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Removal of colour from textile effluent by adsorption using banana stem and coffee husk: A Review

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Abstract:
Background*: The effluent from the textile industry is an important source of dye pollution. Many dyes and their break down products may be toxic for living organism. Therefore, decolourisation of dyes is an important aspect of wastewater treatment before discharge. The various colour removal methods being adopted commonly are coagulation, ultrafiltration, electrochemical adsorption and photo oxidation. Among these methods, adsorption is a widely used for removal of dyes from wastewater. A number of non-conventional low cost adsorbents used for dye removal, include fruit waste of Prosopisn juliflora, wood, waste orange peel, banana stem, maze cobs, barley husk, coffee husk, bagasse pith etc. This study explores the feasibility of banana stem and coffee husk as a natural adsorbent with respect to various parameters such as colour adsorbent capacity of material with initial concentration at different doses and contact time, and to optimize these parameters affecting the adsorption process.*
Materials and Methods*: In this study, banana stem and coffee husk is used.Waste banana stem and coffee husk were collected and their powder is prepared.The batch adsorption experiments are conducted to study optimum removal of colour from textile wastewater. The different doses (0.1 g, 0.2 g, 0.3 g, 0.4 g, 0.5 g) of adsorbents coffee husk and banana stem are taken for analysis. The contact time between the adsorbent and the effluent solution is taken as 20 min, 40 min, 60 min, 80 min, 100 min. The colour concentration is determined using UV-spectrophotometer.*
Results*: Banana stem and coffee husk are indeed viable, affordable adsorbent for the adsorptive removal of Brown R dye from textile wastewater with 80-85% dye removal.the optimum dosage was obtained as 0.1 gram in both the cases.The optimum time duration required for colour removal is 80 minutes forbanana stem and 60 minutes for coffee husk.*
Conclusion:*Banana stem and coffee husk are suitable and efficient adsorbent for removing Brown R from textile dye wastewater.These adsorbents could be employed as eco-friendly adsorbents as an alternative to overcome problems related to an excessive of colour in textile waste water.*
Key Word*: Adsorption, banana stem, colour removal, coffee husk.*

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I. Introduction

Water pollution due to the release of various toxic chemicals from industrialization and urbanization is a global problem. Among the various notorious toxic chemicals, dyes, metals, organics and pharmaceuticals are highly concerned [3]. Synthetic dyes are enormously used to impart colour to the substrates in the textile, plastics, pharmaceutical, paper, printing, rubber, leather, paint, cosmetic, food, pulp and paper industries [5]. Nowadays, with the rapid development of modern industries,the environmental contamination associated with the dyes present in wastewater of various industrial sections, such as dyeing, printing,textile, leather, and coating industries, has drawn much attention. It is estimated that more than 70,000 tonnes of dyes are discharged in effluent from textile and associated industries in the world every year [1]. The presence of dyes and pigments in water, even at very low concentrations, is highly visible and undesirable [2].

These dyes are primarily of synthetic origin and have complex aromatic structures, which make them more stable to light, heat and oxidizing agents, and are usually biologically non-degradable [2]. The discharge of dyes in the environment is worrying for both toxicological and esthetical reasons as dyes impede light penetration, damage the quality of the receiving streams and are toxic to food chain organisms [34]. Furthermore, presence of the dyes in aqueous ecosystems even at low concentrations diminishes photosynthetic phenomena by preventing light penetration thereby deteriorating the water quality, gas solubility and destroying aesthetic value of water [5]. Dyes can have acute and/or chronic effects on exposed organisms depending on the exposure time and dye concentration. Dyes can cause allergic dermatitis, skin irritation, cancer, mutation, etc. Dyes can be classified as: anionic (direct, acid and reactive dyes), cationic (basic dyes) and non-ionic (dispersive dyes) [6]. Anionic dyes are extensively used in dyeing process, but about 20–40% of these remain in the effluents [7].

Many treatment processes have been applied for the removal of dye from wastewater such as: Fenton processphoto/ferrioxalate system, photo-catalytic and electrochemical combined treatments, photo-catalytic degradation using UV/TiO2, sono-chemical degradation, Fenton-biological treatment scheme, biodegradation, photo-Fenton processes, integrated chemical–biological degradation ,electrochemical degradation, adsorption process, chemical coagulation/flocculation, ozonation, cloud point extraction,oxidation, nano-filtration, chemical precipitation, ion-exchange,reverse osmosis and ultra-filtration [6]. The adsorption process provides an attractive alternative for the treatment of dye-contaminated waters, especially if the sorbent is inexpensive. Natural materials from agriculture, having the ability to adsorb both acidic and basic dyes represent potentially more economical alternative sorbents [7]. Adsorption is widely used in the removal of refractory pollutants (including dye) from wastewaters. The major advantages of an adsorption treatment for the control of water pollution are less investment in terms ofinitial development cost, simple design, easy operation, and free from or less generation of toxic substances [8].

Agro-industrial waste, comprising of lingo-cellulosic biomass, is a readily available, effective, economical and eco-friendly alternative to activated carbon [9]. Agricultural bio-wastes like *Citrus Limetta* Peel (CLP), *Zea Mays* Cobs (ZMC) [30],coir pith [31], bamboo dust, coconut shell, groundnut shell, rice husk, and straw [17], papaya seeds [16], grass waste [13], teak leaf [14], avocado peel [32], pomelo (Citrus grandis) peel [20], jackfruit peel [19], palm kernel fibre [23], parsley stalks (PS), cucumber peels (CP), and watermelon seed hulls(WSH) [48] are continuously being explored for removal of dye from wastewaters due to their abundance, high carbonaceous contents (cellulose, lignin and hemicelluloses) and high affinity towards sequestering organic molecules. In addition agro-materials possess favorable chemical and physical qualities for dye adsorption, require few or no processing before use [5]. Coffee is the second most widely exported commodity in the world. It is estimated that 1 tonne of coffee generates > 600 kg of waste. This enormous amount of waste creates a disposal problem and environmental pollution [9]. Waste Coffee Husk (WCH) belongs to this category of agricultural by-products. WCH residue is the main by-product obtained from a coffee scrub, a cash crop that is cultivated in over 80 countries across the world. During processing of coffee beans, huge amounts of coffee husks are generated. It is estimated that 0.18 ton of the husks are generated per every ton of harvested coffee fruits [5]. Among the agricultural waste reported so far, the use of coffee husk for adsorptive removal of pollutants is not extensively explored [9]. Effort s to find an alternative technology to exploit Coffee husk in solving environmental mess is gainful given its abundance across the globe. In this study, the efficiency Coffee husk in the removal of dye was investigated and factors affecting batch adsorption process optimized.

Banana stem is an agriculture plant waste which is among the most popular fruit grown in Asia particularly India, Thailand, China, Indonesia, and Malaysia. A few tons per hectare of the banana stem has been estimated annually and this can lead to disposal issue. Several studies on activated banana stem and banana peel adsorbent have been conducted by the previous researchers. However, the study on agricultural waste using natural banana stem is still limited and need to be explored as an alternative to remove colour in textile wastewater [33]. One of the aim of this study was to investigate the potential use of banana stem as adsorbent media for the removal of colour from dye solution. The effect of various adsorbent dosage and contact time were evaluated.

The overall aim of this study is to check the feasibility of coffee husk and banana stem as a natural adsorbent and the effect of adsorbent dosage and contact time on adsorption.

II. Material And Methods

Preparation of adsorbents

Waste Coffee Husks were collected.Suspended impurities were removed through extensive washing with tap water then sun dried for four days. Dried husks were crushed into fine powder.Clean powder was dried in an oven at 60°C [5].The banana stem was washed using tap water to remove dirt. Then, it was cut into small particle size in the range of 5 - 7 cm. After that, the sample was dried in an oven for 105°C. Dried banana stem were powdered and for one and a half hour and crushed into fine powder. The banana stem powder obtained is used for experimental purposes.

Batch adsorption studies

Batch adsorption experiment was conducted to determine the adsorption capacity and removal efficiency of colour [33]. All the experiments were carried out at temperature 30◦C in batch mode [10]. Batch experiments were conducted in 500 mL Erlenmeyer flask and agitated at 600 rpm using magnetic stirrer until the equilibrium was reached at 25°C [5]. The batch adsorption experiments were performed for a wide range of contact time (20, 40, 60, 80 and 100 min) and adsorbent dosage (0.1, 0.2, 0.3, 0.4 and 0.5 gram) [4]. Dye adsorbed per unit mass of the adsorbent q_e (mg/g) and the extent of adsorption (%) was calculated using Eq.;

$q_e = \frac{V(Co - Ce)}{W}$

Where Coand Ceare the initial and the equilibrium CV dye concentrations (mg/l), Vis the volume of solution (L) and Wis the amount of WCH used (g). Percentage dye removal (%) was calculated using Eq.;

$$\% \text{ dye removal} = \frac{Co - Ce}{Co} \times 100$$

III. Result

Factors affecting adsorption

Effect of adsorbent dosage

Adsorbent efficiency in treatment of polluted wastewaters mainly depends on the number of active adsorption sites available on adsorbent. The amount of adsorbent used in adsorption is particularly important because it determines the sorbent–sorbate equilibrium in the system and can also be used to predict the treatment cost of adsorbent per unit of dye solution [11]. The influence of adsorbent dose on adsorption of dyes was investigated using dye concentrations of WCH and banana stem dose ranging from 0.1 g to 0.5 g.

150 ml of the textile effluent sample is taken in five beakers. Initial pH of the sample that is the textile effluent was 11.84. Initial absorbance of all samples are taken using uv-spectrophotometer. Absorbent (banana stem and coffee husk separately) is added at dosages 0.1g, 0.2g, 0.3g, 0.4g and 0.5g and stirred using magnetic stirrer for 10 minutes. Final absorbance is also taken using uv-spectrophotometer. Initial and final absorbance of samples using banana stem and coffee husk as adsorbent are given in Table no1 and Table no2 respectively.

Table no1 : Showsinitial and final absorbance of samples using banana stem powder as adsorbent.

Adsorbent dosage (g)	Initial absorbance	Final absorbance
0.1	3.15	0.440
0.2	3.15	0.509
0.3	3.15	0.552
0.4	3.15	0.557
0.5	3.15	0.889

Table no2 : Showsinitial and final absorbance of samples using coffee husk powder as adsorbent.

Adsorbent dosage(g)	Initial absorbance	Final absorbance
0.1	3.15	0.501
0.2	3.15	0.682
0.3	3.15	0.721
0.4	3.15	0.934
0.5	3.15	1.180

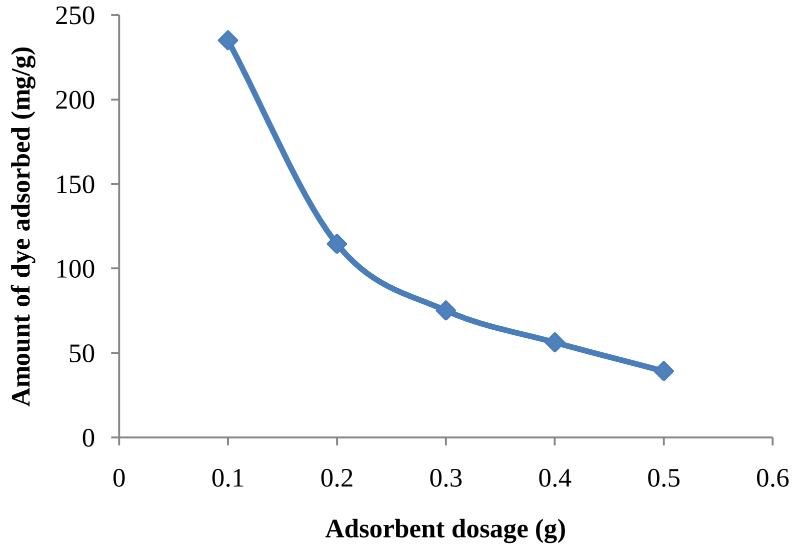

Fig no1: Shows effectof adsorbent dosage on dye removal using banana stem as adsorbent.

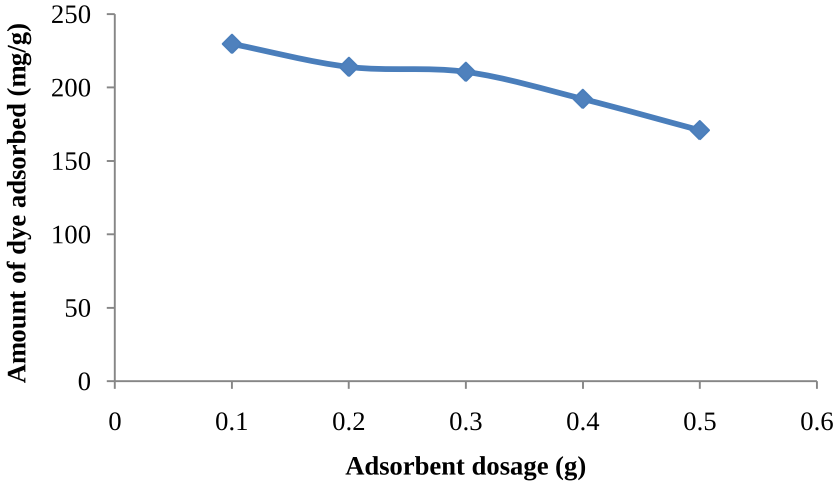

Fig no2: Showseffectof adsorbent dosage on dye removal using coffee husk as adsorbent.

The experimental results shows that as the dosage of the adsorbent increases time needed to attain equilibrium decreased when high doses were employed.This may be attributed to overlapping or aggregation of adsorption sites resulting in a decrease in the total adsorption surface area available to the dye [5].The optimum dosage was obtained as 0.1gram in both the cases i.e.,using adsorbent as banana stem and coffee husk powder (Fig no1 and Fig no2 respectively).The result shows that available surface sites for small dosages were sufficiently covered by dye molecules in solution [5].

Effect of contact time

The period of contact between the bio-sorbent and bio-sorbate is crucial in costing when designing a bio-sorption system for large scale application in an industry.Generally, dye uptake increased with increase in time [5]. At somepoint in time, reached a constant value where no more dye was removed from the solution. At this point, the amount of dye being adsorbed onto the material was in a state of dynamic equilibrium with the amount of dye desorbed from the adsorbent. The time required to attain this state of equilibrium was termed the equilibrium time (t_e in min) and the amount of dye adsorbed at t_e reflected the maximum dye adsorption capacity of the adsorbent [12]. The rate of dye removal was studied by varying the contact time from 20 min to 100 min.

150 ml of the textile effluent sample is taken in 5 beakers. Initial pH of textile effluent sample was 11.84. Initial absorbance of all samples are taken using uv-spectrophotometer. Absorbent is added at optimum dosage and stirred using magnetic stirrer. The contact time is changed from 20 to 100 minutes ie., 20, 40, 60, 80 and 100 minutes. Final absorbance is also taken using uv-spectrophotometer. Initial and final absorbance of samples using banana stem and coffee husk as adsorbent are given in Table no3 and Table no4 respectively.

Table no3 : Shows initial and final absorbance of samples using banana stem powder as adsorbent.

Contact time (min)	Initial absorbance	Final absorbance
20	3.15	0.464
40	3.15	0.443
60	3.15	0.432
80	3.15	0.409
100	3.15	0.410

Table no4 : Shows initial and final absorbance of samples using coffee husk powder as adsorbent.

Contact time (min)	Initial absorbance	Final absorbance
20	3.15	0.690
40	3.15	0.672
60	3.15	0.561
80	3.15	0.572
100	3.15	0.590

To study the effect of time on efficient removal of colour from textile waste the study was done. It is clear from the results that time plays an important role is colour removal for coffee husk and banana stem. The optimum time duration required for colour removal is 80 minutes for banana stem and 60 minutes for coffee husk (Fig no3 and Fig no4 respectively). As contact time increases, dye uptakes increases initially, and then it reaches optimum value and then decreases. This trend in dye uptake may be due to the fact that, initially, all adsorbent sites were vacant and the solute concentration was high. After some period, dye uptake decrease was observed because there were few surface active sites on the cell wall of coffee husk and banana stem powder [3].

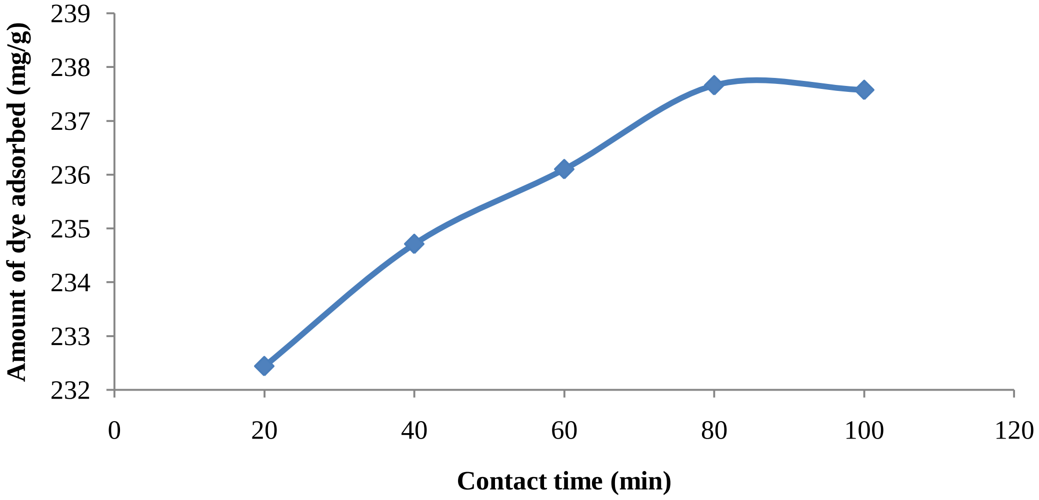

Fig no3: Showseffect of contact time on dye removal using banana stem as adsorbent.

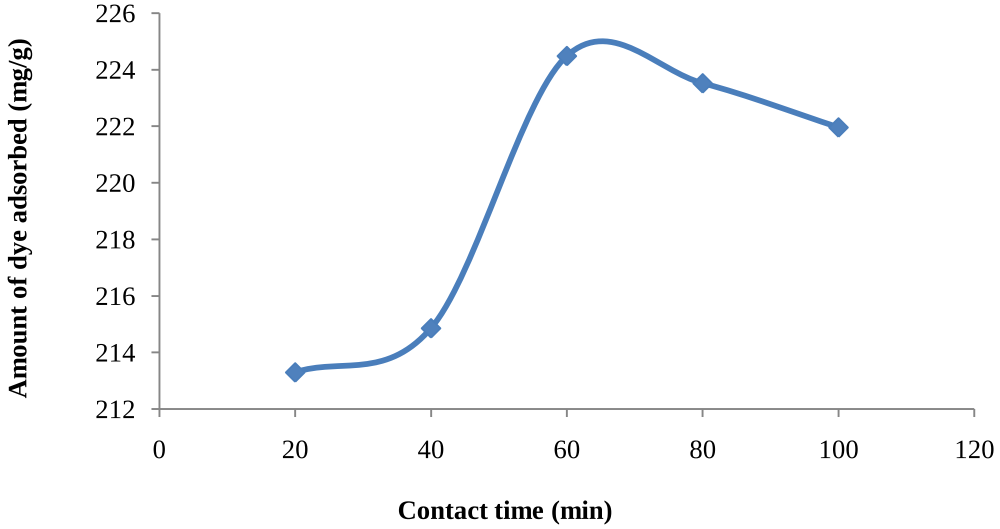

Fig no4 : Showseffect of contact time on dye removal using coffee husk as adsorbent

Adsorption isotherm

The adsorption isotherm indicates how the adsorption molecules are distributed between the liquid phase and the solid phase when the adsorption process reaches an equilibrium state. The analysis of the isotherm data by fitting them to different isotherm models is an important step to find a suitable model that can be used for design purposes [34]. It is widely used to elucidate the relationship between the amount of dye adsorbed at constant temperature and its concentration in equilibrium solution. It is an important tool of both theoretical and practical point of view [35]. The parameters obtained from the different models provide important information on the sorption mechanisms, the surface properties and affinities of the sorbent. Equilibrium data can be expressed by several equations, such as the Langmuir, Freundlich, Koble-Corrigan, Redlich- Peterson, Tempkin, Dubinin-Radushkevich and generalized isotherm equations and the applicability of isotherm equations is compared by judging the correlation coefficients [36].

Langmuir isotherm

The Langmuir isotherm is a mechanistic model which is based on the assumption that adsorption occurs over a uniform adsorbent surface by a monolayer of adsorbed material at a constant temperature (in a liquid, such as dye) and the distribution of the compound between the two phases is controlled by the constant equilibrium. The Langmuir equation is expressed as Eq.;

$$q_e = \frac{Q_m K_L C_e}{(1 + K_L C_e)}$$

The linear expression of the Langmuir isotherm equation is given as Eq.;

$$\frac{Ce}{q_e} = \frac{1}{Q_m} C_e + \frac{1}{Q_m K_L}$$

Where C_e (mg/L) is the equilibrium concentration of the dye and q_e (mg/g) is the amount of dye adsorbed per unit mass of adsorbent. Q_m (mg/g) and K_L (L/mg) are Langmuir constants related to adsorption capacity and the affinity of the binding sites, respectively.

The essential characteristics of the Langmuir isotherm can be expressed in terms of a dimensionless equilibrium parameter (R_L), defined as given in Eq.;

$$R_L = \frac{1}{1 + K_L C_o}$$

Where C_o (mg/L) is the initial solute concentration of dye and K_L (L/mg) is the Langmuir constant described above. There are four probabilities for the RL value: favourable adsorption ($0 < R_L < 1$), unfavourable adsorption ($R_L > 1$), linear adsorption ($R_L = 1$) or irreversible adsorption ($R_L = 0$) [37].

Fig no5, Fig no6 represent plot of $1/q_e$ versus $1/C_e$ for the adsorption of Brown R onto coffee husk and banana stem respectively, and the correspondent Langmuir isotherm constants are tabulated in Table no5. R_L =0 in both the cases indicates that the adsorption is irreversible. The experimental data showed a good fit to Langmuir model with correlation coefficient R^2 = 0.958 and R^2 = 0.832 indicating that the model was appropriate to describe the adsorption process of Brown R onto banana stem and coffee husk.

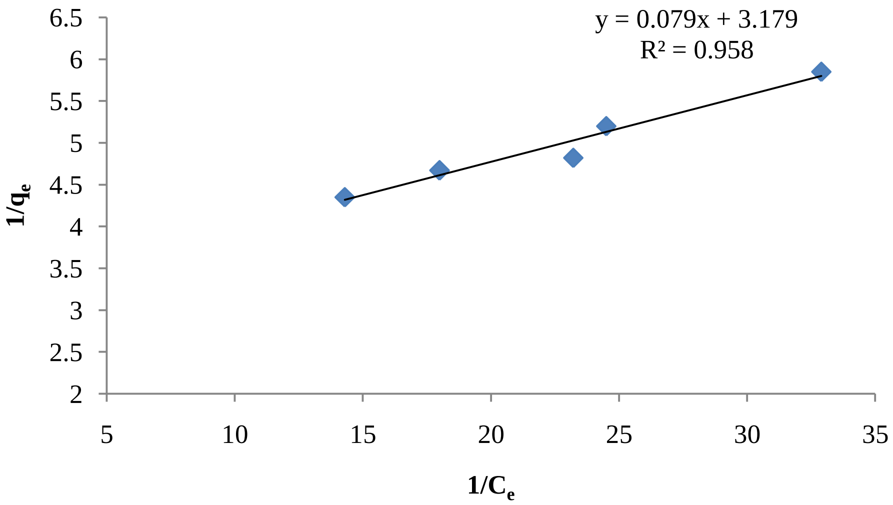

Fig no5 : ShowsLangmuir Isotherm plot for Brown R adsorption on coffee husk.

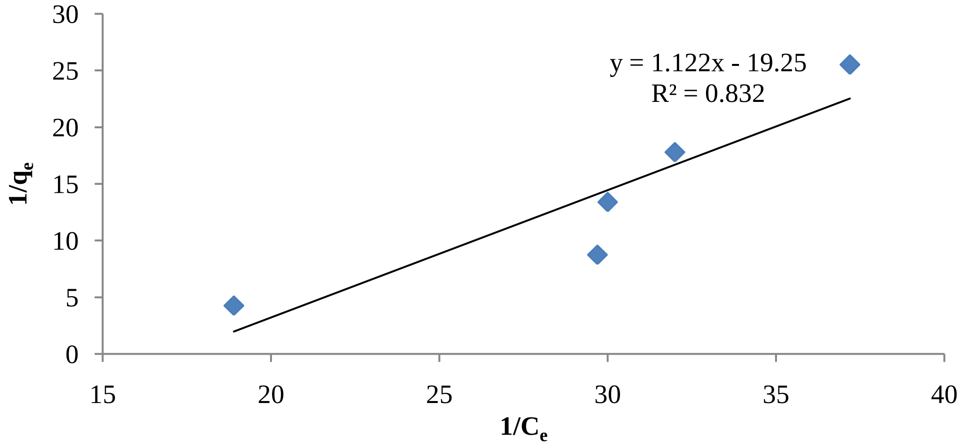

Fig no6 : ShowsLangmuir Isotherm plot for Brown R adsorption on banana stem.

Table no5 : ShowsLangmuir isotherm constants for adsorption of Brown R.

Langmuir Isotherm constants	Banana stem	Coffee husk
q_0	1.122	0.079
b	-19.25	3.179
R_L	0 (irreversible)	0 (irreversible)

Freundlich isotherm

The Freundlich isotherm endorses the heterogeneity of the surface and assumes that the adsorption occurs at sites with different energies of adsorption. The energy of adsorption varies as a function of the surface coverage. A mathematical expression of Freundlich isotherm was as follows:

$$q_e = K_F C_e^{1/n}$$

Where K_F (L/mg) is Freundlich constant and n is the heterogeneity factor. The K_F value is related to the adsorption capacity; while the 1/n value is related to the adsorption intensity. 1/n values indicate the type of isotherm to be irreversible (1/n =0), favorable (0<1/n< 1), unfavourable (1/n> 1) [38].

The linear form of Freundlich equation is given by Eq.;

$$\log q_e = \log K_F + \frac{1}{n}\log C_e$$

Fig no7, Fig no8 shows a plot of log q_e versus log C_e for the adsorption of Brown R onto banana stem and coffee husk respectively, and the corresponding Freundlich isotherm constants summarized in Table no6 .

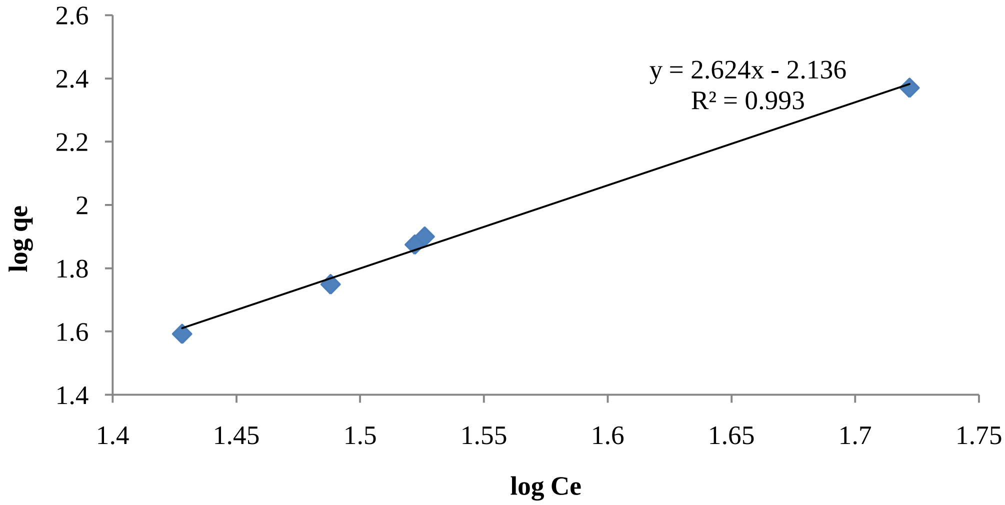

Fig no7 : ShowsFreundlich Isotherm plot for Brown R adsorption on banana stem.

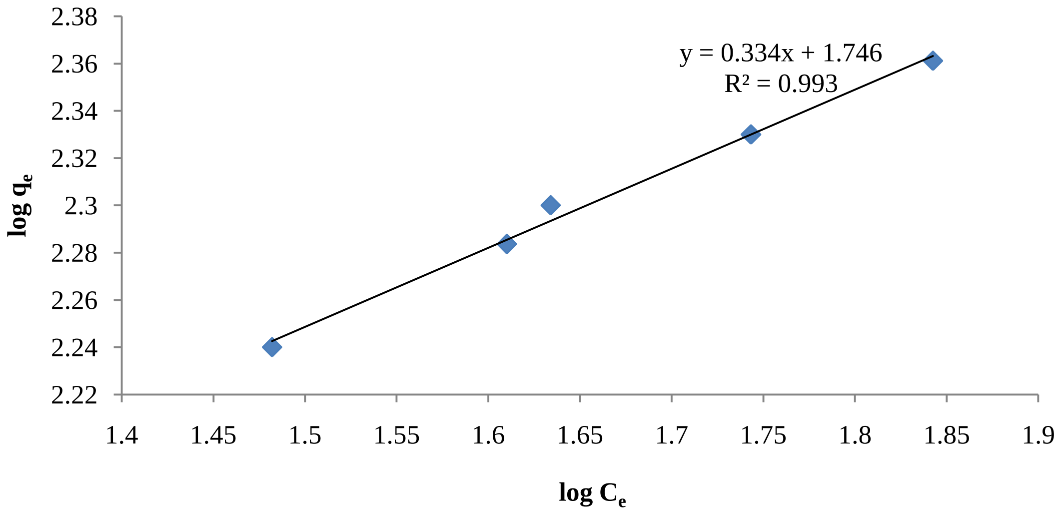

Fig no8 : ShowsFreundlich Isotherm plot for Brown R adsorption on coffee husk.

Table no5 : ShowsFreundlich isotherm constants for adsorption of Brown R.

Freundlich Isotherm constants	Banana stem	Coffee husk
K_F	-2.136	1.746
n	2.624 (favourable)	0.334
R^2	0.993	0.993

The results suggest that Brown R dye was favourably adsorbed by banana stem with high values of the correlation coefficient ($R^2 = 0.993$) indicate that the Freundlich isotherm has been best fitted for the adsorption of Brown R dye on banana stem and also for coffee husk ($R^2 = 0.993$) .

IV. Discussion

The study revealed that banana stem and coffee husk are indeed viable, affordable adsorbent for the adsorptive removal of Brown R dye from textile wastewater with 80-85% dye removal.

Batch studies consideration of operating conditions such as contact time and adsorbent dosage showed varied influence on adsorption process. The experimental results shows that as the dosage of the adsorbent increases the adsorption capacity decreases and the optimum dosage was obtained as 0.1 gram in both the cases ie., using adsorbent as coffee husk and banana stem powder. The optimum time duration required for colour removal was 80 minutes for banana stem and 60 minutes for coffee husk. It was also observed that the maximum dye uptake was obtained when the pH is in the acidic range is., pH=3. Among these adsorbents banana stem has relatively max dye adsorption compared to coffee husk. This study found that the adsorption process of colour fitted to the Freundlich isotherm model rather than Langmuir isotherm model. The correlation coefficient for Freundlich isotherm model was obtained as $R^2 = 0.9936$ for banana stem and $R^2=0.9932$ for coffee husk. In the case of Langmuir isotherm separation factor R_L is obtained as zero in both the cases which indicates that the adsorption process is irreversible. Langmuir isotherm plot is fitted for coffee husk with correlation coefficient $R^2 = 0.9583$. These findings demonstrated that banana stem and coffee husk are suitable and efficient adsorbent for removing Brown R from textile dye wastewater.

V. Conclusion

Thus, the present study concludes that these adsorbents could be employed as eco-friendly adsorbents as an alternative to overcome problems related to an excessive of colour in textile wastewater.

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