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Full Length Research Paper

Biosorption of Foron turquoise SBLN using mixed biomass of white rot fungi from synthetic effluents

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In the present study, biosorption of Foron turquoise SBLN using mixed biomass of white rot fungi was investigated in batch mode. The effect of process parameters such as pH of solution, medium temperature, biosorbent concentration, dye initial concentration, contact time etc. was investigated for enhanced removal of the dye. Maximum dye removal was observed at pH 2, biosorbent dose, 0.1 g/100 ml and temperature 30°C. The equilibrium data were analyzed by commonly employed Langmuir and Freundlich isotherm equations. The results show that the equilibrium data were better described by Freundlich isotherm model as compared to Langmuir equation. The biosorption kinetic data were found to follow the pseudo-second-order model. The results therefore indicated that mixed biomass of white-rot fungi could be used as natural biosorbent to remove dyes from aqueous effluents.

Key words: Biosorption, disperse dye, *Ganoderma lucidum*, *Coriolus versicolor*.

INTRODUCTION

Different industries utilize large quantity of water and organic chemicals such as dyes. Synthetic dyes have increasingly been used in textile and dyeing industries because of their ease and cost-effectiveness in synthesis, high stability of light, temperature and microbial attack (Deniz and Karaman, 2011). Dyes are complex organic compounds having diverse structure. There is a great difference in the chemical structure and toxicity of these compounds (Safa and Bhatti, 2010). More than 10,000 different dyes and pigments are being synthesized worldwide and during their application in industries, 10 to 15% of these dyes are released in wastewater (Deveci et al., 2004). Mostly synthetic dyes are used in different industries and due to complex aromatic molecular structures of these dyes they are highly stable and not easily biodegradable (Asgher et al., 2009). There are three types of dyes: cationic, anionic and nonionic based on their ionic structures. The wastewater released from the textile industries contains dyes and other pollutants and the presence of organic as well as inorganic pollutants in textile effluents create dangerous environmental problems (Eftekhari et al., 2010). Hence, these dyes must be removed from industrial wastewater before it is discharge into rivers.

Different methods used for wastewater treatment are coagulation, chemical oxidation, photo catalysis, electro-chemical, adsorption techniques and biological methods (Akar et al., 2006; Bibi et al., 2009). In the 17th century, the adsorption phenomenon was discovered when it was observed that gases can be adsorbed on porous materials. Later the same phenomenon was observed for solutions (Fernandes et al., 2007). Activated carbon is an effective adsorbent for dyes and has been widely used in wastewater treatment for its large specific surface area and high load capacities. However, this adsorbent has been limited in practice because of problems with its disposal (Xiong et al., 2010). Desorption process can also be carried out in order to recover the adsorbed dye/metals (Almeida et al., 2004). In addition, biosorption has been extensively applied for the treatment of industrial wastewater containing different pollutants (Fernandes et al., 2007). Recently, researchers have used various wastes, like low-cost agro-wastes (Akar et al., 2009), *Citrus sinensis* (Asgher and Bhatti, 2010), fermentation waste (Vijayaraghavan and Yun, 2007) and *Mentha arvensis* biomass (Hanif et al., 2009) for biosorption of pollutants.

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Biosorption is the process in which solutes are attached to the biomass and in biosorption no metabolic energy or transport is involved. Biosorption takes place in both living and dead biomass (Tobin et al., 1994). Extensive research work has been done to investigate the capability of fungi for the removal of dyes from wastewater (Azmi et al., 1998; Coulibaly et al., 2003; Bhatti et al., 2008). So far, fungi have been proven to be better organisms for the dye removal from industrial effluents (Asgher et al., 2009). In industrial fermentation processes, waste fungal biomass is obtained as a side product and it can be used as biosorbent (Gazso, 2001). In the cell wall of fungi, different groups are present which are responsible for binding dye molecules. These groups include amino, carboxyl and thiol (Bayramoglu et al., 2006). Biosorption of dyes on the cell wall is a rapid process and it mostly completes within few hours (Mou et al., 1991). This paper reports the ability of dead biomasses of white rot fungi (*Ganoderma lucidum* and *Coriolus versicolor*) to remove Foron Turquoise SBLN from aqueous solution.

MATERIALS AND METHODS

Chemicals and reagents

All the reagents and chemicals were of analytical-laboratory grade and mainly purchased from Sigma-Aldrich Chemical Co. USA. Disperse textile dye Foron Turquoise SBLN was a gift by Clariant Pakistan (Pvt) Limited, Canal Road, Faisalabad.

Batch biosorption study

Two white rot fungi *G. lucidum* and *C. versicolor* were obtained from Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan. The fungi culture was grown on dextrose agar medium. The slants were incubated at 30 ± 2°C for sporulation. The spore suspensions of *G. lucidum* and *C. versicolor* were obtained by filtering the inoculum of both fungi after autoclaving it. The spore suspensions were oven dried at 80°C for 24 h to get them dried. The first step was the cutting of dried biomass and then it was ground by food processor and sieved using Octagon siever. Appropriate size (0.255 mm) was used in the sorption studies. 1 g of sieved mixed biomass was dissolved in 100 ml of 2% sodium alginate solution. The mixture was then reacted carefully with 0.1 M $CaCl_2$ to obtain the uniform sized beads of biomass. The immobilized mixed biomass was used in evaluation of all experimental parameters. In order to investigate the effect of various influencing parameters on the biosorption of Foron turquoise SBLN, different conditions of pH, temperature, biosorbent dose, dye concentration and contact time were studied as described elsewhere (Bhatti et al., 2010).

Analytical methods

The removal of dye by the fungal mixed biomass was checked by using a spectrophotometer (Hitachi-2001, Japan). The λ_{max} value of the dyes was 754 nm. The concentration difference method was used to calculate the biosorption capacity of biomass (Volesky and Holan, 1995). The initial dye concentration C_i (mg/g) and equilibrium dye concentrations C_e (mg/g) was determined by simple mass balance equation. The amount adsorbed q (mg dye adsorbed/gadsorbent) was determined using following Equation;

$$q = \frac{(C_i - C_e)}{W} \times V$$

Where, V is the volume of the solution in ml and W is the mass of the sorbent in g.

RESULTS AND DISCUSSION

Influence of pH

Influence of pH on the biosorption of Foron Turquoise SBLN onto dead mixed biomass of *G. lucidum* and *C. versicolor* was checked over a pH range from 1 to 9 (Figure 1). The results show that dye removal decreased with an increase in pH value. Maximum dye removal (16.44%) was observed at pH 2. After pH 2, a decrease in the dye removal was observed. The equilibrium sorption capacity decreased as the pH increased and it was minimum (0.85 mg/g) at pH 9. The interaction of dye molecules with positively charged fungal biomass took place at a lower pH, which resulted in an increase in biosorption capacity.

Bayramoglu et al. (2006) reported a similar trend for the removal of Reactive Blue 4 on the fungal biomass. Hu (1992) studied the sorption of different reactive dyes on the *Aeromonas* sp. biomass and observed maximum removal of dyes at pH 3.0. O'Mahony et al. (2002) reported maximum biosorption of different reactive dyes on *Rhizopus arrhizus* biomass at pH 2.0. Aksu and Tezer (2000) also studied the effect of initial pH on dried *R. arrhizus* binding of Remazol Black B and observed that maximum dye removal takes place at pH 2.0. In addition, Yang et al. (2011) also observed that maximum biosorption capacities in single system for AB 25 and AR 337 onto unmodified and CDAB-modified biosorbents was at pH 2.0 and then decreased as the pH increased.

Influence of temperature

The wastewater released by textile industries has slightly high temperature; therefore temperature plays a significant role in biosorption of dyes from these effluents (Fu and Viraraghavan, 2001). The results of biosorption experiment performed at different temperatures showed that the biosorption of Foron Turquoise SBLN onto fungal mixed biomass was an exothermic process. Maximum dye removal (16.44%) was obtained at 30°C and then showed a decreasing trend with increase in the temperature (Figure 2). The equilibrium sorption capacity was minimum (0.55 mg/g) at 70°C. Aksu and Tezer (2000) studied the sorption of Remazol Black B by *R. arrhizus* biomass and they also examined that 35°C was the optimum adsorption temperature, and with further increase in temperature the adsorption decreased.

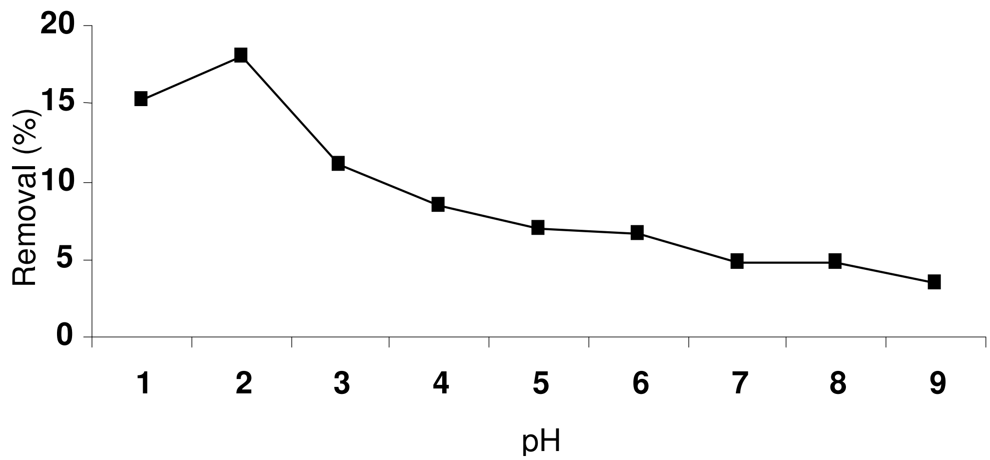

Figure 1. Effect of pH on biosorption of Foron Turquoise SBLN by *Ganoderma lucidum* and *Coriolus versicolor* biomass.

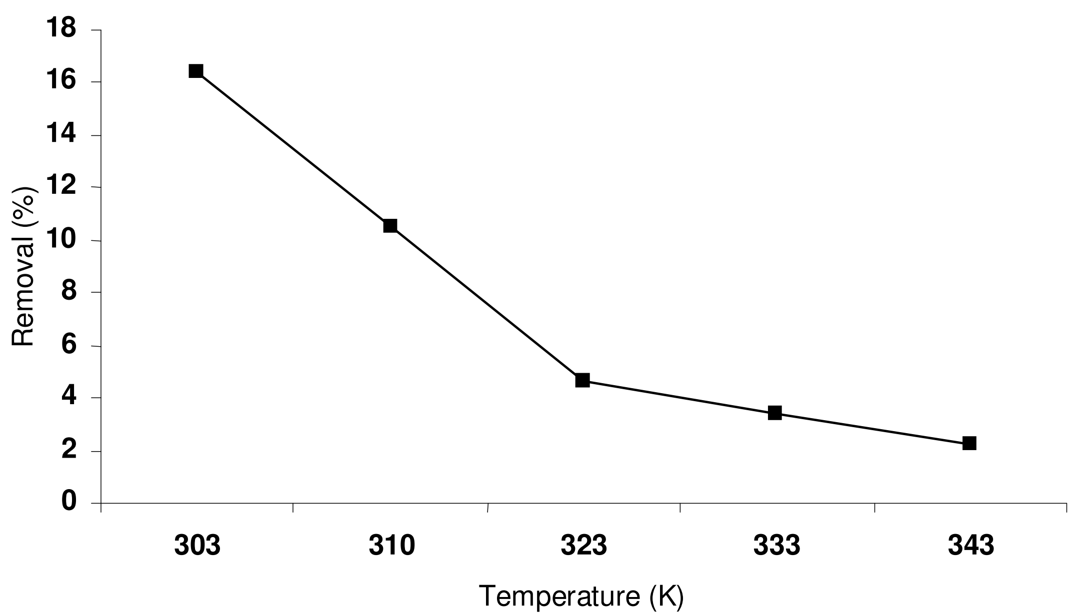

Figure 2. Effect of temperature on biosorption of Foron Turquoise SBLN by *G. lucidum* and *C. versicolor* biomass.

Influence of the dye concentration

The dye concentration has a significant effect on color removal efficiency of different biomasses hence; the adsorption process could also be improved by increasing the initial concentration of dye. The removal of dye by fungal biomass corresponding to initial dye concentrations (25 to 500 mg/L) is shown in Figure 3. An increase in dye adsorption at higher initial concentration was observed. The initial dye concentration therefore provided the driving force to overcome all mass transfer resistances of the dyes between the aqueous and solid phases (Aksu and Karabaylr, 2008).

Equilibrium modeling

Equilibrium data is modeled since it gives information for comparison among different biomasses under different operating procedures (Benguella and Benaissa, 2002). The sorption isotherm models which are commonly used for fitting the data are Freundlich and Langmuir isotherm models. These adsorption isotherms are used to investigate the relationship between adsorbed (q) and equilibrium concentrations (C_e). In order to get the equilibrium data, initial dye concentrations were varied keeping constant biomass. The results indicate that equilibrium data fitted well to the Freundlich model (Figure 4), as

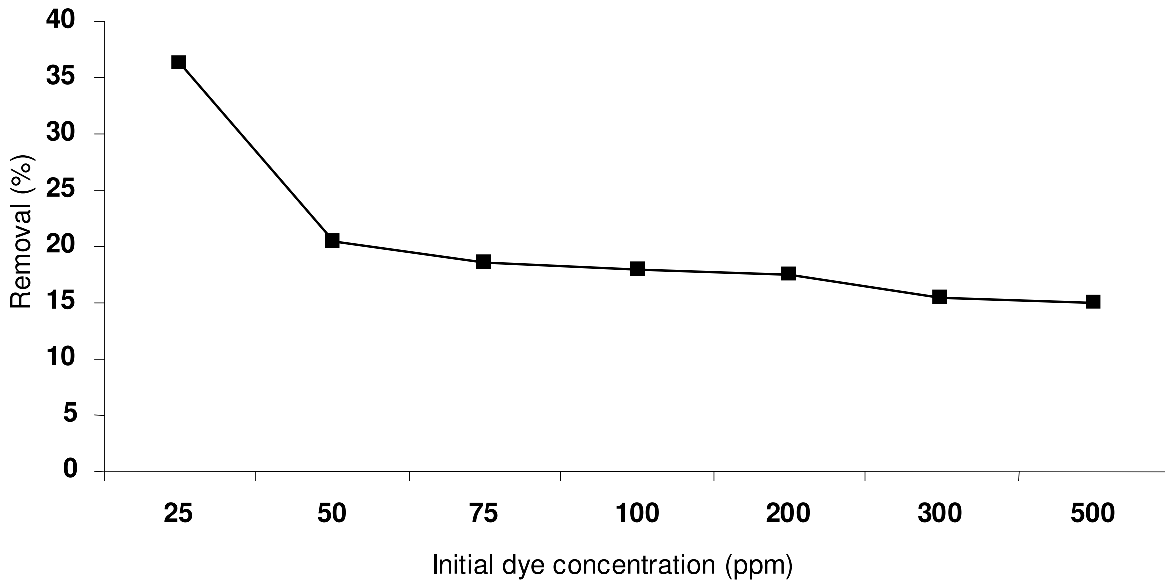

Figure 3. Effect of initial concentration of Foron Turquoise SBLN on the biosorption by *Ganoderma lucidum* and *Coriolus versicolor* biomass.

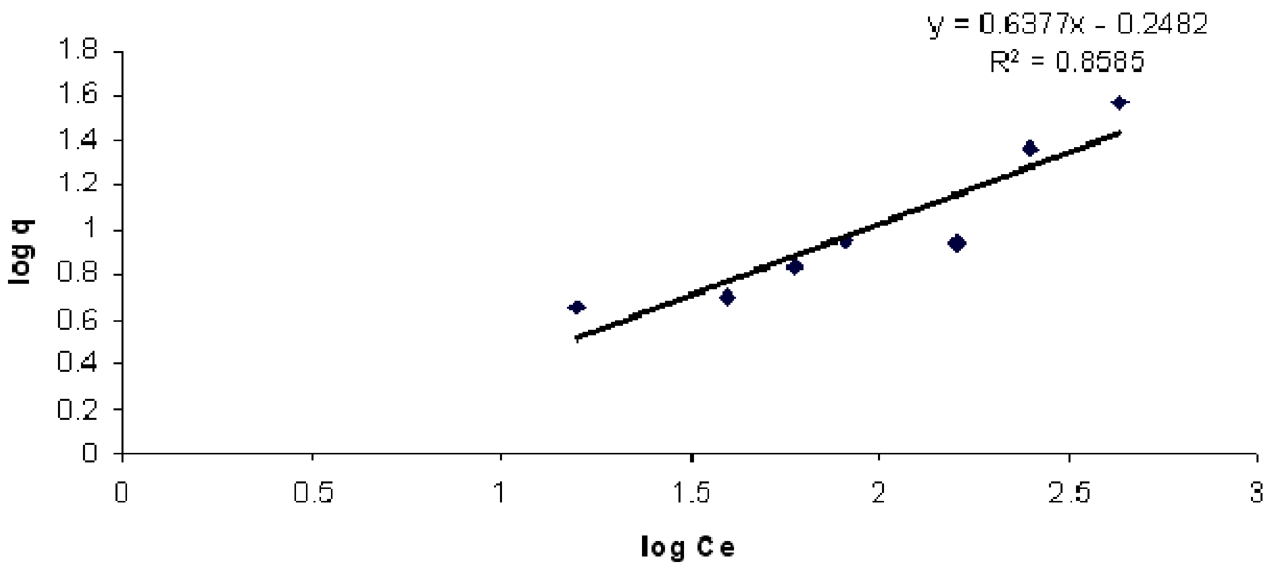

Figure 4. Freundlich adsorption isotherm for uptake of Foron Turquoise SBLN by *G. lucidum* and *C. versicolor* biomass.

compare to the Langmuir model due to high value of coefficient of determination. The fitting of data to Freundlich model suggested that adsorption of Foron Turquoise SBLN on fungal biomass was physical in nature.

Influence of biosorbent dosage

Biosorbent dose plays a very important role in the process of biosorption (Asgher and Bhatti, 2010). The effect of biosorbent doses (0.05 to 0.3 g/100 ml) on the biosorption of Foron Turquoise SBLN by fungal mixed biomass is represented in the Figure 5. The results demonstrate that dye removal increased with increase in bioosrbent dose up to 0.1 g, afterwards the dye removal decreased. The maximum dye removal (24.82%) was observed with 0.1 g biosorbent dose. It is suggested that when the biomass concentration is increased, the surface area increases resulting in the more availability of vacant biosorption sites and thus increasing the biosorption capacity (Gong et al., 2005). However, when the

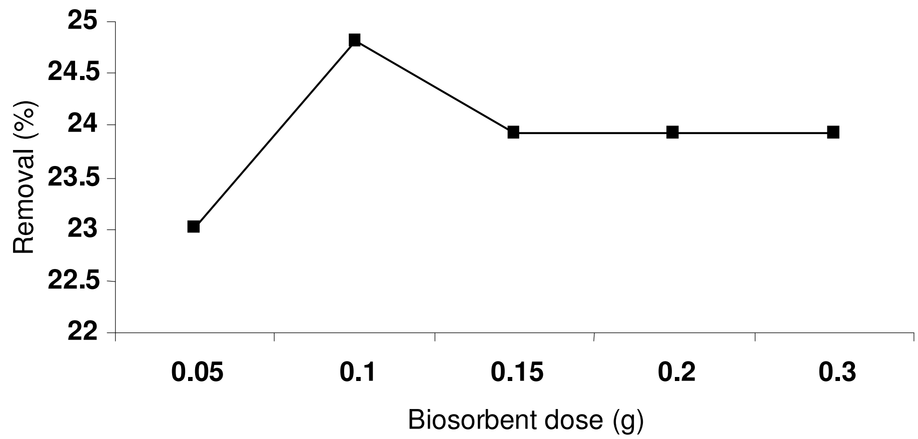

Figure 5. Biosorption of Foron Turquoise SBLN at different biosorbent doses by *G. lucidum* and *C. versicolor* biomass.

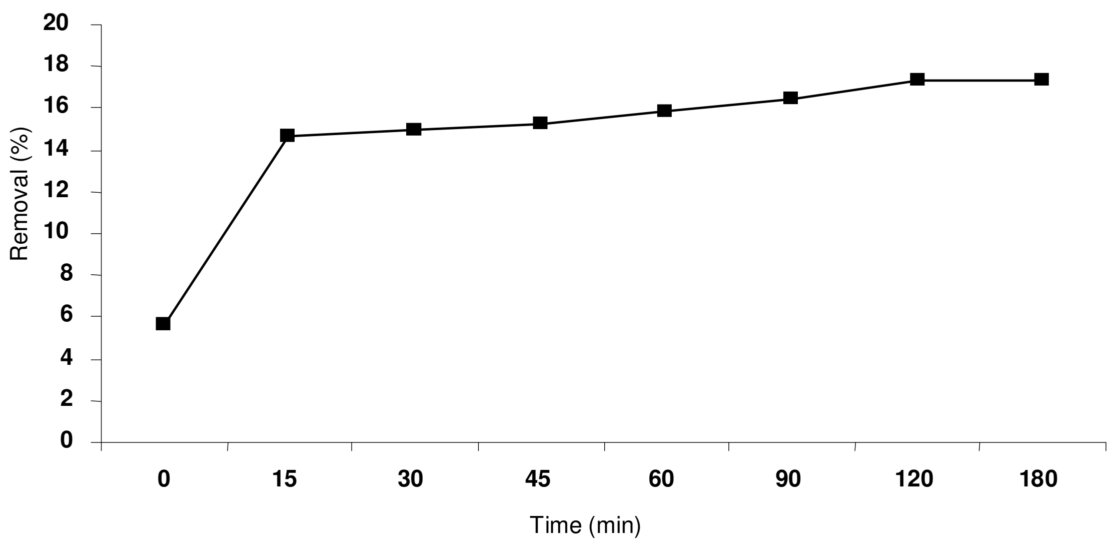

Figure 6. Effect of contact time on the biosorption of Foron Turquoise SBLN by *G. lucidum* and *C. versicolor* biomass.

biosorbent dose was further increased there was no effect on the dye removal due to unavailability of the vacant sites on biosorbent surface (Akkaya and Özer, 2005).

Influence of equilibrium time

The results regarding the effect of contact time on the removal of the dye are shown in Figure 6. The results show that during the initial stages of biosorption process the removal efficiency was very rapid followed by slow increase and finally reached to equilibrium. Optimum contact time for the biosorption of Foron Turquoise SBLN was found to be 120 min. Aksu and Isoglu (2006) investigated that 2 to 4 h contact was sufficient to achieve the equilibrium. Yasin et al. (2007) also reported similar results for the removal of methylene blue.

Biosorption kinetics

The kinetic study was performed at different time intervals by keeping dye and biosorbent concentration fixed. Kinetics of sorption by any adsorbent has been commonly tested by pseudo-first-order (Lagergren, 1898) and pseudo-second-order approach. In the present study, the coefficient of determination (R^2) for the pseudo-second-order-model (Ho et al., 2000) was higher in comparison to pseudo-first-order model, which showed that the kinetic data followed the pseudo-second-order model (Figure 7) and thus described the biosorption as

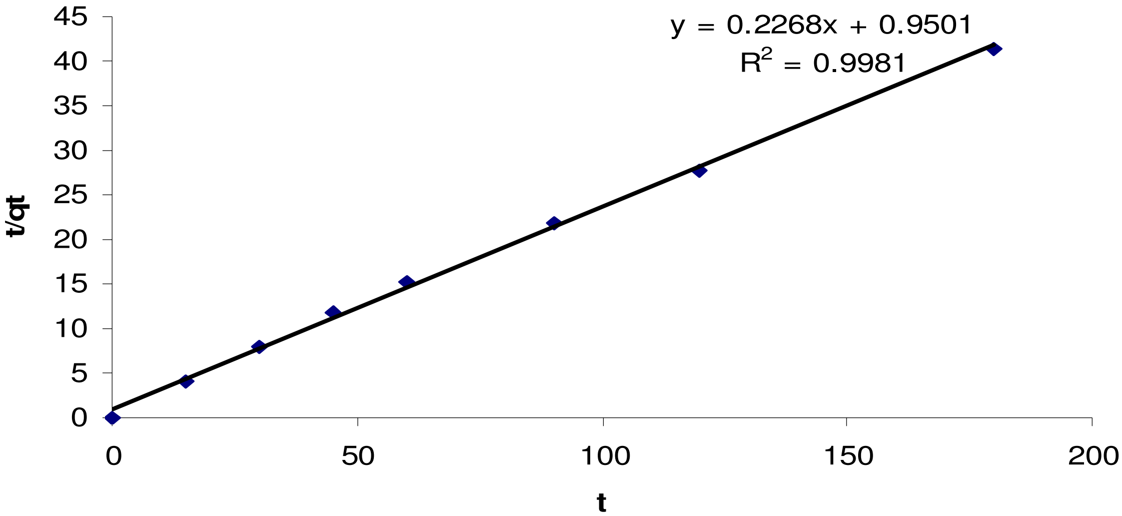

Figure 7. Pseudo 2nd order kinetic model for Foron Turquoise SBLN dye removal by *G. lucidum* and *C. versicolor* biomass.

the rate limiting step (Zubair et al., 2008). Asgher and Bhatti (2010) also investigated the mechanism of biosorption of reactive azo dyes on *C. sinensis* waste biomass and the results indicated that the experimental data followed the second-order kinetics.

Conclusion

Biosorption of Foron Turquoise SBLN on mixed biomass of white rot fungi was investigated in batch mode. The result reveals that biosorption of dye was affected by different process parameters such as pH of solution, medium temperature, adsorbent concentration, dye concentration and contact time. Results show that the equilibrium data were better described by Freundlich isotherm model. Moreover, the kinetic data followed the pseudo-second-order model. These results therefore demonstrated that mixed fungal biomass could be a potential source to remove dyes from synthetic effluents.

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