Food Control 47 (2015) 326–333

Contents lists available at ScienceDirect

Food Control

journal homepage: www.elsevier.com/locate/foodcont

Growth behavior prediction of fresh catfish fillet with *Pseudomonas aeruginosa* under stresses of allyl isothiocyanate, temperature and modified atmosphere☆

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ARTICLE INFO

Article history:
Received 23 April 2014
Received in revised form
14 July 2014
Accepted 16 July 2014
Available online 24 July 2014

Keywords:
Modeling
Pseudomonas aeruginosa
Catfish fillet
Allyl isothiocyanate
Modified atmosphere packaging

ABSTRACT

Pseudomonas aeruginosa, an opportunistic pathogen which can be found on fresh catfish fillet, grows rapidly when temperature rises above 4 °C. The combination of allyl isothiocyanate (AIT) and modified atmosphere (MA) was applied and proved effective to retard the growth of *P. aeruginosa*. The objective of this research was to develop simple mathematical models to predict the growth behavior of *P. aeruginosa* in catfish fillet and its potential storage time (in abuse temperature condition) as a function of AIT and temperature with/without MA treatment. The antimicrobial effect of gaseous AIT (0, 18 and 36 μL/L) on the growth of *P. aeruginosa* cocktail was evaluated at 8, 15 and 20 °C. Furthermore, the effects of MA (49% CO_2, 50.5% N_2 and 0.5% O_2) alone and AIT/MA combination were also investigated. These data obtained through an experimental design were used for model development. The regression models for lag phase, growth rate and "shelf life" (based on *P. aeruginosa* which closely related to *Pseudomonas fluorescens* and *Pseudomonas pudita* and all belong to the same RNA group used to classify the *Pseudomonas* at the subgenus level) were validated experimentally. Surface plot of models was also drawn to lucidly represent the interaction of AIT and temperature. The developed models may provide useful information for food industry in designing or selecting the proper packaging system with incorporation of AIT to attain the food safety with acceptable "shelf life" of fresh fish products under specified and potential abuse (with temperature deviation) distribution and storage conditions.

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1. Introduction

Catfish is an important economic contributor in the United States. Over 420 million pounds of processed catfish were produced in the US in 2011 (National Agricultural Statistic Service and Agricultural Statistic Board, 2011). Since the huge amount of catfish is consumed in the US, the safety issues caused by bacteria contaminated catfish should be noticed and prevented. The microorganisms developing in fresh catfish typically consist of Gram-negative psychrotrophic bacteria, because the storage environment is usually aerobic and under refrigerated temperature (Flick, 2008; Gram & Huss, 1996; Najiah et al., 2009). Therefore, *Pseudomonas aeruginosa*, one of the common opportunistic pathogens, which conforms to the characteristics mentioned above, may be selected as the target microorganism (Sadikot, Blackwell, Christman, & Prince, 2005).

To inhibit the growth of *P. aeruginosa* and also satisfy the healthy demand from consumers at the same time, allyl isothiocyanate (AIT), a natural antimicrobial food ingredient may be applied to control the growth behavior of fresh catfish fillet (Lopez, Sanchez, Batlle, & Nerin, 2005, 2007; Nychas, 1995). However, AIT contains organosulfur group (CH_2CHCH_2NCS) which might have strong and distinctive odor, thus limiting the applied concentration of AIT (Fenwick, Heaney, Mullin, & VanEtten, 1982). In addition, modified atmosphere (MA) may become a supplementary technology to enhance the natural antimicrobial system. The combination of AIT and MA was proved to be an antimicrobial packaging solution for fresh catfish fillet in maintaining its safety and quality (Pang, Sheen, Zhou, Liu, & Yam, 2013).

Although *P. aeruginosa* is a common pathogen for immunocompromised patient and rarely cause infections for healthy

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http://dx.doi.org/10.1016/j.foodcont.2014.07.030
0956-7135/Published by Elsevier Ltd.

individuals, it is important to control its population for food safety and quality concerns (Sadikot et al., 2005). *P. aeruginosa* may function similarly to other *Pseudomonas* spoilage strains in damages of fish qualities. Seafood manufacturing might be interested in understanding the growth behavior of *P. aeruginosa* on fresh catfish fillet to effectively control/monitor quality attributes. Understanding the correlation between the lag phase of *P. aeruginosa* and the concentration of AIT combined with MA could further maintain the safety and extend the quality of fresh catfish to certain time while minimizing the cost. In addition, some microbial enzymes extracted from *P. aeruginosa* were found related to food spoilage, which might shorten the shelf life of fresh catfish fillet by producing unacceptable organic compounds (Al-Haddad, Al-Qassemi, & Robinson, 2005; Braun, Fehlhaber, Klug, & Kopp, 1999; Gram & Dalgaard, 2002). Therefore, developing mathematical models to predict the growth behavior of *P. aeruginosa* in catfish fillet to estimate its shelf life as a function of AIT and temperature with/without MA treatment is also critical to improve the safety and quality of fresh catfish.

In the past, a food model, which is typically liquid media such as broth instead of actual food product, was used to develop the predictive models. Broth is a simple and homogeneous system in which many factors can be easily controlled and monitored. Many researchers recently observed and reported that microorganisms in real food systems would not behave in the same way as in broths, which could be due to that many factors such as matrix structure and microbial interactions are significantly different in two systems (Koutsoumanis & Nychas, 2000). It was also observed in our study shown in the results, Fig. 2, where the growth rates of *P. aeruginosa* in catfish were much higher than those in broth. Therefore, in order to develop reliable models to represent and describe the real situations, all experiments were conducted using the commercially available catfish products.

To better understand and monitor the safety and qualities of fresh fish products, it is highly desired to develop models, which may describe the survival and growth behavior of *P. aeruginosa* under different stresses including packaging. Most currently available mathematical models to predict microbial behaviors in foods, also known as "predictive microbiology", include the empirical and semi-empirical models (Ross & Dalgaard, 2004). The empirical models were regression models (Buchanan, 1993) based on experimental design and semi-empirical models may be further

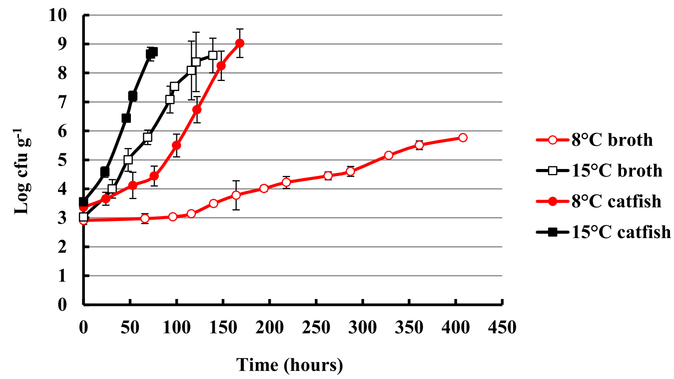

Fig. 2. Growth behavior of *P. aeruginosa* in broth and in fresh catfish.

regarded as the primary and secondary models. The primary models typically are the growth models in iso-thermal condition to describe the lag phase, growth rate and etc. (Baranyi & Roberts, 1994). The secondary models may be better used in describing the environmental stresses which affect the growth and survival. The Ratkowsky-type model (growth rate) may take into account the dynamic temperature conditions (Ratkowsky, Lowry, McMeekin, Stokes, & Chandler, 1983). The Zwietering-type model (lag phase) can be applied to microbial surrounding stresses like pH, water activity, antimicrobial agents, and etc. (Zwietering, Cuppers, deWit, & van't Riet, 1994). Huang (2013a, 2013b, 2014) developed the dynamic models to take into account the time-dependent temperature conditions which may facilitate the predictive modeling applications in microbial growth and inactivation study. There is also a good potential that Huang's models may be further modified to include other factors, e.g. pH, salt and other parameters. But, it also may encounter much higher difficulty and more computer time to implement the simulation. Generally speaking, when multiple factors were build-in to the models, it became more difficult to develop the reliable models. Sheen et al. (Sheen, Hwang, & Juneja, 2012; Sheen, Hwang, & Juneja, 2011) expanded the Ratkowsky-type and Zwietering-type models to include chlorine and abuse temperature stresses. Since most of models are constrained to specified application conditions and foods, our objective was to develop regression models with

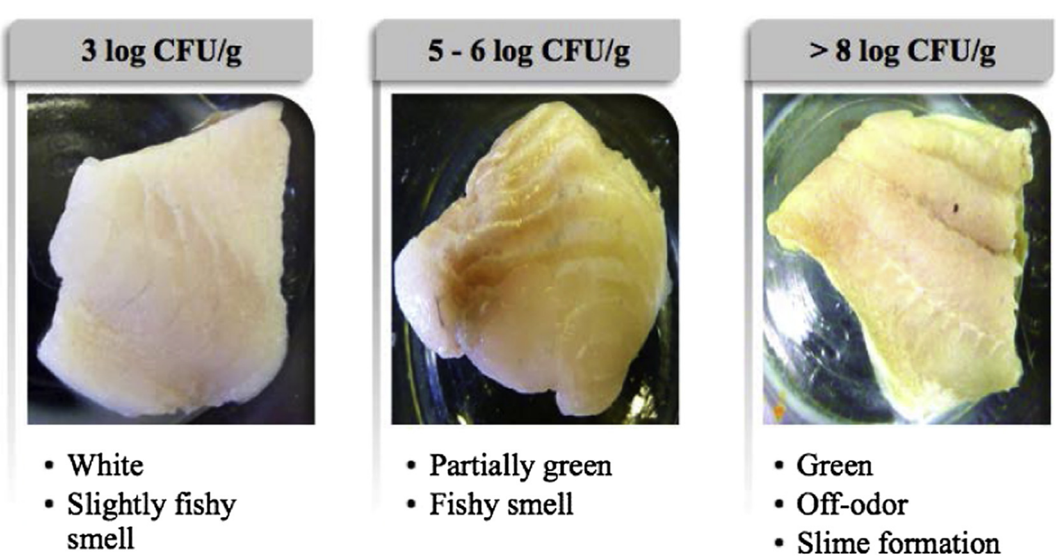

Fig. 1. Sensory manifestation with the growth of *P. aeruginosa*.