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The effect of storage temperature on histamine production and the freshness of yellowfin tuna (*Thunnus albacares*)

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Abstract

The present study was undertaken to assess the effect of storage temperatures on the shelf life and safety of yellowfin tuna (*Thunnus albacares*) by studying the changes in microbial, chemical, and organoleptical attributes. Shelf life of yellowfin tuna was determined through changes in total aerobic mesophilic and psychrotrophilic bacterial plate counts, *K* values, and organoleptic properties, whereas one aspect of its safety was determined through histamine development during storage at 0, 8, and 20 °C. The *K* value increased linearly at a slow rate (2.4%/day, $r^2 = 0.90$, $p < 0.05$) during storage at 0 °C. Based on *K* value indices, yellowfin tuna maintained an acceptable shelf life for 12, 5 and 1 day at 0, 8, and 20 °C, respectively. However, yellowfin tuna were rejected earlier by the sensory panelists than their *K* value indicated. Histamine development was found to be lower than the Food and Drug Authority (FDA) safety level of 5 mg/100 g fish during storage at 0 °C for 17 days. Yellowfin tuna stored at 8 and 20 °C became unsafe for human consumption, reaching unacceptable histamine levels after 4 and 1 day, respectively. Aerobic mesophilic bacteria initially dominated the microflora on yellowfin tuna, however, as storage time increased, aerobic psychrotrophic bacteria became dominant at cold storage but the numbers did not exceeded the International Commission on Microbiological Specifications for Foods (ICMSF) limit of 10^7 cfu/g.

Keywords: Yellowfin tuna; Shelf life; Safety; Histamine; Mesophilic; Psychrotrophic; Organoleptic properties; Quality

1. Introduction

Tuna and tuna-like species are important fish species due to their high global economic value and their prevalence in international trade for canning and sashimi. Yellowfin tuna (*Thunnus albacares*) are large pelagic fish that prevail in the tropics and subtropics; with landings accounting for about 22% of the world's tuna catch (Al-Abdessalaam, 1995). They are commercially important in many countries and there is high demand from international markets.

Fish and shellfish are perishable protein sources for human consumption. Scientists have been constantly searching for improved methods to preserve or extend the shelf life and safety of various aquatic food products (Chang, Chang, Shiau, & Pan, 1998). Shelf life is defined as the period of time under defined conditions of storage for which a food product remains safe and fit for use. In other words, during this period, it should retain its desired sensory, chemical, physical, functional or microbiological characteristics (IFST, 1993). The safety of food is a fundamental and legal requirement. It follows that all food products offered for sale must be safe although they do not necessarily have to be of the highest quality (Man, 2002). The quality of fish degrades because both microbial spoilage and biochemical reactions occur during

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handling and storage. Many methods have been used for the assessment of fish muscle quality during storage. Such methods include changes in the microbial population (Gram & Huss, 1996), total volatile basic nitrogen (TVB-N or VB-N) (Botta, Lauder, & Jewer, 1984; Malle & Poumeyrol, 1989), and *K* value (Saito, Arai, & Matsuyoshi, 1959). Postmortem nucleotide catabolism of fish results in different breakdown products of adenosine triphosphate (ATP). Different ratios of these compounds, such as the *K* value (Saito et al., 1959) and K_i indicator (Karube, Matsuoka, Suzuki, Watanabe, & Toyama, 1984) have been proposed. The *K*-value index is estimated by measuring the ratio of inosine (Ino) and hypoxanthine (Hx) to the quantity of ATP, ADP (adenosine diphosphate), AMP (adenosime monophosphate) and IMP (inosine monophophate). For the calculation of K_i index the values of ATP, ADP and AMP are omitted. The *K* and K_i are defined as follows:

$$K\ [\%] = \frac{(\mathrm{Ino} + \mathrm{Hx})}{(\mathrm{ATP} + \mathrm{ADP} + \mathrm{AMP} + \mathrm{IMP} + \mathrm{Ino} + \mathrm{Hx})} \times 100,$$

$$K_i\ [\%] = \frac{(\mathrm{Ino} + \mathrm{Hx})}{(\mathrm{IMP} + \mathrm{Ino} + \mathrm{Hx})} \times 100.$$

Ehira & Uchiyama (1987) reported that the *K* value was a good indicator for fish freshness. Surette, Gill, & LeBlanc (1988) proved that both autocatalytic and bacterial enzymes contributed to the changes in nucleotide compounds. It is known that biochemical changes and microbiological spoilage are closely related. Many factors affect the *K* value of fish such as fish species (Hattula & Kiesvaara, 1992), type of muscle (Murata & Sakaguchi, 1986) and storage temperature (Chang et al., 1998). The *K* value was found to be strongly influenced by storage temperature. In this respect, the *K* value of fish for sashimi did not exceed 20% and the fish was kept safely for two weeks at −3 °C, whereas *K* value reached 58% in 5 days for fish kept in ice (Uchiyama & Kato, 1974).

Scombroid poisoning results from ingestion of foods containing high levels of histamine and is one of the three most frequently reported illnesses associated with seafood consumption in the US (Bean & Griffin, 1990). Among seafood, it is mainly associated with scombroid fish species, such as tuna, bonito and mackerel, which develop high levels of free histidine during decomposition (Taylor, 1986). Histidine can be converted to histamine during decomposition by histamine-producing bacteria using histidine decarboxylase. Various types of fish implicated in scombroid poisoning have been found to contain high levels of histamine, usually exceeding 100 mg/100 g fish muscle. Histamine formation is most often induced by high temperature abuse of fish after harvest, and the accumulated level is affected by the combination of time and temperature.

Many scientists have studied the effects of storage temperatures on histamine formation in fish, and their results have been very often ambiguous (Guillén-Velasco, Ponce-Alquicira, Farrés-González Saravia, & Gerrero-Legarreta, 2004; Silva, Ponte, & Dapkevicius, 1998). This can be explained by the differences in the composition and the level of bacterial flora in the fish. Histamine-producing bacterial species and strains vary considerably in amounts of histamine formation, and the type of spoilage bacteria present depends on the aquatic environment (Lopez-Sabater, Rodriguez-Jerez, Hernadez-Herrero, Roig-Sagues, & Mora-Ventura, 1995).

Histamine remains one of the obstacles for exporting tuna species from the tropics and subtropics to international markets. The Food and Drug Administration (FDA, 1998) set the safety level of histamine as 5 mg/100 g to ensure safety of the products. The European union have proposed that the average content of histamine in fish should not exceed 10 mg/100 g, and no sample may contain more than 20 mg/100 g. Mishandling coupled with high temperature abuse are common practice in handling fish in the tropics and subtropics, which significantly enhance histamine formation. The effect of storage temperature on histamine production has been intensively studied. For instance, Arnold, Price, & Brown (1980) reported that the highest histamine level was found in fish stored at 30 °C, whereas no histamine was found when fish was stored at 1 °C. Nevertheless, no data is currently available on the conditions of histamine production in the tropics and subtropics. Moreover, Oman is one of the subtropical countries faced with many regulations mainly from the European Union to maintain histamine levels at or below the allowable level. Despite the high demand for yellowfin tuna in international markets, neither yellowfin freshness nor its safety has been studied. Therefore, the current study was undertaken to assess the effect of storage temperatures on the shelf life of yellowfin tuna by determining *K* value, mesophilic and psychrotrophic plate counts and one aspect of its safety through histamine formation during storage. This study was also aimed to elucidate the modes of quality loss and safety concerns in fish from tropical and subtropical countries.

2. Materials and methods

2.1. Fish

Three batches of fresh yellowfin tuna (*Thunnus albacares*) harvested off the coast of Oman were purchased from the local fish market, Muscat, Sultanate of Oman. Upon arrival at the laboratory, fish were placed individually in a clean plastic bag and stored at an appropriate temperature. Three storage temperatures were tested: