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Modeling the time to fail of peach nectars formulated by hurdle technology

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Abstract

The use of regression with life-data is helpful to observe whether one or more factors affect the failure time (spoilage) of a product, obtaining a model that predicts the time to fail (TTF). TTF models link kinetic (lag time) and probabilistic (growth/no-growth prediction) models for selected formulation/storage conditions. Our objective was to assess the individual and combined effects of pH, a_w, and the incorporation of potassium sorbate (KS) or sodium benzoate (BNa) at selected concentrations on the microbial stability of peach nectar during storage at 25°C, in order to model and predict TTF. Peach nectars were formulated with 40% fruit pulp and the necessary sucrose syrup and citric acid to attain a_w 0.96, 0.97, or 0.98 and pH 3.0, 3.5, or 4.0; while 0, 500, or 1000 ppm of KS or BNa were added. Nectars were stored for 180 days in glass jars at 25°C, and periodically analyzed (standard plate as well as yeast and mould counts). The experimental design and analyses were replicated three times. Storage times that revealed microbial populations higher than 10^4 CFU/mL and signs of spoilage were registered to model TTF by survival analysis. From the 54 combinations tested, 9 formulations (without antimicrobials) exhibited early spoilage (<5 days). For the combinations formulated with 500 ppm of BNa, spoilage was detected after 30 days; much longer spoilage times were observed for nectars with 1000 ppm of KS or BNa. In general, KS was more effective than BNa in delaying spoilage when 1000 ppm were added. TTF models included individual and interaction effects of the evaluated factors and revealed good agreement among experimental and predicted data (R^2>0.90). Survival analysis through TTF models can be used to predict spoilage time under specific factor combinations or to select factor levels for a specific shelf-life of peach nectars.

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Keywords: survival estimation; time-to-fail models; shelf-life evaluation; peach nectar; hurdle technology

1. Introduction

Most fruits can be consumed in its fresh state, in some cases refrigerated storage can extend their shelf-life; but in general, with some exceptions, their useful shelf-life is relatively short. However, to take advantage of fruits for longer periods it is necessary to transform them into less perishable products using diverse techniques or methods of conservation[1, 2].

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These methods are based on eliminating pathogens and reducing and controlling spoilage flora, as well as inactivation of biochemical reactions, mainly resulting from enzymatic activities, which can deteriorate the product[1,3]. The use of simple and low-cost technologies for the conservation of fruits using "hurdle" or "combined methods" technology is based on the simultaneous implementation of various preserving factors, which by themselves are not enough to maintain food quality and safety, but when combined become a barrier to microbial growth, while causing minimal changes to product quality[3, 4]. The practical importance of hurdle technology is recognized by the food industry and is widely used in designing new products. The preservation factors to be chosen should maintain product safety, generate a similar quality to that of fresh produce, and increase product shelf life[2].

On the other hand, time to growth or time to fail (TTF) models constructed through regression with time-to-fail or time-to-grow data allows investigating the relationship between TTF and several microbial stress factors. TTF models have been utilized by Lindblad and Lindqvist[5] to estimate the response of acid-adapted *Escherichia coli*; by Jenkins et al. (6) for *Zygosaccharomyces bailii* in acidified products; by Evans et al.[7] to evaluate the response of selected yeasts as function of several factors; and by Gómez-Ramírez et al.[8] to assess the individual and combined effects of a_w and incorporation of selected concentrations of Mexican oregano essential oil on the time to growth of *Aspergillus niger* in dried tomatoes during storage at 25°C. Our objective was to assess the individual and combined effects of pH, a_w, and the incorporation of potassium sorbate (KS) or sodium benzoate (BNa) at selected concentrations on the microbial stability of peach nectar during storage at 25°C, in order to obtain a model that adequately predicts the nectar's time-to-fail.

2 Materials and Methods

Peaches (*Prunus persica* Diamond variety) grown in the region of Huejotzingo, Puebla (México) were selected (free of defects and mature), washed, peeled, pitted, and pulped. The pulp was used to prepare nectars with different water activity (a_w), pH, and KS or BNa concentration (Table 1). Nectar preparation consisted of mixing the pulp with sucrose syrup (commercial sugar and purified water) in the amount and concentration necessary to obtain the desired a_w. The obtained mixture was heated to 68°C for 15 min, preventing evaporation. Then, nectars were cooled (20°C); subsequently their pH was adjusted by adding citric acid (Globe Chemicals, Germany), and as required, food grade KS or BNa (ASSA QUIMICA, Mexico) were added. Finally, nectars were packaged in glass jars (previously sterilized) and stored at 25°C. pH was measured in triplicate by electrode immersion with a pH-meter (Denver Instrument UB-10, Bohemia, NY,). Soluble solids content was determined through AOAC[9] method, using a digital refractometer (AR200, Reichert Inc., Depew, NY,). Water activity was determined using a Decagon CX-2 (Decagon Devices, Inc., Pullman, WA). Determinations were performed by triplicate.

Native flora counts were performed in tested nectars. Determinations of aerobic mesophilic bacteria using standard plate agar (after 24 h at 35°C); and yeast and mould counts using acidified (with 0.1% tartaric acid) potato-dextrose agar after 72 h at 25°C. Nectars were daily observed and samples were taken to microbiological analysis, observations focused to detect signs of microbial deterioration, changes in odor, turbidity, fermentation, gas presence, among others. On the day that microbial spoilage was observed, the incubation time at which it occurred was recorded and corroborated through microbial counts.

The collected data, time where peach nectars presented spoilage signs (microbial counts $>10^4$ CFU/ml) for the tested combinations, was modeled using regression with life-data (in our case time-to-failure for every combination and replica) by means of Minitab software v. 16 (Minitab, Inc., State College, PA). A polynomial quadratic expression involving the normalized variables was built using the subroutine in the software. Values of a_w, pH, and antimicrobial concentration were normalized before the regression analysis as follows: normalized value = (value – mean)/standard deviation. Since no observable growth was detected in some cases by the end of the 180 days of incubation, analyzed data was right-censored. Predictions of the TTF were obtained from the model for different a_w, and pH values, as well as antimicrobial concentration in the evaluated ranges.

3. Results and Discussion

Table 1 presents TTF for peach nectars stored at 25°C, it was observed that nectars formulated with pH 3.0 or 3.5, a_w 0.96 or 0.97, and with 500 or 1000 ppm of BNA or KS presented longer shelf-lives. The results of microbiological analysis indicate that peach nectars have low initial counts. Peach nectars, without BNa or KS incubated at 25°C showed signs of deterioration, in average, after 4 days with microbiological counts $>10^6$ CFU/ml