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Physicochemical and microbiological characteristics of fresh Indian mackerel, spotted sardine and yellowtail scad, from Eritrea Red Sea waters

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ABSTRACT

Fresh small pelagic fish (Indian mackerel, spotted sardine and yellowtail scad) from the Eritrean waters of the Red Sea were investigated for their physicochemical properties (morphometric measurements, proximate composition, pH, salt, mineral content, color and oxidation indicators) and microbiological characteristics (total plate count; TPC, total coliforms; TC, *E. coli, S. aureus,* Salmonella spp.*; V. parahaemolyticus*, halophilic count and total fungal count; TFC). The morphometric measurements indicated that the yellow tail scad had the largest weight (47.6 g) and the smallest number of fish pieces (21) per kg. These small pelagic fish can be characterized as low-fat fish (3.26–3.85%) and a good protein source, with the highest protein content recorded in fresh Indian mackerel (21.29%). The ash and fiber content fell within the range of 1.57–1.77% and 0.24–0.38% respectively. The oxidation indicators (free-fatty acid, peroxide value, thiobarbituric acid, and *p*-anisidine value) were below the maximum allowable values in fresh fish. The fish were good sources of minerals (Ca, Mg, Fe and Zn), but the Indian mackerel exhibited the highest level of Cd content (0.04 mg/kg weight) which was still below the maximum permitted levels (0.25 mg/kg weight). The TPC, TC, *E. coli*, *S. aureus*, and halophilic count were below maximum allowable levels while *Salmonella*, *V. parahaemolyticus* and TFC were absent in the fresh fish samples.

1. Introduction

Indian mackerel, spotted sardine and yellowtail scad belong to a group of fish referred to as the small pelagic fish, and this includes other fish like sardine, anchovy, scad, herring, mackerel, sprat and menhaden (Hunter and Alheit, 1995). The term 'small pelagic fish' refers to a diverse group of mainly planktivorous fish that share the same habitat, the surface layers of the water column, usually above the continental shelf and in waters not exceeding 200 m in depth. They prefer warmer waters, where they swim in massive schools. These small pelagic fish account for a third of the global yield of marine fish, and make an enormous contribution to the global economy, livelihood and nutrition, especially protein supply (Hunter and Alheit, 1995). In Eritrea, where fish can be abundantly found, the small pelagic fish (Indian mackerel, spotted sardine and yellowtail scad) of Eritrean Red Sea waters account for about 60% of the total MSY (maximum sustainable yield) of marine fish resources (EMFRRSD, 2005), but their utilization for human consumption is minimal. Indeed, these fish are largely incorporated into animal feed rather than human use. The low utilization of the fish for human consumption can be attributed to the physicochemical changes of the fish during the post-harvest phase arising from poor handling of the fish due to poor infrastructure (equipped vessels, storage facilities, processing facilities) for post-harvest handling; and limited distribution chains among other factors (Teweldemedhin, 2008). Given the high ambient temperatures at the time and place of harvest, the lack of a cold chain infrastructure and with limited distribution systems, the fish reaches the consumer market with objectionable sensory properties (Teweldemedhin, 2008).

In general, the chemical composition of fresh fish is given as 66–81% water, 16–21% protein, 0.2–15% fat, 1.2–1.5% mineral and 0–0.5% carbohydrate (Love, 1980; Mazumder et al., 2008). Fish are also a good source of essential fatty acids, amino acids, vitamin A, D, E, and K (Murray and Burt, 2001), and minerals, including phosphorus, magnesium, iron, zinc, and iodine (Arino et al., 2013). The chemical composition of Eritrean Red Sea waters pelagic fish could vary from the general chemical composition of fish, due to different environmental conditions, differences in water quality, location, feeding conditions, sex, and state of maturity (Brett et al., 1969; Craig et al., 1989; Javaid et al., 1992) and capture conditions (Oliveira et al., 2003).

Indeed, information on physicochemical properties (proximate

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Plate 1. Small pelagic fresh fish samples; a) Indian mackerel (*Rastrelliger kanagurta*); b) spotted sardine (*Amblygaster sirm*); c) yellowtail scad (*Atule mate*).

composition, oxidation indices, pH, salt content, color, mineral composition, and microbiological analysis) of small pelagic fish from the region is limited. Moreover, due to the changes in climate conditions, season and industrial growth, there could be wide differences in the biochemical constituents of the fish (Brett et al., 1969; Craig et al., 1989; Javaid et al., 1992).

Hereto, the main objective of this study was to investigate the physicochemical properties (proximates, oxidation indices, pH, color, salt, mineral composition) and microbiological characteristics of fresh Indian mackerel, spotted sardine and yellowtail scad, from Eritrea Red Sea waters. Furthermore, the findings of this study could be used to optimize the post-harvest handling systems of the fish and subsequent processing, so as to deliver a wholesome and safe product to the consumer.

2. Materials and methods

2.1. Fish sample treatment

Indian mackerel (*Rastrelliger kanagurta*), yellowtail scad (*Atule mate*) and spotted sardine (*Amblygaster sirm*) (Plate 1) were caught using purse seines, around the Dahlak Archipelago Islands, Hergigo Bay, Tiwalet Bay, and surrounding waters of Massawa town of Eritrea Red Sea waters. The freshly caught fish were immediately transferred into ice buckets and on landing; they were transported to the fish processing laboratory of Marine, Food and Biotechnology Department at Massawa College of Marine Science and Technology. These fish were identified using FAO species identification sheets (Smith-Vaniz, 1983; Collete, 1983; Whitehead et al., 1988) in collaboration with the Department of Marine Biology and Fisheries at Massawa College of Marine Science and Technology. Then, the fish were grouped into their species, frozen and stored at −18 °C. Approximately 4 kg of the frozen samples were transported in a cold chain to the Department of Food Science and Technology, Jomo-Kenyatta University of Agriculture and Technology (JKUAT), Nairobi, Kenya, for determination of their physicochemical properties. Before the analyses were carried out, the samples were defrosted.

2.2. Determination of morphometric characteristic of the fish

The morphometric characteristics (total length, standard length and total weight) of the fish samples were determined using a measuring scale-ruler (for length measurement) and weighing balance (Model F-1200; Jiangmen Winchun Electronics, Jiangmen, China). The average weight (g) of fish pieces per kg was determined by weighing 1 kg of fish and counting the number of pieces. This value is important in estimating production and yield of a given fish species.

2.3. Physicochemical analysis

2.3.1. Reagents and standards

All chemicals used were of analytical grade and all the reagents were prepared using distilled water. The following standards were obtained from Sigma Aldrich (St Louis, MO): mono, di and triglyceride mix, FAME mix, *p*-anisidine reagent and malondialdehyde tetrabutylammonium salt (MDA standard).

2.3.2. Proximate analysis (crude protein, moisture, fat, and ash)

Crude protein, moisture, fat, and ash were determined using the conventional methods of AOAC (1990). In summary, the crude protein content was determined using the semi-micro Kjeldahl method. Moisture content was determined by drying the samples in hot-air oven for 4 h at 105 °C where by the samples reached a constant dried weight. The crude fat content was determined by the Soxhlet method. Ash content was determined by incineration, whereby the samples were combusted in a muffle furnace at 550–600 °C for 2 h.

The crude fiber was determined by Hennenberg-Stohmann method (AOAC, 1995), whereby 2 g of sample were weighed and transferred to a 250-mL volumetric flask and then 200 mL of 1.25% sulfuric acid (H_2SO_4) were added and the mixture was boiled for 30 min. The digest was then filtered over fiber glass and washed. The filtrate on the fiber glass was put in a conical flask and 200 mL of 1.25% NaOH were added and the solution was further boiled for 30 min. The solution was filtered and washed with 1% HCl and then heated over boiling water. The filter was then washed with diethyl ether. The fiber glass and samples were then transferred to a crucible. This was oven dried, cooled and then weighed (W_1). Then the crucible with the sample was incinerated at 550 °C; it was then cooled and weighed (W_2). The percentage of crude fiber was expressed as: $((W_1 - W_2) \times 100)$/sample weight.

2.3.3. Determination of mineral composition, pH, salt content and visual color properties

Mineral concentrations (calcium, magnesium, zinc, iron, and cadmium) were determined using the atomic absorption spectrophotometry (Shimadzu 6300 AAS AA/AE; Shimadzu, Kyoto, Japan) as described by Alvin and Gardner (1986).

The pH was determined using a digital pH meter (HI8519N; Hanna Instruments Inc., Woonsocket, RI): 5 g of fish were ground with 5 mL of distilled water, and the pH measurement of the mixture was recorded.

The color of the fish samples was measured using a hand-held tristimulus colorimeter (Chroma Meter CR-200b; Minolta, Osaka, Japan) and a CIE standard illuminant C to determine CIE color space coordinates, $L^*a^*b^*$ values (Wawire et al., 2016). The L^* value, indicates the darkness/lightness of the sample (varying from 0 for black to 100 for white), a^* value is a measure of greenness/redness (−60 to +60) and b^* value is a measure of blueness/yellowness (−60 to +60). The colorimeter was calibrated against a standard white reference tile. The color measurements were performed on the samples in transparent plastic pouches. The color measurements were done at six different spots on each side of the fish contained in a plastic bag (Wawire et al., 2016).

Salt content, expressed as sodium chloride, was estimated by Mohr's method, as described by Sheen and Kahler (1938).

2.3.4. Determination of lipid oxidation (total lipids, free fatty acids, peroxide value, thiobarbituric acid value (TBARS) and p-anisidine value)

The levels of lipid oxidation were determined by evaluating the total lipids, free fatty acids, peroxide value, TBARS and *p*-anisidine