Mathematical modelling of the growth of *Byssochlamys fulva* in concentrated apple juice under isothermal conditions

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INTRODUCTION

Apple juice is a popular product, widely accepted by consumers and attractive from an industrial point of view. *Byssochlamys fulva* is an ascospores producer fungi, known to be heat resistant and commonly found in fruit juices. The presence of fungi in juices compromises product's safety and quality. The aim of this work was to model the effect of soluble solids concentration and storage temperature on the growth of *B. fulva* in concentrated apple juice.

MATERIAL AND METHODS

Apple juice (70 ºBrix) → Soluble solids adjusted (12, 20, 25, 35 and 45 ºBrix) → Medium preparation (apple juice + agar) → Pasteurization (115 ºC - 1 min) → Inoculation *B. fulva* (depositing a loop of microorganism in the center of plate) → Incubation at 10, 15, 20, 25 and 30 ºC → Measuring the radial growth (every day) → *B. fulva*

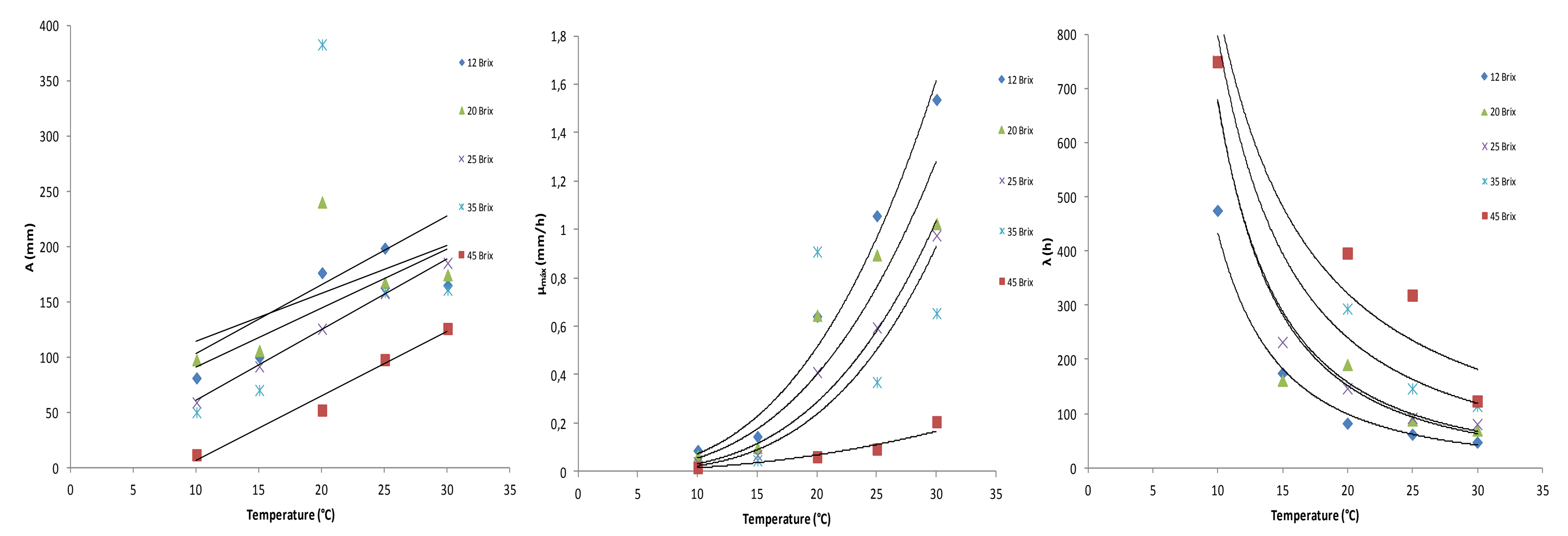
Figure 1. Flowchart of methodology.

$$y = A.\exp\left\{-\exp\left[\frac{\mu_{max}.e}{A}(\lambda - t) + 1\right]\right\} \quad \text{Eq. 1}$$

A Gompertz-based model (Equation 1) was used to fit the fungi radial growth, y(mm), throughout time, t(h), at given temperatures, T (ºC), and soluble solids concentration, S (ºBrix). The model parameters were the lag adaptation phase (λ), the assymptotic population value (A) and the maximum specific growth rate (μ_{max}). The effect of soluble solids concentration and temperature on Gompertz model parameters was described by Equations 2, 3 and 4. These equations were incorporated into the Gompertz model to obtain a global description of the fungi radial growth as function of time, temperature and soluble solids concentration (Equation 5). The confidence bands of the responses at 95% were also calculated. Data analysis procedures were performed in IBM SPSS Statistics (version 20) and Excel (2010 Microsoft Corporation).

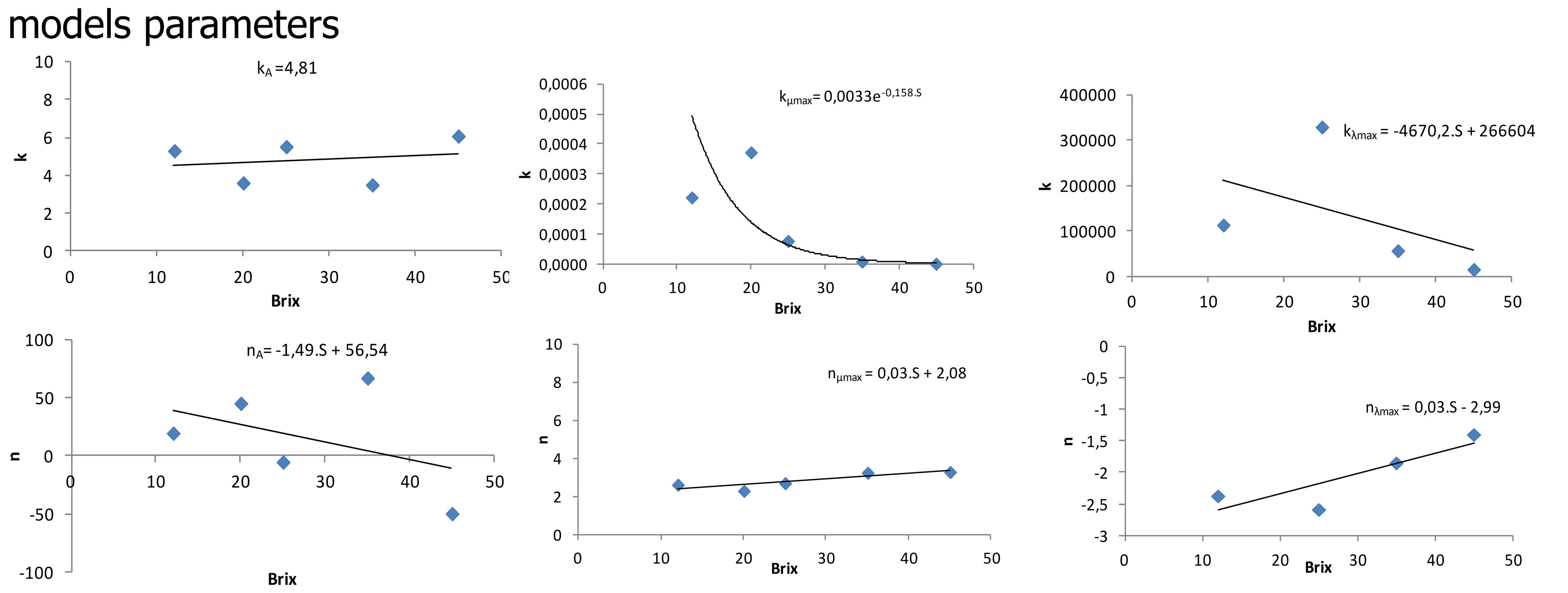
RESULTS

Secondary models to describe the influence of temperature on the growth parameters A, μ_{max} and λ.



$A = k_A.T + n_A$ $\quad \mu_{max} = k_{\mu max}.T^{n_{\mu max}}$ $\quad \lambda = k_\lambda.T^{n_\lambda}$

Models to describe the influence of soluble solids concentration on secondary (T) models parameters



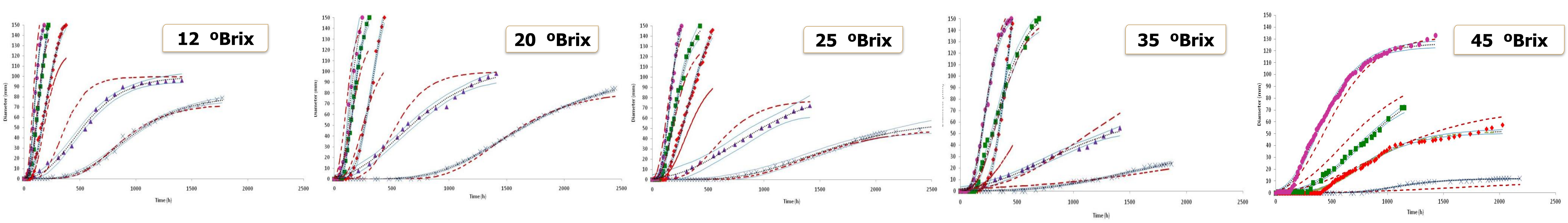
$A = 4.81\,T + (-1.49.S + 56.54)$ Eq. 2

$\mu_{max} = 3.30.10^{-3}\exp(-0.16.S)T^{(0.03.S+2.08)}$ Eq. 3

$\lambda = (-4670.2.S + 266604).T^{(0.03.S-2.99)}$ Eq. 4

Predictive global model as function of temperature (T) soluble solids concentration (S) and time (t)

$$y = (4.81.T + (-1.49.S + 56.54))\exp\left\{-\exp\left[\left[\frac{((3.30.10^{-3}.\exp(-0.16.S).T^{(0.03.S+2.08)}).\exp 1}{4.81.T + (-1.4907.S + 56.541)}\right].\left[(-4670.2.S + 266604).T^{(0.03.S-2.99)} - t\right] + 1\right]\right\} \quad \text{Eq. 5}$$



(●) 30 ºC (■) 25 ºC (♦) 20 ºC (▲) 15 ºC (x) 10 ºC ········ Gompertz model fits (Eq. 1) – – – Predictions by the global model (Eq. 5) —— Limits of the 95% confidence bands of the response

Experimental results of the measured diameter of *B. fulva* throughout time showed an initial lag, followed by a maximum growth rate period, tending, in some experimental conditions, to an asymptotic value. Such complete or incomplete sigmoidal tendencies were adequately described by a Gompertz-based model. The growth was significantly affected by soluble solids concentration of the juices and by the storage temperatures. The increase of soluble solids concentration implied higher lag periods and lower growth rates, the increase in temperature resulted in lower initial lags and in higher growth rates.

The predictive ability of the global model that included these effects was proven for the majority of conditions tested. However, in some situations, difficulties in reproducing (and / or stabilize) the experimental conditions implied a lack of model prediction. The problems related to evaluate fungi growth could explain these results.

CONCLUSIONS

A mathematical model that included the soluble solids concentration of apple juice and the storage temperature effects on the growth of *B. fulva* was successfully developed. It allows predictions of the fungi kinetic behaviour merely based on juice soluble solids characteristics and temperature, which is an important tool for assessment of the overall quality of the juices after given storage periods.

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