of 16 to 18% to overall fish production, or around 2.7% of global production (Obiero et al., 2019; Adeleke et al., 2020).

Fish degradation and customer rejection are mostly caused by microbial oxidation and spoiling. Due to their high moisture content, which encourages the growth of microorganisms and serves as a reactant in many hydrolytic processes, fish and fishery products are considered to be very perishable (Abbas et al., 2009). Highly unsaturated fatty acids are more likely to oxidise, which lowers their nutritional value and produces a disagreeable taste and odor (Chotphruethipong and Benjakul, 2019). Proteolytic enzymes and gut bacteria break down a significant amount of proteins, resulting in the production of ammonia and nitrogenous substances, which compromises the safety and sensory qualities of the proteins (Olatunde et al., 2019; Pongsetkul et al., 2017).

Synthetic antioxidants and antimicrobials have been linked to toxicity, cancer risk, and other health issues. As a result, the use of synthetic antioxidants and antimicrobials is strictly controlled. People have become increasingly interested in natural products free of chemicals in recent years (Xu et al., 2017). As a result, there has been a sharp increase in consumer and industrial inclination toward adopting antimicrobials and antioxidants obtained from natural sources to preserve fish and fisheries goods. Therefore, in order to ensure safety, processors or vendors must look for natural antimicrobials or antioxidants.

For many years, applications of antimicrobials from plant origin have been used to preserve fish and fisheries products. Plant parts in their entirety, extracts, derivatives, essential oils are used, but they have not yet been fully exploited (Nikmaram et al., 2018). Many phenolic compounds, including phenolic acids, flavonoids, tannins, alkaloids, glycosides, saponins and numerous peptides with antibacterial characteristics, are present in plants used for preservation (Cushnie and Lamb, 2011).

Ginger (*Zingiber officinale*), a rhizome or subterranean stem from the Zingiberaceae family that is used as a spice in food, is one of the medicinal plants. Alkaloids, flavonoids, polyphenols, saponin, steroids, and tannins are just a few of the biologically active substances that ginger contains. It also contains nutrients like fiber, carbohydrates, vitamins, carotenoids, and minerals (Zadeh and Kor, 2014). Additionally, ginger contains a lot of natural antioxidants such gingerols, shogaols, and Zingerone (Yashin et al., 2017; Si et al., 2018). Due to its antibacterial (Beristain-Bauza et al., 2019), antiparasitic (Fu et al., 2019), and anti-inflammatory (Sukumaran et al., 2016) capabilities, it has also received a lot of research attention.

Indian gooseberry or amla (*Emblica officinalis* Gaertn. or *Phyllanthus emblica* Linn.), members of the Euphorbiaceae family (Madhuri et al., 2011; Umashanker and Shruti, 2011). It contains highly significant phytochemicals like phyllaemblic compounds, alkaloids (Phyllantidine and Phyllantine), gallic acid, ellagic acid, flavonoids (kaempferol), hydrolysable tannins (Emblicanin A and B), pectin, quercetin, vitamin C, and various polyphenolic compounds, which are accountable for their antioxidant, immunostimulatory, anticarcinogenic, antitumor, antigenotoxic (Madhuri et al., 2011). It helps both male and female reproductive systems and strengthens digestion, absorption, liver function, assimilation of food, and protein synthesis (Singh et al., 2012).

Due to the foregoing, the current experiment was conducted to examine the effect of incorporating of amla and ginger powder as antimicrobial, antioxidant agents as well as their effects on the storage stability of fish finger under cold conditions.

2. Material and Methods

2.1. Fish sample, chemicals and other

Catfish with an average weight of 435.6 ± 0.63 g were obtained from the experimental fish unit, Department of Fish Production, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt. Fish were transferred to the Departments of Food Science and Technology, Biochemistry Laboratories, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt.

Salt, wheat flour, starch, sugar, spices mixture, garlic, onion, and palm oil were bought from local market.

All of the media and chemicals utilised were analytical grades, purchased from Mumbai's Himedia Pvt. Ltd. Other ingredients employed in product development were of the highest quality and were purchased locally. Powdered ginger and amla were bought at the neighborhood market.

2.1.1. Preparation of catfish fingers

The catfish washed in cold water (5 ± 1 °C), beheaded, gutted, washed once more in chilled water, and then filleted. The fillets were minced using meat mincer by a plate with holes that were 4.5 mm in diameter. Catfish fingers were prepared according to the recipe of ESS (2005), 75% minced catfish meat, 8% palm oil, 8% starch, 2.5% onion, 2.5% salt, 2% spices mixture, 1% sugar, 0.5% garlic, 0.40% sodium bicarbonate and 0.30% sodium polyphosphate. Using a laboratory mixer minced meat and other ingredients were mixed for 3 min (Hobbart Kneading machine, Italy). The prepared mixtures were spread in thin layers (1.5 cm) in stainless steel trays and formed to fingers (9.0 × 2.0 cm) then stored in refrigerator at 5 ± 1 °C. Eight distinct batches of the cold fish fingers were created. Each batch was submerged for roughly two minutes in the corresponding edible coating, as can be seen in Table 1. Each sample of fish fingers was placed in a foam plate, covered with polyethylene film, and kept at 5 °C for 12 days. Every three days, samples were collected for periodic investigation of sensory, physical, chemical, and microbiological characteristics.

2.1.2. Characterization of amla and ginger powder

Proximate analysis

Proximate analysis (moisture, proteins, fats, fiber and ash contents) of raw materials (catfish, amla and ginger) was conducted according to AOAC (2016). Meanwhile, carbohydrates were calculated by means of the difference method using the Formula 1:

$$\text{Total carbohydrates (\%)} = 100 - \%\ (\text{moisture} + \text{protein} + \text{fat} + \text{ash}) \quad (1)$$

2.1.3. Phytochemicals evaluation

The extraction of phytochemicals was carried out according to Keskin and Özkök (2020). Then the extracts were used to assess the total phenolic, total flavonoid, ascorbic acid, total tannin and antioxidant capacity.

Table 1. Treatments for catfish fingers.

Sample	Treatments
Control	Normal formula (without any additives)
BHT	Containing 0.02% Butyl hydroxytoluene
A1	Containing 1% amla powder
A2	Containing 2% amla powder
A3	Containing 3% amla powder
G1	Containing 1% ginger powder
G2	Containing 2% ginger powder
G3	Containing 3% ginger powder

The total phenolic content was determined by Folin-Ciocalteu reagent method according to (Sakooei-Vayghan et al., 2020; Amarasinghe et al., 2021). The results were calculated as mg of Gallic acid (GAE) /100 g.

The total flavonoid content was measured using the method adapted by Baba and Malik (2015), and the result was expressed as mg of Quercetin equivalents / 100 g of sample.

The antioxidant activities was measured by DPPH method as describe by (Amarasinghe et al., 2021).

Ascorbic acid content was determined by titration method using the 2.6 dichlorophenol indophenol as described by AOAC (2005). The result was expressed as mg / 100 g of sample.

For tannins estimation the measurement of blue color formed by the reduction of phosphotungstomolybdic acid by tannin like compounds in alkaline solution (Ranganna, 1986). Total tannin content as expressed as mg tannic acid equivalent /100 g of sample.

2.1.4. pH value

The pH value was estimated according to Taheri et al. (2013) using a pH meter (Jenway, 3510, UK) at ambient temperature.

2.1.5. Total volatile basic nitrogen (TVB-N)

Total volatile basic nitrogen (TVB-N) values were estimated by the direct distillation method according to Goulas and Kontominas (2005) method. The bases are steam distilled into standard acid and back-titration with standard alkali. The values (mg nitrogen/100 g sample) were determined regarding the consumed volume of sulphuric acid reagent.

2.1.6. Tri-methylamine (TMA-N)

The process for determining the tri-methylamine nitrogen (TMA-N) levels was similar to that used to determine the TVB-N. TMA-N concentration in fish sample expressed as mg per 100 g (Phadtare et al., 2021).

2.1.7. Thiobarbituric acid reactive substances (TBA-RS)

The presence of thiobarbituric acid reactive compounds (TBA-RS) was assessed in fish finger samples using the technique described by Babuskin et al. (2014). The results were expressed as mg of malonaldehyde/ kg of fish samples.

2.1.8. Microbiological analysis

At days 0, 3, 6, 9 and 12 of cold storage, the microbiological analysis (total bacteria, psychrophilic bacteria, salmonella, molds and yeasts counts) of the catfish finger were performed in accordance with APHA (2005) guidelines.

2.1.9. Sensory evaluation

The most effective way to determine whether a product will be accepted by the market is through sensory evaluation. Sensory evaluation was carried out according to the Pawar et al. (2020) sensory assessment scheme. At first, the samples were grilled (Tornado grill, Egypt -Temp: 170 °C) then evaluated by 20 staff members from Food Science and Technology Department. Taste, color, odor, tenderness and overall acceptability were assessed by the panel. The catfish fingers were subjected to sensory evaluation based on 10 point hedonic scale, with 10 (like extremely) to 1 (dislike extremely), 5 (being borderline of acceptability) and samples scores below 5 were considered unacceptable for consumption.

2.1.10. Statistical analysis

The present study used SPSS software version 22 for data analysis. Each of the chosen tests was carried out in triplicate for each sample. The analysis of variance (ANOVA) test was used to find significant differences between the collected data with a 0.05 level of confidence.

3. Results

3.1. Proximate analysis

Table 2. provides a summary of the catfish mince, amla and ginger proximate analysis (moisture, crude protein, ether extract, ash and total carbohydrates). On wet weight basis, the mean values of the catfish proximate composition were 75.37% for moisture, 20.09% for crude protein, 2.49% for ether extract, 1.23% for ash and 0.82% for total carbohydrates.

Additionally, for amla and ginger powder, total carbohydrates represented 86.13 and 77.96%, respectively. Meanwhile, crude protein concentrations was 9.84 and 10.76 g/100 g as well as ash contents was 3.2 and 5.69 g/100 g respectively. For ether extracts ginger powder had the highest content (5.59 g/100 g) compare to amla powder (0.61 g/100 g).

3.2. Phytochemical contents

From Figure 1, the amla powder is contain approximately twice (594.83 mg GAE/g) as much total phenols (TPC) as ginger powder (289.65 mg GAE/g). According to Figure 1, the amounts of total flavonoids in the amla and ginger powders were 172.14 and 129.32 mg QE/g respectively. Amla powder's antioxidant activity was greater than ginger powder's. The DPPH (%) for the amla and ginger powders, respectively, were 60.88 and 48.35%. While the ascorbic acid concentration of the amla and ginger powder was 425.6 and 2.33 mg/100g, respectively. According to Figure 1, the amount of tannins in amla powder was reported at 186.22 mg GAE/g compared to 118.43 mg GAE/g for ginger powder.

Table 2. Proximate analysis of catfish mince, amla and ginger powder.

Analysis	Catfish mince	Amla	Ginger
Moisture	75.37	13.0	13.0
Crude protein	20.09	9.84	10.76
Ether extract	2.49	0.61	5.59
Ash	1.23	3.20	5.69
Total carbohydrate	0.82	86.13	77.96

3.3. pH value

Figure 2. shows the impact of various amla and ginger powder addition amounts on the pH value of fish fingers stored at 5 ± 1 °C. The results showed that the pH increased significantly over time, reaching its peak at the conclusion of the storage period. It was noticed that, the control sample had the highest ($p<0.05$) pH value (7.19) on day 9 of cold storage. Meanwhile, the samples containing 3% amla powder had the lowest value (6.59) as compared to other treatments (was ranged between 6.61 to 6.76), at the 12th day of storage, pH value ranged from 6.72 to 6.93.

3.4. Total volatile basic nitrogen

Figure 3 displays modifications in total volatile basic nitrogen (TVB-N) values for fish fingers during cold storage. At zero time, the TVB-N measured values for the control, BHT, A1, A2, A3, G1, G2, and G3 were 13.85, 13.84, 13.83, 13.80, 13.78, 13.79, 13.78 and 13.80 mg/100 g, respectively. However, these values significantly ($p<0.05$) increased with longer cold storage (up to 12 days) periods (17.08, 19.86, 18.38, 18.04, 20.65, 19.98 and 19.32 mg/100 g, respectively).

3.5. TBA-RS values

At the beginning of storage, the TBA-RS values were 0.453, 0.451, 0.450, 0.451, 0.452, 0.453, 451 and 0.449 mg malonaldhyde/kg, respectively in control, BHT, A1, A2, A3,

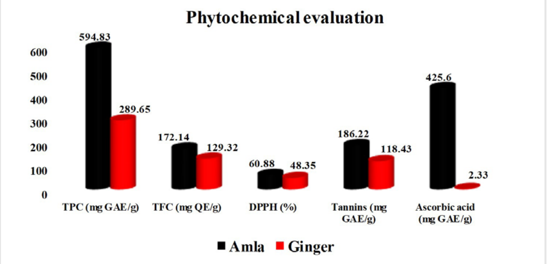

Figure 1. TPC, TFC, DPPH and tannins contents of ginger and amla powder.

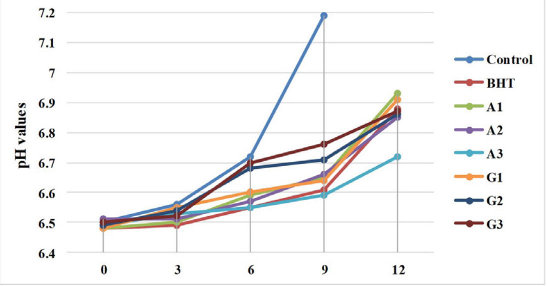

Figure 2. Effect of different added levels of ginger and amla powder on pH value of fish fingers during cold storage.

G1, G2 and G3 (Figure 4). The lowest increases in TBA-RS were recorded for samples treated with BHT (2.03), A3 (2.76) and G3 (3.11). TBA-RS increase with longer storage times to reach 2.03, 3.44, 3.18, 2.76, 4.09, 3.78 and 3.11 on the 12th day of cold storage.

3.6. TMA values

Figure 5. shows the impact of several additives on fish fingers' trimethylamine (TMA) during cold storage. The TMA values significantly increased during fish fingers cold storage. During storage, the TMA values of the control, BHT, A1, A2, A3, G1, G2, and G3 increase from 0.64, 0.63, 0.60, 0.59, 0.60, 0.61, 0.60 and 0.59 mg/100 g respectively, at day zero to 3.53, 1.45, 2.33, 2.07, 1.68, 3.11, 2.45 and 2.03 mg/100 g respectively, at the day 12.

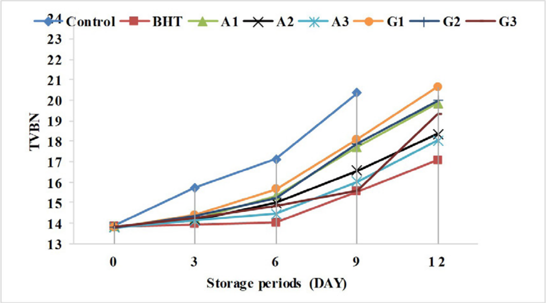

Figure 3. Effect of ginger and amla powder on total volatile basic nitrogen (mg/100 g) values of fish fingers during cold storage.

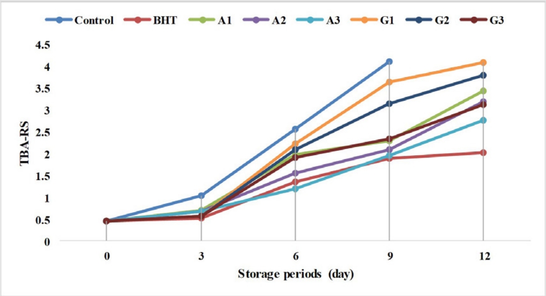

Figure 4. Effect of ginger and amla powder on TBA values of fish fingers during cold storage

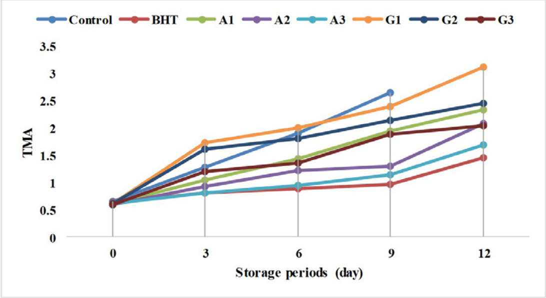

Figure 5. Effect of ginger and amla powder on Trimethylamine (TMA) values of fish fingers during cold storage.

3.7. Microbiological evaluation

The TBC of fish fingers at zero time were 2.29 to 2.34 Log CFU/g, confirming sanitary processing conditions (Figure 6). At the 6th days, TBC values reached 6.43, 3.35, 3.24, 3.20, 3.18, 3.30, 3.23 and 3.21 Log CFU/g, respectively for control, BHT, A1, A2, A3, G1, G2, and G3. On the 12th day of storage, the lower aerobic plate count was recorded for fish finger treated with amla powder at different concentrations (5.03 to 5.19 Log CFU/g), followed by samples treated with ginger powder at 2 and 3% (5.77 and 5.48 Log CFU/g).

It was observed that changes in psychrophilic bacteria counts (PSC) during storage at low temperatures (5 ± 1 °C) followed a pattern that was similar to changes in total bacteria count for all samples (Figure 7). Additionally, it is evident that the initial PSC for all fish finger treatments ranged from 3.08 to 3.10 10^{-2} cfu/g. At zero time and throughout the cold storage period, PSC of the control sample were higher than those of the fish finger treatments. PSC in all samples gradually increased throughout cold storage and up until the end. The greatest PSC (6.47 × 10^{-2} cfu/g) was noted on day six for control. The A3 treatment, resulted in the lowest count of PSC (4.47 × 10^{-2} cfu/g), while other treated samples ranged from (4.50 to 4.62 × 10^{-2} cfu/g). At the end of storage, the lowest count of PSC (4.47 × 10^{-2} cfu/g) was recorded for A3, G1 and A2 treatments (6.31, 6.27 and 6.24 × 10^{-2} cfu/g).

Figure 8 shows how different additives affected the mold and yeast counts (M&Y) of catfish fingers during storage

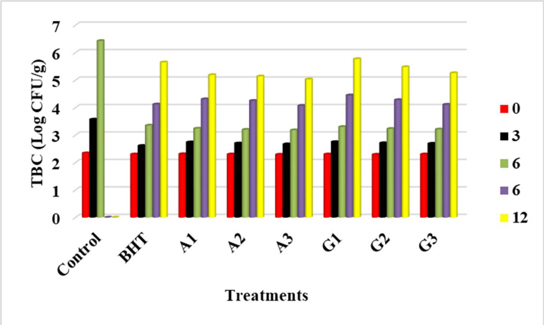

Figure 6. Changes in total bacterial counts (Log cfu/g) of different fish fingers treatments during cold storage.

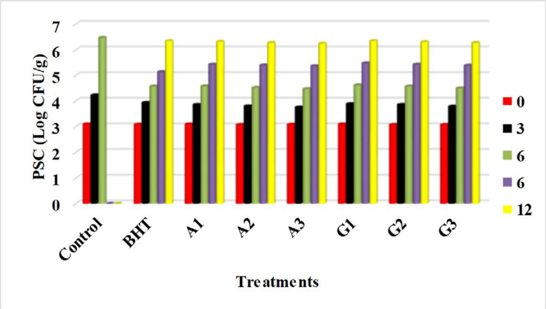

Figure 7. Changes in psychrophilic bacterial counts (PSC) of different fish fingers treatments during cold storage.

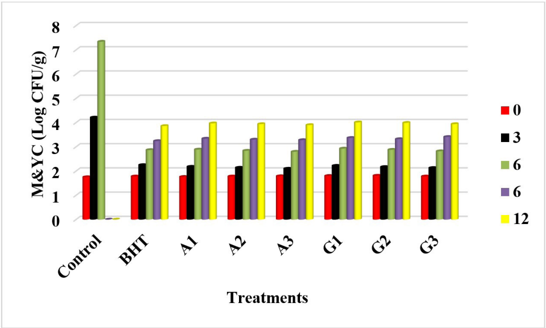

Figure 8. Changes in molds and yeasts counts (M&Y) of different fish fingers treatments during cold storage.

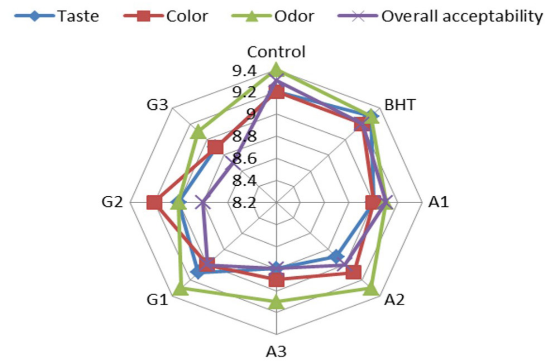

Figure 9. Effect of amla and ginger powder on sensory evaluation of catfish fingers during cold storage.

at 5 ± 1 °C. The incorporation of different additives affect M&Y counts at zero time and during the cold storage. On the other hand, M&Y values in all treatments increased during the cold storage of fish fingers. Control, BHT, A1, A2, A3, G1, G2, and G3 had initial M&Y counts of 1.75, 1.78, 1.76, 1.78, 1.79, 1.80, 1.81 and 1.78 × 10^{-2} cfu/g, respectively. Following six days of cold storage, these values rose to higher levels 7.34, 2.87, 2.89, 2.84, 2.80, 2.93, 2.88 and 2.82 × 10^{-2} cfu/g, respectively. These findings concur with those of Talab and Abou-Taleb (2021), who found that the initial value of M&Y of carp fish fingers varied from 1.10 to 1.25 log cfu/g. At the conclusion of storage (day 12), the count of M&Y in samples treated with BHT, A1, A2, A3 and G3 recoded the lowest M&Y values were 3.59, 3.67, 3.64, 3.50 and 3.55 × 10^{-2} cfu/g respectively.

All fish fingers treatments whether the control and treatments with different additives were completely free from *Salmonella* and *staphylococcus aureus* at a zero-time and throughout the cold storage.

3.8. Sensory evaluation

Figure 9. provides a sensory assessment of various catfish finger treatments as influenced by various additives and their percentages. It is obvious that the panellists gave the control catfish finger the highest taste rating (9.40), followed by the BHT, A2, and G1 treatments (9.30 for each treatment), while the lowest rating (9.0) was recorded for the fingers made with 2% ginger powder, with no statistically significant differences between them (Figure 9). Odor scores ranged from 8.9 to 9.2, while color evaluations varied from 8.8 to 9.3. The highest overall acceptability score (9.30) was given by panelists for control fish fingers followed by that prepared with BHT (9.20) and finally both of fish fingers prepared with 1, 2% amla powder and 1% ginger powder (9.10, 9.0 and 9.0 respectively) with no statistically significant differences between them. In contrast to the other samples, the sample made with 3% amla powder and 2% or 3% ginger powder scored lower (8.8, 8.8 and 8.7, respectively).

These findings show that although the ratios (1 and 2%) performed better than the ratio (3%) in both attributes, the addition of amla and ginger powder in amounts of 1, 2, and 3% had no discernible impact on the sensory rating.

4. Discussion

Results of proximate analysis (Table 2), of the catfish, amla and ginger were in agreement with findings of Habiba (2018) for *Clarias gariepinus* has a proximate composition of 76.48% moisture, 19.88% crude protein, 1.63% ether extract, 1.22% total ash, and 0.79% total carbohydrates on wet weight basis. For amla and ginger powder the total carbohydrates content are the major constituent of which accounts for nearly 4/5 of its total weight. These values are consistent with other research published by Odebunmi et al. (2010), Shirin and Jamuna (2010) and Naliato et al. (2021) they found that ginger powder contains roughly 5.98- 10.2, 3- 7.3 and 11.5- 57% respectively, of ether extract, crude protein, and ash content. Meanwhile, Srivastava et al. (2019), Kc et al. (2020), Sonkar et al. (2020) and Hussain et al. (2021) recorded that the chemical composition of amla powder were between 2- 4.5% for crude protein, 0.2- 0.6% for ether extract, 2- 3.1% for ash and 85.80% for total carbohydrates, respectively. The variability in the composition has been attributed to the cultivar in many studies (Tewari et al., 2019; Sonkar et al., 2020).

Figure 1 summaries the phytochemical contents including the amounts of total phenols (TPC), total flavonoids (TFC), antioxidant capacity (DPPH), ascorbic acid, and tannins of the amla and ginger powder before utilization to improve quality of catfish fingers. For all analyses, there were significant differences ($p < 0.05$) between the ginger and amla powder. Our results found that the amla powder was the highest in phytochemical compounds compared to ginger powder. Results were similar to those obtained by Naliato et al. (2021) who found that ginger powder had a total phenolic content of 1113.9 mg/g and 2855.7 mg QE/g of total flavonoids. Amla powder's antioxidant activity was greater than ginger powder's, measuring more than 1.26 times as much as that of ginger powder. These results were comparable to those of Goraya and Bajwa (2015) and Makanjuola (2017), who found that the DPPH (%) for amla and ginger powder, respectively, was 55.88 and 44. Moreover, ginger powder contained very small amounts of ascorbic acid compared to the rich in content of the amla powder. Our concur with those of Devi et al. (2020), Dinesh et al., (2015) who discovered that the ascorbic acid content of amla powder ranged from 200 to 900 mg/100g and that the concentration of ginger powder ranged from 5 to 7.16 mg/100g. With respect to the tannins content amla powder had almost 1.57 times the amount of tannins than ginger. These findings are in agreement with KC et al. (2020) determination that amla powder contains 198.9 mg of tannins and with Okunade et al. (2019) determination that ginger powder contains 0.68-2.66 mg of tannins per 100 g, respectively.

Figure 2 shows the impact of different concentration of amla and ginger powder on the pH value of fish fingers during cold storage. The increases in pH values during storage are caused by an increase in volatile compound (such as trimethylamine and ammonia), which are created by microbial or endogenous enzymes over the course of storage (Bazargani-Gilani et al., 2015). Increased pH in tilapia burgers during frozen storage was discovered by Lithi et al. (2020). Rani et al. (2017) also found similar increased value of pH in fish finger and fish burger during frozen storage.

The total volatile basic nitrogen (TVB-N) is the chemical method used to evaluate fish spoilage, as it mostly contains ammonia, dimethylamine, trimethylamine, and others compounds linked to seafood spoilage (Pal et al., 2022). TVBN is a quality indicator found in fish and fishery products and is created when bacteria break down the protein (Don et al., 2018). TVB-N values increased during storage however, none of the treatments has exceeded the upper limit of TVB-N (30mg/100g). The control sample had higher TVB-N than samples treated with BHT, amla and ginger powder. Meanwhile, the lowest TVB-N value was detected for the BHT -treated sample.

The TBA-RS is frequently used to evaluate the secondary lipid oxidation of PUFA that results in malonaldhyde. This aldehyde is significant in seafood because it occasionally emits a rancid odor (Banerjee et al., 2017). It is considered as one of the major lipid oxidation parameters (Pereira and Abreu, 2018). The TBA-RS levels of catfish finger were nearly comparable in all the samples at the beginning of storage, although they gradually ($p<0.05$) increase with longer storage times (Figure 4). The TBA-RS values of the treatments were lower than those of the control, which supports the additives' function as oxidative protectors. Also, the effectiveness of the amla and ginger powders as antioxidants inhibiting lipid oxidation during storage could be shown in the following order of decreasing TBA-RS values: 3 > 2 > 1%. This can indicate that the used powders were effective against TBA-RS formation when incorporated into fish fingers. Ibrahim et al. (2011) found similar finding in lamb meat treated with some natural plants during cold storage.

Additionally, the addition of various additives had no discernible impact on TMA values at the beginning of the experiment; nevertheless, between the third and the twelfth days of cold storage, the BHT, amla, and ginger treatments saw a marked decline in TMA values compared to the control. This implies that the BHT, amla and ginger powder inhibited the production of TMA from TMAO. The TMA values significantly increased during cold storage. These increases may be related to the activity of endogenous and microbial protolytic enzymes, which results in breaking down the proteins into volatile nitrogenous compounds (Yasin and Abou-Taleb, 2007; Bekhit et al., 2021).

Controlling the microbial load is essential for maintaining good quality, especially the hygienic state of the finished product. Our findings for TBC and PSC concur with those made by Talab and Abou-Taleb (2021), who found that the first TBC and PSC for carp fish fingers ranged from 2.25 to 2.65 and 1.10 to 1.55 Log CFU/g, respectively. The initial TBC and PSC values linearly increased for all samples as the storage period lengthened, although the control sample increased more quickly than that of the other treated samples, as seen in Figure 7 and 8. The decrease in TBC and PSC in samples treated with amla and ginger powder may be to the rich source of polyphenols, ascorbic acid, flavonoids, tannins, fiber and carbohydrates. Additionally, TBC and PSC was higher in samples treated with BHT and ginger powder than in samples treated with amla powder. The TBC did not exceed the maximum permissible limits defined by Egyptian standard specifications and International Commission Specifications, except the control sample which exceeded this limit and recorded 6.43 log CFU/g on the 6^{th} day. The results showing the effectiveness of these additives as antibacterial agent in fish fingers. These findings support Firdous et al. (2021) that amla extracts reduce the number of bacteria in Indian white prawn fish. For mold and yeast count our results demonstrate that, when compared to the control sample and the sample that was added to the industrial antioxidant, treating fish fingers with amla powder and ginger powder at a rate of 3% for each had the best and highest results in reducing the microbial load of M&Y and reducing their growth during the storage period.

The sensory assessment of various catfish finger treatments as influenced by various additives and their percentages. The impacts of various additives and their percentages did not significantly affect the color or odor scores for the various treatments of fish fingers (Figure 9). These findings support those made by Idris et al. (2010); Ibrahim et al. (2011); Biassi et al. (2019), the application of ginger, amla, and rosemary had no appreciable impact on how well the sensory evaluation of the fish items under study.

5. Conclusion

The use of amla and ginger has demonstrated the ability to extend the shelf life and maintain the nutritional value of catfish fingers while also inhibiting bacteria and lowering lipid oxidation. They contain significant amounts of phenols compounds which have strong antioxidant properties. Additionally, the biochemical qualities and sensory characteristics of catfish were significantly impacted by the application of amla and ginger powder. As natural and secure preservatives for fish fingers, amla and ginger powder can thus take the role of synthetic antioxidants in the food processing business. In conclusion, In conclusion, catfish may be made into tasty fish fingers by adding some natural ingredients like amla and ginger.

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References

ABBAS, K.A., SALEH, A.M., MOHAMED, A. and LASEKAN, O., 2009. The relationship between water activity and fish spoilage during cold storage: a review. *Journal of Food Agriculture and Environment*, vol. 7, no. 3-4, pp. 86-90.

ADELEKE, B., ROBERTSON-ANDERSSON, D., MOODLEY, G. and TAYLOR, S., 2020. Aquaculture in Africa: A comparative review of Egypt, Nigeria, and Uganda vis-a-vis South Africa. *Reviews in Fisheries Science & Aquaculture*, vol. 29, no. 2, pp. 167-197. http://dx.doi.org/10.1080/23308249.2020.1795615.

AMARASINGHE, N.K., WICKRAMASINGHE, I., WIJESEKARA, I., THILAKARATHNA, G. and DEYALAGE, S.T., 2021. Functional, physicochemical, and antioxidant properties of flour and cookies from two different banana varieties (*Musa acuminata* cv. *Pisang awak* and *Musa acuminata* cv. *Red dacca*). *International Journal of Food Sciences*, vol. 2021, pp. 6681687. http://dx.doi.org/10.1155/2021/6681687. PMid:34124236.

AMERICAN PUBLIC HEALTH ASSOCIATION – APHA, 2005. *Compendium of methods for the microbiological examination of foods*. 4th ed. Washington D.C.: Sperk M.L.

ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS – AOAC, 2005. Official methods of analysis of official analytical chemists. 18th ed. Washington DC: AOAC.

ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS – AOAC, 2016. *Journal of the Association of Official Agricultural Chemists*. 20th ed. Maryland: AOAC.

BABA, S.A. and MALIK, S.A., 2015. Determination of total phenolic and flavonoid content, antimicrobial and antioxidant activity of a root extract of *Arisaema jacquemontii* Blume. *Journal of Taibah University for Science : JTUSCI*, vol. 9, no. 4, pp. 449-454. http://dx.doi.org/10.1016/j.jtusci.2014.11.001.

BABUSKIN, S., RADHA KRISHNAN, K., BABU, P.A.S., SASIKALA, M., SABINA, K., ARCHANA, G., SIVARAJAN, M. and SUKUMAR, M., 2014. Antimicrobial and antioxidant effects of spice extracts on the shelf life extension of raw chicken meat. *International Journal of Food Microbiology*, vol. 171, pp. 32-40. http://dx.doi.org/10.1016/j.ijfoodmicro.2013.11.011. PMid:24308943.

BANERJEE, R., VERMA, A.K. and SIDDIQUI, M.W., 2017. Methods and their applications for measuring and managing lipid oxidation: meat, poultry, and seafood products. In: R. BANERJEE, A.K. VERMA and M.W. SIDDIQUI, eds. *Natural antioxidants*. New York: Apple Academic Press, pp. 223-280. http://dx.doi.org/10.1201/9781315365916.

BAZARGANI-GILANI, B., ALIAKBARLU, J. and TAJIK, H., 2015. Effect of pomegranate juice dipping and chitosan coating enriched with *Zataria multiflora* Boiss essential oil on the shelf-life of chicken meat during refrigerated storage. *Innovative Food Science & Emerging Technologies*, vol. 29, pp. 280-287. http://dx.doi.org/10.1016/j.ifset.2015.04.007.

BEKHIT, A.E.D.A., GITERU, S.G., HOLMAN, B.W. and HOPKINS, D.L., 2021. Total volatile basic nitrogen and trimethylamine in muscle foods: potential formation pathways and effects on human health. *Comprehensive Reviews in Food Science and Food Safety*, vol. 20, no. 4, pp. 3620-3666. http://dx.doi.org/10.1111/1541-4337.12764. PMid:34056832.

BERISTAIN-BAUZA, S.D.C., HERNÁNDEZ-CARRANZA, P., CID-PÉREZ, T.S., ÁVILA-SOSA, R., RUIZ-LÓPEZ, I.I. and OCHOA-VELASCO, C.E., 2019. Antimicrobial activity of ginger (*Zingiber officinale*) and its application in food products. *Food Reviews International*, vol. 35, no. 5, pp. 407-426. http://dx.doi.org/10.1080/87559129.2019.1573829.

BIASSI, D.C., SILVA, L.S., DELFINO, L.A., OLIVEIRA, J., TORMEN, L. and BAINY, E.M., 2019. Effect of ginger and rosemary extracts as antioxidant and antibacterial agents in tilapia fish fingers. *Boletim do Centro de Pesquisa e Processamento de Alimentos*, vol. 36, no. 1, pp. 14-27. http://dx.doi.org/10.5380/bceppa.v36i1.55635.

CHOTPHRUETHIPONG, L. and BENJAKUL, S., 2019. Use of cashew (Anacardium occidentale L.) leaf extract for prevention of lipidoxidation in Mayonnaise enriched with fish oil. *Turkish Journal of Fisheries and Aquatic Sciences*, vol. 19, no. 10, pp. 825-836. http://dx.doi.org/10.4194/1303-2712-v19_10_02.

CUSHNIE, T.T. and LAMB, A.J., 2011. Recent advances in understanding the antibacterial properties of flavonoids. *International Journal of Antimicrobial Agents*, vol. 38, no. 2, pp. 99-107. http://dx.doi.org/10.1016/j.ijantimicag.2011.02.014. PMid:21514796.

DAUDA, A.B., NATRAH, I., KARIM, M., KAMARUDIN, M.S. and BICHI, A., 2018. African catfish aquaculture in Malaysia and Nigeria: status, trends and prospects. *Fisheries and Aquaculture Journal*, vol. 9, no. 1, pp. 1-5. http://dx.doi.org/10.4172/2150-3508.1000237.

DEVI, S., GUPTA, E. and MAURYA, N.K., 2020. Development of a value added Amla product. *International Archive of Applied Sciences and Technology*, vol. 11, pp. 90-93.

DINESH, B., YADAV, B., REDDY, R.D., PADMA, A.S. and SUKUMARAN, M.K., 2015. Determination of ascorbic acid content in some Indian spices. *International Journal of Current Microbiology and Applied Sciences*, vol. 4, no. 8, pp. 864-868.

DON, S., XAVIER, K.M., DEVI, S.T., NAYAK, B.B. and KANNUCHAMY, N., 2018. Identification of potential spoilage bacteria in farmed shrimp (*Litopenaeus vannamei*): application of relative rate of spoilage models in shelf life-prediction. *Lebensmittel-Wissenschaft + Technologie*, vol. 97, pp. 295-301. http://dx.doi.org/10.1016/j.lwt.2018.07.006.

EGYPTIAN STANDARD SPECIFICATION – ESS, 2005. *Egyptian organization for standardization and quality control for quick frozen fish products breaded or in batter 3495.* Cairo: ESS, pp. 1-10.

FIRDOUS, A., RINGØ, E. and ELUMALAI, P., 2021. Effects of green tea-and amla extracts on quality and melanosis of Indian white prawn (*Fenneropenaeus indicus*, Milne Edwards, 1837) during chilled storage. *Aquaculture and Fisheries*, vol. 6, no. 6, pp. 617-627. http://dx.doi.org/10.1016/j.aaf.2020.09.003.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS – FAO, 2014a. *The state of world fisheries and aquaculture: opportunities and challenges*. Rome: FAO.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS – FAO, 2014b. *Food and Agriculture Organization year book: fishery and aquaculture statistics*. Rome: FAO.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS – FAO, 2016a. *The state of world fisheries and aquaculture. Contributing to food security and nutrition for all.* Rome: FAO.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS – FAO, 2016b. *Cultured aquatic species information programme: Clarias gariepinus*. Rome: Fisheries and Aquaculture Department, FAO.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS – FAO 2020. *The state of world fisheries and aquaculture*. Rome: FAO.

FU, Y.W., WANG, B., ZHANG, Q.Z., XU, D.H., LIU, Y.M., HOU, T.L. and GUO, S.Q., 2019. Efficacy and antiparasitic mechanism of 10-gingerol isolated from ginger *Zingiber officinale* against *Ichthyophthirius multifiliis* in grass carp. *Veterinary Parasitology*, vol. 265, pp. 74-84. http://dx.doi.org/10.1016/j.vetpar.2018.11.011. PMid:30638524.

GENERAL AUTHORITY FOR FISH RESOURCES DEVELOPMENT – GAFRD, 2019. *Fish statistics year*. Egypt: GAFRD, pp. 16.

GORAYA, R.K. and BAJWA, U., 2015. Enhancing the functional properties and nutritional quality of ice cream with processed amla (*Indian gooseberry*). *Journal of Food Science and Technology*, vol. 52, no. 12, pp. 7861-7871. http://dx.doi.org/10.1007/s13197-015-1877-1. PMid:26604358.

GOULAS, A.E. and KONTOMINAS, M.G., 2005. Effect of salting and smoking-method on the keeping quality of chub mackerel (*Scomber japonicus*): biochemical and sensory attributes. *Food Chemistry*, vol. 93, no. 3, pp. 511-520. http://dx.doi.org/10.1016/j.foodchem.2004.09.040.

HABIBA, R.A., 2018. Effect of Transglutaminase enzyme, chitosan and rosemary extract on some quality characteristics of ready to eat fish fingers made from catfish (*Clarias gariepinus*) during frozen storage. *E C Nutrition*, vol. 13, pp. 716-731.

IBRAHIM, H.M., ABOU-ARAB, A.A. and ABU SALEM, F.M., 2011. Antioxidant and antimicrobial effects of some natural plant extracts added to lamb patties during storage. *Grasasy Acetates*, vol. 62, no. 2, pp. 139-148. http://dx.doi.org/10.3989/gya.066510.

HUSSAIN, S.Z., NASEER, B., QADRI, T., FATIMA, T. and BHAT, T.A., 2021. *Anola (Emblica officinalis): morphology, taxonomy, composition and health benefits. in fruits grown in highland regions of the Himalayas*. Cham: Springer, pp. 193-206. http://dx.doi.org/10.1007/978-3-030-75502-7_15.

IDRIS, G.L., OMOJOWO, F.S., OMOJASOLA, P.F., ADETUNJI, C.O. and NGWU, E.O., 2010. The effect of different concentrations of ginger on the quality of smoked dried catfish (*Clarias gariepinus*). *Nature and Science*, vol. 8, no. 4, pp. 59-63.

KC, Y., RAYAMAJHI, S., DANGAL, A. and SHIWAKOTI, L.D., 2020. Phytochemical, nutritional, antioxidant activity and sensorial characteristics of amala (*Phyllanthus emblica* L.) chutney. *Asian Food Science Journal*, vol. 18, no. 1, pp. 43-52. http://dx.doi.org/10.9734/afsj/2020/v18i130209.

KESKIN, M. and ÖZKÖK, A., 2020. Effects of drying techniques on chemical composition and volatile constituents of bee pollen. *Czech Journal of Food Sciences*, vol. 38, no. 4, pp. 203-208. http://dx.doi.org/10.17221/79/2020-CJFS.

LITHI, U., FARIDULLAH, M., UDDIN, M., MEHBUB, M. and ZAFAR, M., 2020. Quality evaluation of mince-based fish burger from tilapia (*Oreochromis mossambicus*). *Journal of Bangladesh Agricultural University*., vol. 18, no. 2, pp. 524-528.

MADHURI, S., PANDEY, G. and VERMA, K.S., 2011. Antioxidant, immunomodulatory and anticancer activities of *Emblica officinalis*: an overview. *International Research Journal of Pharmacy*, vol. 2, no. 8, pp. 38-42.

MAKANJUOLA, S.A., 2017. Influence of particle size and extraction solvent on antioxidant properties of extracts of tea, ginger, and tea–ginger blend. *Food Science & Nutrition*, vol. 5, no. 6, pp. 1179-1185. http://dx.doi.org/10.1002/fsn3.509. PMid:29188046.

NALIATO, R.F., CARVALHO, P.L.P.F., VICENTE, I.S.T., XAVIER, W.D.S., GUIMARÃES, M.G., RODRIGUES, E.J.D., ITO, P.I., SARTORI, M.M.P., BONFIM, F.P.G., ORSI, R.O., PEZZATO, L.E. and BARROS, M.M., 2021. Ginger (*Zingiber officinale*) powder improves growth performance and immune response but shows limited antioxidant capacity for Nile tilapia infected with Aeromonas hydrophila. *Aquaculture Nutrition*, vol. 27, no. 3, pp. 850-864. http://dx.doi.org/10.1111/anu.13229.

NIKMARAM, N., BUDARAJU, S., BARBA, F.J., LORENZO, J.M., COX, R.B., MALLIKARJUNAN, K. and ROOHINEJAD, S., 2018. Application of plant extracts to improve the shelf-life, nutritional and health-related properties of ready-to-eat meat products. *Meat Science*, vol. 145, pp. 245-255. http://dx.doi.org/10.1016/j.meatsci.2018.06.031. PMid:29982079.

OBIERO, K., MEULENBROEK, P., DREXLER, S., DAGNE, A., AKOLL, P., ODONG, R., KAUNDA-ARARA, B. and WAIDBACHER, H., 2019. The contribution of fish to food and nutrition security in Eastern Africa: emerging trends and future outlooks. *Sustainability*, vol. 11, no. 6, pp. 1636. http://dx.doi.org/10.3390/su11061636.

ODEBUNMI, E.O., OLUWANIYI, O.O. and BASHIRU, M.O., 2010. Comparative proximate analysis of some food condiments. *Journal of Applied Sciences Research*, vol. 6, no. 3, pp. 272-274.

OKUNADE, A., AGBOOLA, T., OGUNSINA, B., SALAU, A. and SALAMI, A., 2019. Physicochemical properties of four selected food spices of Nigerian origin: alligator pepper, black pepper, ginger and cloves. *Ife Journal of Technology*, vol. 26, no. 1, pp. 7-12.

OLATUNDE, O.O., BENJAKUL, S. and VONGKAMJAN, K., 2019. Comparative study on nitrogen and argon-based modified atmosphere packaging on microbiological, chemical, and sensory attributes as well as on microbial diversity of Asian sea bass. *Food Packaging and Shelf Life*, vol. 22, pp. 100404. http://dx.doi.org/10.1016/j.fpsl.2019.100404.

OPIYO, M.A., ORINA, P. and CHARO-KARISA, H., 2017. Fecundity, growth parameters and survival rate of three African catfish (*Clarias gariepinus*) strains under hatchery condition. *Journal of Aquaculture Engineering and Fisheries Research*, vol. 3, no. 2, pp. 75-81. http://dx.doi.org/10.3153/JAEFR17010.

PAL, J., RAJU, C.V., PANDEY, G., TRIPATHI, H.H. and PRASAD, L., 2022. Effect of pomegranate and orange peel extracts on the quality of fish ham under frozen storage. *Journal of Environmental Biology*, vol. 43, no. 2, pp. 197-204. http://dx.doi.org/10.22438/jeb/43/2/MRN-1826.

PAWAR, P.P., PAGARKAR, A.U. and RATHOD, N.B., 2020. Effect of chilled storage on quality characteristics of battered and breaded snack product from large sized Catla (*Catla catla*). *Journal of Food Science and Technology*, vol. 57, no. 1, pp. 52-59. http://dx.doi.org/10.1007/s13197-019-04028-6. PMid:31975707.

PEREIRA, A.L.F. and ABREU, V.K.G., 2018. Lipid peroxidation in meat and meat products. In: M.A. MANSOUR, ed. *Lipid peroxidation research*. London: IntechOpen.

PHADTARE, M.C., RANVEER, R.C., RATHOD, N.B., SHARANGDHAR, S.T., SWAMI, S.B., VARTAK, V.R., KOLI, J.M. and PATANGE, S.B., 2021. Extraction, characterization and utilization of fish protein concentrate. *Aquatic Food Studies*, vol. 1, no. 2, pp. AFS47. http://dx.doi.org/10.4194/AFS47.

PONGSETKUL, J., BENJAKUL, S., SUMPAVAPOL, P., OSAKO, K. and FAITHONG, N., 2017. Characterization of endogenous protease and the changes in proteolytic activity of Acetes vulgaris and Macrobrachium lanchesteri during kapi production. *Journal of Food Biochemistry*, vol. 41, no. 1, pp. e12311. http://dx.doi.org/10.1111/jfbc.12311.

RANGANNA, S., 1986. *Handbook of analysis and quality control for fruits and vegetables*. New Delhi: Tata McGraw Hill, pp. 9-10.

RANI, T.S., DHANAPAL, K., REDDY, G.V.S., REDDY, D.R.K., SRAVANI, K. and PRAVEEN KUMAR, G., 2017. Quality assessment of mince based products made from mrigal (*Cirrhinus mrigala*) during frozen storage. *International Journal of Current Microbiology and Applied Sciences*, vol. 6, no. 12, pp. 3230-3241. http://dx.doi.org/10.20546/ijcmas.2017.612.376.

RATHOD, N.B., RANVEER, R.C., BENJAKUL, S., KIM, S.K., PAGARKAR, A.U., PATANGE, S. and OZOGUL, F., 2021. Recent developments of natural antimicrobials and antioxidants on fish and fishery food products. *Comprehensive Reviews in Food Science and Food Safety*, vol. 20, no. 4, pp. 4182-4210. http://dx.doi.org/10.1111/1541-4337.12787. PMid:34146459.

SAKOOEI-VAYGHAN, R., PEIGHAMBARDOUST, S.H., HESARI, J. and PERESSINI, D., 2020. Effects of osmotic dehydration (with and without sonication) and pectin-based coating pretreatments on functional properties and color of hot-air dried apricot cubes. *Food Chemistry*, vol. 311, pp. 125978. http://dx.doi.org/10.1016/j.foodchem.2019.125978. PMid:31865114.

SHIRIN, A.P. and JAMUNA, P., 2010. Chemical composition and antioxidant properties of ginger root (*Zingiber officinale*). *Journal of Medicinal Plants Research*, vol. 4, no. 24, pp. 2674-2679. http://dx.doi.org/10.5897/JMPR09.464.

SI, W., CHEN, Y.P., ZHANG, J., CHEN, Z.Y. and CHUNG, H.Y., 2018. Antioxidant activities of ginger extract and its constituents toward lipids. *Food Chemistry*, vol. 239, pp. 1117-1125. http://dx.doi.org/10.1016/j.foodchem.2017.07.055. PMid:28873530.

SINGH, E., SHARMA, S., PAREEK, A., DWIVEDI, J., YADAV, S. and SHARMA, S., 2012. Phytochemistry, traditional uses and cancer chemopreventive activity of Amla (*Phyllanthus emblica*): the sustainer. *Journal of Applied Pharmaceutical Science*, vol. 2, no. 1, pp. 176-183.

SONKAR, N., RAJORIYA, D., CHETANA, R. and VENKATESH MURTHY, K., 2020. Effect of cultivars, pretreatment and drying on physicochemical properties of Amla (*Emblica officinalis*) gratings. *Journal of Food Science and Technology*, vol. 57, no. 3, pp. 980-992. http://dx.doi.org/10.1007/s13197-019-04131-8. PMid:32123419.

SRIVASTAVA, A., ANSAL, M.D. and KHAIRNAR, S.O., 2019. Effect of amla (*Phyllanthus emblica*) fruit powder supplemented feed on growth performance and proximate composition of an Indian major carp, *Labeo rohita* (Ham.) fingerlings. *Journal of Entomology and Zoology Studies*, vol. 7, no. 3, pp. 955-959.

SUKUMARAN, V., PARK, S.C. and GIRI, S.S., 2016. Role of dietary ginger Zingiber officinale in improving growth performances and immune functions of *Labeo rohita* fingerlings. *Fish & Shellfish Immunology*, vol. 57, pp. 362-370. http://dx.doi.org/10.1016/j.fsi.2016.08.056. PMid:27574828.

TAHERI, S., MOTALLEBI, A., FAZLARA, A. and AGHABABYAN, A., 2013. Effect of *Zataria multiflora* Boiss (*Avishan shirazi*) essential oil on oxidative progress in frozen cobia fish fillets during storage. *Journal of Aquatic Food Product Technology*, vol. 22, no. 3, pp. 310-321. http://dx.doi.org/10.1080/10498850.2011.646387.

TALAB, A. and ABOU-TALEB, M., 2021. Effect of different hydrocolloids on the quality criteria of fish fingers during frozen storage. *Egyptian Journal of Aquatic Biology and Fisheries*, vol. 25, no. 5, pp. 323-335. http://dx.doi.org/10.21608/ejabf.2021.199622.

TEWARI, R., KUMAR, V. and SHARMA, H.K., 2019. Physical and chemical characteristics of different cultivars of Indian gooseberry (*Emblica officinalis*). *Journal of Food Science and Technology*, vol. 56, no. 3, pp. 1641-1648. http://dx.doi.org/10.1007/s13197-019-03595-y. PMid:30956345.

UMASHANKER, M. and SHRUTI, S., 2011. Traditional Indian herbal medicine used as antipyretic, antiulcer, anti-diabetic and anticancer: a review. *International Journal of Research in Pharmacy and Chemistry*, vol. 1, no. 4, pp. 1152-1159.

UNITED STATES DEPARTMENT OF AGRICULTURE – USDA, 2020. *Dietary guidelines for Americans, 2020-2025.* 9th ed. Washington D.C.: U.S. Department of Health and Human Services.

XAVIER, M., PIYADARSHINI, B., NINAN, G., ZYNUDHEEN, A.A., MATHEW, P.T., NAIR, K.G.R. and JOSEPH, A.C., 2018. Enrobed snack product from Devis's Anchovy (*Stolephorus commersonnii*) and its quality evaluation during frozen storage. *Journal of Aquatic Food Product Technology*, vol. 27, no. 7, pp. 859-867. http://dx.doi.org/10.1080/10498850.2018.1504846.

XU, D.P., LI, Y., MENG, X., ZHOU, T., ZHOU, Y., ZHENG, J., ZHANG, J.J. and LI, H.B., 2017. Natural antioxidants in foods and medicinal plants: Extraction, assessment and resources. *International Journal of Molecular Sciences*, vol. 18, no. 1, pp. 96. http://dx.doi.org/10.3390/ijms18010096. PMid:28067795.

YASHIN, A., YASHIN, Y., XIA, X. and NEMZER, B., 2017. Antioxidant activity of spices and their impact on human health: a review. *Antioxidants*, vol. 6, no. 3, pp. 70. http://dx.doi.org/10.3390/antiox6030070. PMid:28914764.

YASIN, N.M. and ABOU-TALEB, M., 2007. Antioxidant and antimicrobial effects of marjoram and thyme in coated refrigerated semi fried mullet fish fillets. *World Journal of Dairy & Food Sciences*, vol. 2, no. 1, pp. 1-9.

ZADEH, J.B. and KOR, N.M., 2014. Physiological and pharmaceutical effects of Ginger (*Zingiber officinale* Roscoe) as a valuable medicinal plant. *European Journal of Experimental Biology*, vol. 4, no. 1, pp. 87-90.