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Short communication

Estimation of the Q_{10} value; the Temperature Coefficient for the Growth of *Pseudomonas* sp. AQ5-04 on Phenol

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ABSTRACT

The Q_{10} value is tied to an increase in the surrounding temperature with an increase in 10 ◦C, and usually resulted in a doubling of the reaction rate. When this happens, the Q_{10} value for the reaction is 2. This value holds true to numerous biological reactions. To date, the Q_{10} value for the biodegradation of phenol is almost not reported. The Q_{10} values can be determined from the Arrhenius plots. In this study, the growth rate or biodegradation rates in logarithmic value for the bacterium *Pseudomonas* sp. AQ5-04 was plotted against 1000/temperature (Kelvin) and the slope of the Arrhenius curve is the value of the Ea, which was utilized to obtain the Q_{10}. The value obtained in this work was 1.834, which is slightly lower than the normal range of between 2 and 3 for the biodegradation rates of hydrocarbon in general and shows that this bacterium is a very efficient phenol-degrading bacterium.

INTRODUCTION

One of the most important factors affecting phenol biodegradation by microorganisms is temperature [1,2]. Due to their small size, nearly all microorganisms suffer instantly by the environmental temperature, which is they are ectothermic. Consequently, temperature influences bacterial adaptation and physiology to the new temperature they are exposed to and this takes place by means of modulation of their inner biochemical pathway. Consequently, temperature is the one thing which needs to be taken into consideration whenever researching biodegradation of xenobiotics.

For modelling and design purposes, the effect of temperature to the maximum growth rate of bacteria on substrates is often described by the Arrhenius function. Currently, a proposed theory being brought forward is the universal temperature dependence theory or UTD. This theory attempts to ascribe a limited range of E_a values (Arrhenius activation energy) of between 57.9 and 67.5 kJ mol/l for all metabolic activities. The range when translated into Q_{10} values is equal to the range of between 2.3 and 2.7. However, there is an intense debate regarding the adoption of this range [3–5] as works on the biodegradation of hydrocarbon have shown that less than 20% of reported Q_{10} values fall within this range [5].

Biological reactions usually exhibit Q_{10} values ranging from 2 to 3 [6]. As a rule of thumb, for every 10 °C rise in temperature, the reaction rates will double, resulting in an expected Q_{10} value of 2. A Q_{10} value of less than 2 suggests that the rates at the particular temperature studied are higher than predicted by the Q_{10} equation.

In this work, the values of the Q_{10} for the phenol biodegradation by *Pseudomonas* sp. AQ5-04 are presented for the first time. The values obtained, especially the Q_{10} value, shows that this bacterium is a very efficient phenol-degrading bacterium and hence, can be a potential bioremediation agent.

MATERIALS AND METHODS

Determination of the specific growth rates on phenol at various temperatures

Growth kinetics was studied using a batch culture of the bacterium *Pseudomonas sp. AQ5-04* grown in MSM with phenol supplemented at 500 mg/L (**published elsewhere**). The initial inoculum of the bacterium was standardized at an OD_{600} nm of 0.1. The maximum specific growth rate of the bacterium, μ_m, to be utilised in the calculation for estimation of Q_{10} was calculated using the modified Gompertz model [7–9] instead of the commonly linearized form as follows;

$$y = A\exp\left\{-\exp\left[\frac{\mu_m e}{A}(\lambda - t) + 1\right]\right\}$$ [**Eqn.** 1]

The effect of bacterial growth rate on phenol can be modelled according to the Arrhenius equation [10] as follows,

$$\mu = Ae^{-\frac{E_a}{RT}}$$ [**Eqn.** 2]

Where R (8.314 J mol^{-1}K^{-1}) is the universal gas constant, T (Kelvins or K = ^{o}C + 273.15) is the absolute temperature, E_a (kJ mol^{-1}) is the activation energy and A has a physical meaning in that it signifies the rate constant of which all of the participating molecules possess sufficient energy before reaction can occur (Ea= 0). The linearized form the equation is obtained by plotting the normal logarithms of the growth rate against 1/T as follows;

$$\ln \mu = \ln A - \frac{E_a}{R}\cdot\frac{1}{T}$$ [**Eqn.** 3]

Estimation of Q_{10} coefficient

The temperature dependence of phenol-degrading is often reported using the Q_{10} value. By definition, the value represents the number of times a 10 ^{o}C change in temperature changes the reaction rate of the said reaction. The Q_{10} value and the activation energy can be related through the following equation;

$$Q_{10} = e^{\left(\frac{Ea}{R}\right)\left(\frac{10}{T_2 T_1}\right)}$$ [**Eqn.** 4]

And upon rearrangement,

$$\ln Q_{10} = \left(\frac{E_a}{R}\right)\left(\frac{1}{T_1 T_2}\right)$$ [**Eqn.** 5]

Another important biological constant is the temperature coefficient or theta (Θ) value. This is also called the simplified Arrhenius temperature coefficient Substitution of the obtained values into the reaction rates equation governed by the Q10 rule;

$k_T = k_{20}\Theta^{(T-20)}$ [**Eqn.** 6]

RESULTS AND DICUSSION

The Q_{10} values can be determined from the Arrhenius plots or either as the ratio of growth rates measured at incubation temperatures at ten degrees difference [11]. In the first case, the growth rate or biodegradation rates in logarithmic value is plotted against 1000/temperature (Kelvin) and the slope of the Arrhenius curve is the value of the Ea (**Fig. 1**). Conversion of Q_{10} from Ea value is then calculated according to **Eqn. 1**. The value obtained in this work was 1.834, which is slightly lower than the normal range of between 2 and 3 for the biodegradation rates of hydrocarbon for comparative purposes. However, Q_{10} values for a the biodegradation of a similar xenobiotic; hydrocarbon, has been reported to range from 1.1 to 16.2 [5]. To date, Q_{10} value for the biodegradation of phenol is almost not reported.

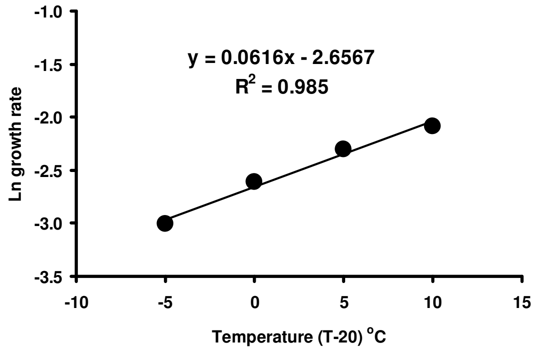

Fig. 1. A plot of growth rate vs temperature.

The Q_{10} value is valid for a range of temperature studied, and a biological process may have more than one Q_{10} values for different range of temperature studied. For example, the biodegradation of oil in a beach gravel column shows a Q_{10} value of 2.7 [12] while a bioventing study on soil contaminated with toluene and decane exhibits a Q_{10} value of 2.2 [13]. Another study on the effect of temperature on the biodegradability of petroleum by a bacterium showed a Q_{10} value of 2.2 [14].In the production of acrylamide by an immobilized bacterial system within the temperature range of 25-45 ^{o}C , a Q_{10} value of 2.8 was calculated for the free and immobilized cells system [15]. In general, lower temperature conditions increase the Q10 value [16,17].

The Q10 value of is within the range of biological activities and its value is less reported for growth on phenol, but the value is important in assigning the growth process to a typical biological activity.

CONCLUSION

Temperature effects growth and biodegradation rates of microorganism on substrates. The small size of a microorganism especially bacterium makes it susceptible to change of the surrounding temperature. In this work, the Q10 value for the biodegradation of phenol showed that is slightly lower in value than the normal reported range. The value obtained indicates that the bacterium

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