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Steam Precooking to Delay Spoilage of Shrimp Stock Awaiting for Processing in Cottage Industry

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Abstract Steaming as precooking methods were explored to reduce spoilage of raw shrimp awaiting for smoking process in cottage industry. Raw shrimp steamed for 20 min are stocked at ambient temperature (29-30°C) to assess spoilage kinetic. Microbiological and physico-chemical parameters are recorded. Data showed that steam precooking eliminated spoilage bacteria (*Enterobacteriaceae*, *Pseudomonas* spp.) and delays production of basic volatile compounds, extending raw shrimp storage up to 12 hours at ambient temperature, while raw non steamed shrimp were stored up to 6 hours in the same conditions. This study identified an attainable method to be used by stakeholders to delay spoilage of shrimp stocks awaiting smoking.

Keywords: *shrimp, spoilage, storage, smoking, food condiment*

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1. Introduction

Most of shrimp collected in Benin, about 65% of 3000 tons/year, are artisanally smoked to be commercialized in local retail market [1]. Each stakeholder processed about 26 kg/day within batches of 5 Kg per smoking grid lasting 3 to 5 hours [2]. In a previous study, Laghmari and El Marrakchi [3] reported shrimps as highly perishable food products, able to be spoiled within 6 hours at ambient temperature. Therefore, shrimps awaiting smoking are subjected to spoilage. Indeed, quality management of raw shrimp stock has been reported to be a major concerns claim by stakeholders in traditional processing sector [2]. Several studies investigated the mechanism of fresh shrimp spoilage in tropical conditions. It has been reported that at the beginning of storage, endogenous enzymes are mainly involved in the gradual loss of shellfish freshness. Thereafter, bacterial metabolism predominates and leads to final spoilage [4]. Specific shrimp spoilage bacteria have been isolated and their spoilage potential has been evaluated [5,6]. Shelf-life prediction and preservation techniques have been developed [7]. It has been shown that preservation under ice delays shrimp spoilage [8]. Also, it is known that most of proteolytic and collagenolytic enzymes involved in shrimp spoilage are located in the hepatopancreas [9,10] and spoilage begins by autolysis of cephalothorax where hepatopancreas and other internal organs are located [11]. Therefore, pretreatment methods including beheading have been proposed to extend the shelf-life of shellfish during storage in ice [12]. According to Thepnuan et al. [12], Lu [13] and Sriket et al. [10], shellfish decapitation delays spoilage activity by endogenous enzymes and could lower the microbial load. But these methods do not fit in with the artisanal practices of stakeholders of low income in developing countries where electricity lacks and shrimp heading off is not profitable.

It is known that steaming is a blanching methods used in fish processing practices. During this treatment, as practiced in common way, fish core temperature could reach 76-80°C within 5-9 min of steaming [14]. Such core temperatures during processing are deemed to be detrimental to microorganism (initial microbial types and viable numbers) [15]. The present study explored steaming as artisanal daily cooking practices of stakeholders to be developed for quality management of shrimp in artisanal processing sector. The aim was to delay spoilage of stocks of raw shrimps awaiting to smoking, using steaming as pretreatment.

2. Material and Methods

2.1. Material

Wild *Penaeus notialis* collected from lake "Nokoué", were purchased at wharves in Cotonou township (Republic of Benin). Raw shrimp of size of 60-70 shrimp/kg were selected and washed three times in tap water to remove slime and any other extraneous material.

2.2. Precooking Treatment

Two batches of previously washed shrimp were used. For one batch (SPS), steam blanching was achieved as described by Kpoclou et al. [16]. Briefly, raw shrimps (thin stratum) were steamed (20 min) in a metallic sieve set on a pot (10 L capacity) containing 2 L tap water boiling on embers. The other non-steamed batch (RNSS) was considered as control.

2.3. Storage Experiment

Steam precooked shrimps (SPS) were conditioned in plastic basket (as in stakeholders' practices) and stored at ambient temperature simultaneously with the RNSS as control. The temperature was monitored in the mass of the product undergoing the storage conditions using a thermocouple (TSTEMP 10 K, Oakton, Singapore). The experiments were repeated three times. Samples were taken out at 3 hours intervals until the sensorial rejection time.

2.4. Samples Analysis

2.4.1. Microbiological Analysis

Ten grams (10 g) of each sample were suspended in 90 ml of buffer peptone water (Oxoid CM0509B, Basingstoke, Hampshire, England), and homogenized for 2 min using a laboratory blender (Stomacher Lab-Blender 400, Seward, London, UK). Serial decimal dilutions were prepared in buffer peptone water as described by ISO 6887-3 [17], and inoculated in respective culture media for total viable count, *Staphylococcus aureus*, *Enterobacteriaceae* *[18]* and *Pseudomonas* spp. [6].

2.4.2. Chemical Analysis

Total volatile basic nitrogen (TVBN) analyses were conducted on TCA extraction by distillation in a Kjeldahl rapid distillation unit (Büchi K-350 Distillation unit. CH-9230 Flawil 1, Switzerland) and titration with sulphuric acid (0.1 N), as described by Malle and Poumeyrol [19]. Polycyclic Aromatic Hydrocarbons were determined with the method used by Kpoclou et al. [18]. Moisture content was measured on whole deshelled and beheaded shrimp [20].

2.4.3. Statistical Analysis

Descriptive statistics (mean ± standard deviation) were achieved on microbiological and physic-chemical data using Microsoft excel 2013. The physicochemical and microbiological data were subjected to ANOVA one way, and the degree of likeness was determined using Newman and Kull's test with XLSTAT version 2012.6.08 software (Addinsoft, Paris, France). Significance difference was accepted when probability $p < 0.05$.

3. Results and Discussion

3.1. Microbiological Characteristics of Steam Precooked Shrimp During Storage

Temperature values recorded during storage in ambient conditions swung between 29.4 °C and 30.2 °C. In such conditions, the load of aerobic mesophilic bacteria (AMB) increased from 5.3 Log cfu (0h) to 7.9 Log cfu (12 h) in RNSS. Following the same trend, *Pseudomonas* spp. (PS) and *Enterobacteriaceae* (EB) increased respectively from 4.3 and 3.4 Log cfu/g to 6.8 and 5.8 Log cfu/g respectively, while *S. aureus* was not detected (Figure 1a). After steaming, only AMB were detected with a load increasing from 2.7 Log cfu/g (0 h) to 7.1 Log cfu/g (12 h) (Figure 1b). It appears that shrimp precooking with hot water steam during 20 minutes reduced AMB load and eliminated PS and EB. Ray and Bhunia [21] reported that Gram-negative aerobic rods such as *Pseudomonas* spp. are the major shrimp spoilage bacteria. According to Dabade et al. [6], *Enterobacteriaceae* are involved in spoilage by off-odor producing. Therefore, the treatment applied could delay bacterial spoilage of shrimp. The International Commission on Microbiological Specifications for Foods [22] set up maximum limits of 7.0 Log_{10} (CFU/g) for AMB in raw crustaceans. This limit was reached after 6 hours and 12 hours storage in RNSS and RSS respectively. This indicates a positive effect of steaming to extend raw shrimp stability for 6 hours more in storage at ambient temperature (29.4°C-30.2°C) before smoking. This aspect is useful for processors. Indeed, Kpoclou et al. [2,23] reported that fresh shrimp quality management is a real problem for stakeholders. Each processor transforms an average quantity of 26 Kg raw shrimps per day during the plenty period, with smoking process (batch of 5 Kg) lasting 3 to 5 hours. Therefore, steaming could help to raw shrimp quality management awaiting to be smoked. Also the relatively low smoking duration with steamed shrimp would help to save processing time and enhance the productivity.

3.2. Chemical Characteristics of Steam Precooked Shrimp during Storage at Ambient Temperature (29.4-30.2°C)

Total volatile basic nitrogen (TVBN) increased gradually from 25.31 mg/100 g (0 h) to 120.34 mg/100 g (12 h) in raw non-steamed shrimp (RNSS) and from 23.24 mg/100 g (0 h) to 35.00 mg/100 g (24 h) in steam precooked shrimp (SPS) (Table 1). Change in TVBN would be due to bacterial and biochemical post-mortem reactions of shrimps' spoilage [24]. Data recorded show that TVBN change becomes significant ($p< 0.05$) after 9 hours and 24 hours storage at ambient temperature in RNSS and SPS, respectively. In SPS, TVBN reached 35 mg/100 g within 24 hours while in RNSS, this TBVN value was reached within less than 6 hours storage in the same condition. In cottage practices where chilling is not used, steaming seems to be a suitable alternative to delay spoilage of shrimp stock waiting to be smoked. The low TVBN formation allowing long storage duration (24 h) of SPS could be due to proteins denaturation by hot steam temperature during treatment (up to 95 °C). Weinman [25] reported that above 60 °C, proteins denaturation occurred. During heat treatment, shrinkage of shrimp occurred due to shrinkage of muscle proteins and collagen which coagulated [20]. According to Vaclavik and Christian [26], treatment at temperatures around 70-80°C causes such irreversible reactions. They denature proteins which lose their functional properties; enzymes are inactivated and so the reactions that they catalyzed can no longer take place. The longer the cooking time, the more serious this effect will be [27]. In the case of our study, enzymes involved in shrimp spoilage would be inactivated. That explains the insignificant difference in TVBN values during 24 h storage. The resumption of TVBN production registered after 24 h would be due to enzymes from microorganisms of post-steaming contamination.

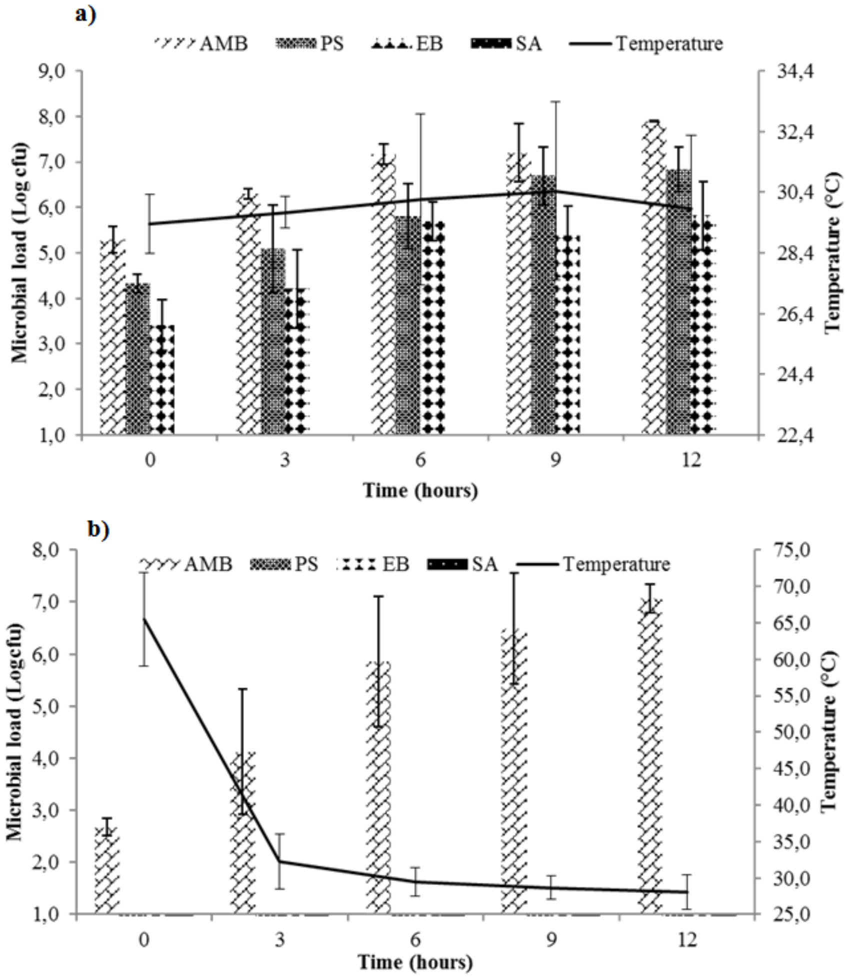

Figure 1. Microbiological characteristics of raw non-precooked shrimp (RNSS) (a) and steamed shrimp (SPS) (b) during storage (n = 3). AMB= aerobic mesophilic bacteria; PS= *Pseudomonas* spp.; EB= *Enterobacteriaceae*; SA= *Staphilococcus aureus*

Table 1. TVBN (mg/100) in raw non-precooked shrimp (RNSS) and steamed shrimp (SPS) during storage at ambient temperature (29-30°C)

Time (hours)	RNSS	SPS
0	25.31±1.40a	23.24±2.28a
3	31.14±2.29a	24.19±1.33a
6	53.70±5.73a	21.73±2.17a
9	89.99±30.36b	20.16±2.42a
12	120.34±22.27b	22.90±0.26a
15	-	24.08±2.77a
18	-	24.92±1.47a
21	-	27.89±4.81a
24	-	35.00±9.84b

Data within the same column with different superscript letters are significantly ($P < 0.05$) different.

4. Conclusion

This study explored steaming as precooking method to reduce spoilage of raw shrimp awaiting for smoking process in cottage industry. Steam-precooking of fresh shrimps during 20 min before smoking delays stored shrimps spoilage for 6 hours (29.4-30.2°C) compared to raw fresh shrimp during storage. These findings constitute a significant contribution to the preservation of commercial quality and safety of smoked shrimp in cottage industry.

Conflicts of Interest

Authors have no competing interest to declare.

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