Yeast growth data

Danmarks
Tekniske
Universitet

Group 39

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Members:
Jacopo Ceccuti
Benjamin Christensen
Sergejs Gorbacovs

Code

The code used for analyzing the data:

```
import numpy as np
import matplotlib.pyplot as plt
from scipy.optimize import curve_fit
import matplotlib.ticker as mticker

""" The following code analyzes and plots the data set (OD values) that has been collected over the week-end.
An easy user interface has been implemented to make the choice of the graph easier."""

# This def. is used in the curve fitting to give a particular shape at the curve
def S_curve(x, L ,x0, k, b):
    y = L / (1 + np.exp(-k*(x-x0)))
    return (y)

# Here, the file is being opened. The last 1328 measurements were not considered and not included in this plot.
# because it was unnecessary to include the stationary phase.
Y_vals = np.loadtxt("DATAEXP2.txt")
Y_vals = Y_vals[:-1328]
X_vals = np.arange(np.size(Y_vals)) # Creates an array that represents the time interval
# (We took one measurement every minute)


p0 = [max(Y_vals), np.median(X_vals),1,min(Y_vals)] # this is an mandatory initial guess
# used by the curve_fit function
popt, pcov = curve_fit(S_curve, X_vals, Y_vals ,p0 ,method='dogbox') # finds the fit of the data

S_curve_fit = S_curve(X_vals, *popt) # assign the fit of data to this variable for future uses
```

```
# Calculates the first derivative and uses the formula to find μ
dAdt = np.gradient(S_curve_fit ,X_vals) #np.gradient take derivative of two all y-axis and x-axis values
μ = dAdt*(1/S_curve_fit)

np.seterr(all="ignore")

# Here we including data that fit into the exponential curve
Y_vals1 = Y_vals[:1900]
X_vals1 = X_vals[:1900]
log_Y_vals = np.log(Y_vals1) #takes the log of the OD values

# function used to make an exponential fit (used from the previous assignment at this course)
val_1, val_2 = np.polyfit(X_vals1, log_Y_vals, 1)
y = np.exp(val_2)*np.exp(val_1*X_vals1) # Create the function of the type y = exp(x)*exp(y*t)

# Creates the small user interface to get the input for the desired graph
request = input("Would you like the plot of:\n -A  Data and fitting\n -B  Growth rate (μ)\n -C  Growth rate (dOD/dt)\n Enter your answer here: ")

if request.lower() == "a": # Creates: scatter plot with data, best fit (red) and exponential fit (orange)
    plt.scatter(X_vals/60, Y_vals, s=1)
    plt.plot(X_vals/60, S_curve_fit,c="r", label = "Fit of data")
    plt.title("Yeast growth S-curve", c="r")
    plt.xlabel("Time")
    plt.ylabel("OD-value") # Set some titles and unit of measure
    plt.gca().xaxis.set_major_formatter(mticker.FormatStrFormatter('%d h'))
    plt.xticks(np.arange(min(X_vals/60), max(X_vals/60)+1, 5))
    plt.plot(X_vals1/60, y, color="orange",ls= "--", label = "Exponential fit")
    plt.ylim(0,5)
    plt.legend()
    plt.show()

elif request.lower() == "b" : # Creates the graph for the growth rate  (μ)
    plt.plot(X_vals/60,μ*10000, "-")
    plt.title("Yeast growth rate", c="r")
    plt.xlabel("Time")
```

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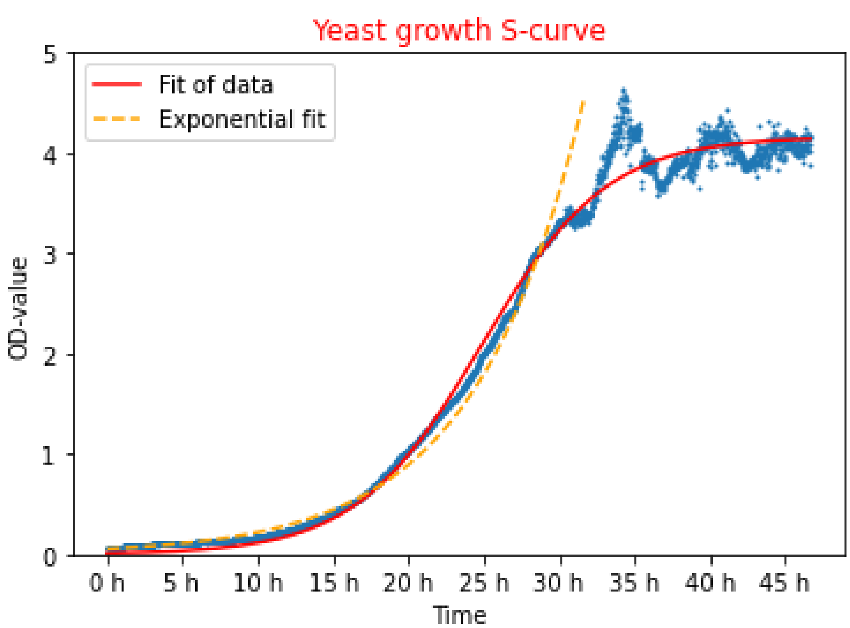
    plt.ylabel("Growth rate (10 mμ)") # Set some titles and unit of measure
    plt.gca().xaxis.set_major_formatter(mticker.FormatStrFormatter('%d h'))
    plt.gca().yaxis.set_major_formatter(mticker.FormatStrFormatter('%d OD · h'))
    plt.xticks(np.arange(min(X_vals/60), max(X_vals/60)+1, 5))
    plt.show()

elif request.lower() == "c": # Creates  the graph for the growth rate (dOD/dt)
    plt.plot(X_vals/60,dAdt, "-")
    plt.title("Yeast growth rate", c="r")
    plt.xlabel("Time")
    plt.ylabel("Growth rate (OD/h)")# Set some titles and unit of measure
    plt.gca().xaxis.set_major_formatter(mticker.FormatStrFormatter('%d h'))
    plt.xticks(np.arange(min(X_vals/60), max(X_vals/60)+1, 5))
    plt.show()

else:
    print("Sorry, invalid input") # Output message if the input is invalid
```

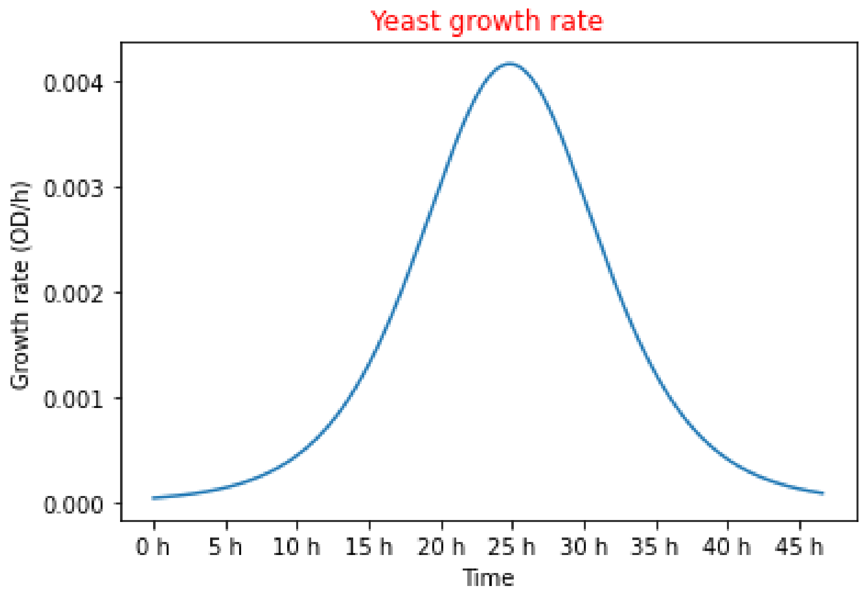
Graphs

The data sample was collected over the weekend. The last 15-17 hours of data were deleted, during the analysis, because the yeast had already reached the stationary phase.

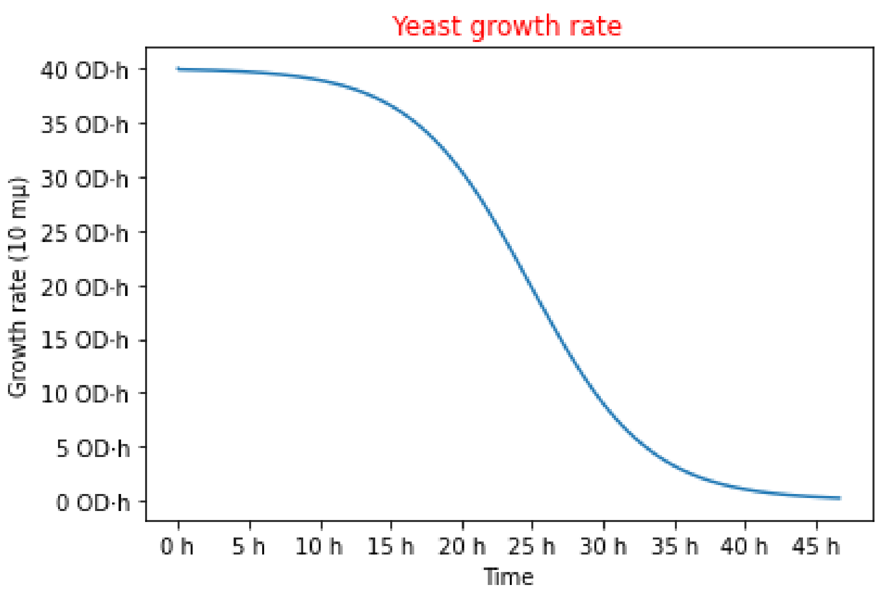


The data used is collected approximately over a 50-hour period.

The graph illustrates plot of $\frac{dOD}{dt}$ and including the first 50 hours.



The last growth rate graph represents μ value (more precisely 10 mμ) over time:



Q&A

1. The data represent the exponential growth at the time range of approximately 5 hours and it starts after 22 h and ends around 27 hours. The data represent the exponential growth starting after the 22nd hour and rapidly continuing for the next 5 hours at the time range of approximately 5 hours.
2. The maximum value of the growth rate is about $4 * 10^{-3}$ in the interval of the first 50 hours.
3. The doubling time t_2 is approximately 294.1 minutes. To calculate this value we used Maple:

   $y_1 = e^{\lambda x} \cdot e^{\lambda 2}$ for $x = 1$

   $y_2 = e^{\lambda x} \cdot e^{\lambda 2}$

   Becomes:

   $2 \cdot (e^{\lambda} \cdot e^{\lambda 2}) = e^{\lambda x} \cdot e^{\lambda 2}$ That we solved with Maple

   $$2 \cdot e^{0.0023649695879088784 - 2.929093859256979} = e^{0.0023649695879088784 \cdot t} \cdot e^{-2.929093859256979} \xrightarrow{\text{isolate for t}} t = 294.0892576$$
   $$1 = e^{0.0023649695879088784 \cdot x} \cdot e^{-2.929093859256979} \xrightarrow{\text{isolate for x}} x = 1238.533415$$
   $$y = e^{0.0023649695879088784 \cdot (1238.533415 + 294.0892576)} \cdot e^{-2.929093859256979} \xrightarrow{\text{at 5 digits}} y = 2.0047$$

   The values of lambda were given by our data analysis program.

   The small initial amount of yeast explains that the doubling time is significantly longer than the average time found on the internet. The curve shows the exponential growth phase starts almost after 24h. This occurred because of different factors such as temperature, yeast strain and level of contamination.

4. The graphs illustrate that the yeast was growing exponentially for five hours with fluctuating growth rate, standing at the maximum value around 0.004 [OD/h] or 40 (10 mμ) [OD*h].