ADSORPTION OF NATURAL DYE ON BAMBOO YARN

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ABSTRACT

Long-established usage of synthetic dye causes detrimental effects not only to the environment but to human as well as these synthetic dyes are often non-biodegradable and have high toxic content. Consequently, various researches are being conducted on the extraction of natural dye and its application in textile industries, indicating that natural dye serves as a feasible alternative to synthetic dye. Usage of natural dye not only has caught the attention of textile industries but also material scientist and engineers long ago. In this current study, pitaya peel and turmeric have been selected as the sources for natural dye. Experiments will be conducted to determine the adsorption level using spectrophotometer aided with several calculations for maximum adsorption using adsorption isotherm. The process of solvent extraction using water as solvent is applied in this study to extract the dye from the pitaya peel and turmeric. The usage of mordant is also needed here to ensure the dye fast on the bamboo yarn. The concentration of total betacyanin and curcumin was measured by using a UV-Vis spectrophotometer and was also used as a measure of the degree of extraction. The rate of adsorption is studied by using different concentrations of dye extracted by using the dilution method. Three major parameters studied in this research includes the rate of adsorption on bamboo yarn using varied dye concentrations, length of time required for the process of adsorption on bamboo yarn and effectiveness of adsorption on bamboo yarn. Result obtained from this study shows that the rate of adsorption increases as the concentration of dye increases. Also, the time required for the process of adsorption on bamboo yarn increases in the same pattern due to the potential of bamboo yarn to adsorb the dye but decreases once the equilibrium time has been reached.

Key words: natural dye, adsorption, pitaya, turmeric, bamboo yarn

ABSTRAK

Penggunaan lama wujud pewarna sintetik menyebabkan kesan memudaratkan bukan sahaja kepada alam sekitar tetapi untuk manusia dan juga pewarna sintetik sering tidak terbiodegradasi dan mempunyai kandungan toksik yang tinggi . Oleh itu , pelbagai kajian sedang dijalankan ke atas pengekstrakan pewarna semula jadi dan aplikasinya dalam industri tekstil , yang menunjukkan bahawa pewarna semula jadi berfungsi sebagai alternatif untuk dilaksanakan pewarna sintetik . Penggunaan pewarna semula jadi bukan sahaja telah menarik perhatian industri tekstil tetapi juga ahli sains dan jurutera bahan lama dahulu . Dalam kajian ini semasa , kulit pitaya dan kunyit telah dipilih sebagai sumber untuk pewarna semulajadi . Eksperimen akan dijalankan untuk menentukan tahap penjerapan menggunakan spektrofotometer dibantu dengan beberapa pengiraan untuk penjerapan maksimum menggunakan penjerapan isoterma . Proses pengekstrakan pelarut menggunakan air sebagai pelarut digunakan dalam kajian ini untuk mengekstrak pewarna daripada kulit pitaya dan kunyit . Penggunaan pedas juga diperlukan di sini untuk memastikan pewarna puasa pada benang buluh . Kepekatan jumlah betacyanin dan curcumin telah diukur dengan menggunakan spektrofotometer UV - Vis dan juga digunakan sebagai ukuran tahap pengekstrakan .Kadar penjerapan dikaji dengan menggunakan kepekatan yang berbeza pewarna diekstrak dengan menggunakan kaedah pencairan. Tiga parameter utama yang dikaji dalam kajian ini termasuk kadar penjerapan pada benang buluh menggunakan kepekatan pewarna pelbagai, tempoh masa yang diperlukan untuk proses penjerapan pada benang buluh dan keberkesanan penjerapan pada benang buluh . Keputusan yang diperolehi daripada kajian ini menunjukkan bahawa kadar penjerapan bertambah apabila kepekatan bertambah pewarna .Juga , masa yang diperlukan untuk proses penjerapan kenaikan benang buluh dalam corak yang sama kerana potensi benang buluh untuk menjerap pewarna tetapi berkurangan sekali masa keseimbangan telah dicapai.

Kata kunci: pewarna semula jadi , penjerapan , pitaya , kunyit , benang buluh

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LIST OF ABBREVIATIONS

q_e	Dye bound per unit amount of adsorbent (mg/g)
q_{max}	Saturation constant
BDMC	Bisdemethoxycurcumin
DMC	Demethoxycurcumin
C_B	Dye bound per unit amount of adsorbent (kg/m^3)
C_e	Unbound dye concentration (in solution) (mg/L)
C_U	Unbound dye concentration (in solution) (kg/m^3)
K_L	Affinity constant for Langmuir isotherm (L/mg)
K_f	Freundlich adsorption constant
R^2	Regression
SEM	Scanned Electron Microscope
UV-Vis	Ultraviolet Visible
V	Volume of solution (m^3)
W	Weight of adsorbent (yarn) used (kg)

1 INTRODUCTION

1.1 Motivation and statement of problem

Natural dyes are commonly known for their use in colouring of food, leather as well as natural protein fibres like wool, silk and cotton as major areas of application since pre-historic times (Samanta and Agarwal, 2009). Natural dyes have the tendency to produce wide range of tints and shades, producing extraordinary diversity of rich and colours that complement each other with the same dye material (Singh et al., 2012).Also, colorants derived from vegetables and fruits sources may provide nutritional value to the coloured food. In addition to this, there is a scientific proof demonstrating that isolated pigments do not provide the same benefits as the consumption of foods with whole fruit or vegetable preparations (Dean 1994).Synthetic dye that is in use now does not only pose serious health hazards but also act as major pollutant to the environment. Most of them contain a high content of toxic material and this constitutes a serious hazard for aquatic animals too (Alver et al.,2012). Untreated disposal of this coloured water into receiving water body causes damage to aquatic life and also it severe damages to the human bodies. In order to overcome and reduce the usage of synthetic dye and its adverse effects, natural dyeing source from pitaya peel and turmeric has been chosen in this study.*Hylocereus polyrhizus* commonly known as red-fleshed pitaya is one the widely used naturaldyeing source that not only has a unique colour but also high nutritional value (Kulkarani *et al.,* 2011)Turmeric on the other hand is mainly valued for its principal colouring constituent curcumin, which imparts the yellow colour on textile fibres and food (Kiran &Kapoor.,2007). According to (Bulut et al., 2006), there are various methods for extraction of dye from aqueous solution but, adsorption is considered to be more reliable compared to other techniques due to its low cost, simplicity in design, viability and ability to treat dyes in more concentrated form. The appropriate and standardized dyeing techniques need to be adopted without scarifying required quality of dyed textiles materials for successful commercial use of natural dyes. Therefore, to obtain contemporary shades with sustainable colour fastness behaviour and reproducible colour yield, appropriate scientific techniques or procedures need to be derived from scientific studies on dyeing methods, dyeing process variables, dyeing kinetics and compatibility of selective natural dyes (Samanta and Agarwal, 2009).

Although this archaic art of dyeing with natural dyes withstand the ravages of time, a speedy decline in natural dyeing was observed due to wide availability of synthetic dyes at an economical price (Samanta and Agarwal, 2009). Though there are upcoming breakthroughs and wide applications of synthetic dye in current industries, the usage of natural dye has not eroded completely and they are still in use. Usage of non-allergic, non-toxic and eco-friendly natural dyes on textiles has become a matter of significant importance due to the increased environmental awareness in order to avoid various hazardous synthetic dyes apart from other advantages of producing very uncommon, soothing and soft shades as compared to synthetic dyes (Samanta and Agarwal, 2009).

1.2 Objectives

The following are the objectives of this research:

- To analyse the effectiveness of adsorption of various natural dye on bamboo yarn.
- To study the Langmuir and Freundlich adsorption isotherm of various natural dye on bamboo yarn.

1.3 Scope of this research

The following are the scope of this research:

i) Identify the time duration required for the process of adsorption on bamboo yarn. In the analysis of suitable isotherm for this study, equilibrium time need to be determined as it plays a crucial role in obtaining the Langmuir and Freundlich isotherm.

ii) Analyse the effectiveness of adsorption of various dye on bamboo yarn by comparing the colour intensity and amount of dye that has been adsorbed at a given time through calculations.

iii) Determine the rate of adsorption of various dye on bamboo yarn is obtained by using varied concentration factor ranging from 0.2 to 1.0in the form of ratio of water to stock solution.

1.4 Main contribution of this work

The main contribution of this research is enlightening the importance of natural dyes in the context of increasing the environmental consciousness in the society. Natural dye from plants has been selected as during the last decade, the use of natural dyes hasgained momentum due to increased demand by thefood, pharmaceutical, cosmetic as well as thetextile coloration industries(Umbreen et al,2008). Not only that natural dyes exhibit better biodegradability comparedto their synthetic counterparts but also generally have ahigher compatibility with the environment. Due to existing limitations and drawbacks of these dyes, usage of it has been restricted in textile dyeing. However, adequate research and developments that has been made are able to resolve these issues and proved that maximum yield and reproducible results can be obtained through standardization of extraction and suitable dyeing profiles. As this research aims to study the adsorption isotherm of natural dyes on bamboo yarn, it reveals that adsorption is commonly considered as the more reliable methods of dye extraction as compared to all other techniques. Viability and ability to treat dyes in more concentrated form, simplicity in design and low cost properties makes adsorption the common method used.

1.5 Organisation of this thesis

The structure of the reminder of the thesis is outlined as follow:

Chapter 2 provides a description of the natural dyes used in this research. A general description on the raw materials used and the main components being extracted are provided. This chapter also provides an in depth discussion on the adsorption isotherm used. A summary of the previous experimental work on adsorption of natural dye on fabrics are also presented. A brief discussion on the structure of bamboo yarn is included to provide deeper understanding of the whole process.

Chapter 3 gives a review of the extraction process done beginning from the preparation of sample dye, determining the equilibrium time, followed by process of adsorption and analysis of absorbance values.Materials description is included apart from the major steps involved in conducting this research. The two different raw materials obtained are analysed accordingly and the equilibrium time needed for the process is also obtained. A brief description of the adsorption isotherm used is also presented in this chapter.

Chapter 4 is devoted to the preliminary work that has been done to date. Part of the analysis has been carried out to obtain the absorbance values needed to study the amount of dye that has adsorbed on the bamboo yarn before the process of mordanting. The result obtained by varying the concentration of dye used to analyse the adsorption of the dye is shown here.

Chapter 5 draws together a summary of the thesis and outlines the future work which might be derived from the model developed in this work.

2 LITERATURE REVIEW

2.1 Overview

Since prehistoric times, natural dyes have been used for many purposes such as the colouring of natural fibres wool, cotton and silk as well as fur and leather(Cristae, 2006).Synthetic dyes derived from petrochemical sources are not only high in toxic content but invites environmental pollution too. On the other hand, natural dyes derived from plant sources are non-toxic, biodegradable and eco-friendly(Vinod & Puttaswamy, 2010). A renewed international interest has arisen in natural dyes due to increased awareness of environmental and health hazards associated with the synthesis, processing and use of synthetic dyes (Umbreen *et al.*,2008).Long-established usage of synthetic dye causes detrimental effects not only to the environment but to human as well as these synthetic dyes are often non-biodegradable and have high toxic content. Usage of natural dye not only has caught the attention of textile industries but also material scientist and engineers long ago. Consequently, various researches are being conducted on the extraction of natural dye and its application in textile industries, indicating that natural dye serves as a feasible alternative to synthetic dye.

2.2 Introduction

This paper presents on natural dyes, natural and synthetic dye, exploration of bamboo yarn in textile industry,adsorption process and adsorption isotherminvolved.

2.3 Natural Dye

In textile dyeing operations, a re-introduction of natural dyes is of interest due to increased attention to water pollution, sustainability of raw materials and products, biodegradability and environmental aspects (Bechtold et al., 2009). A renewed international interest has arisen in natural dyes due to increased awareness of the environmental and health hazards associated with the synthesis, processing and use of synthetic dyes (Kumaresan *et al.,* 2011).Natural dye can be anything that comes from natural resources such as flowers, leaves, plants, bark, roots, shells, and mineral substances (Gupta et al., 2013).It has the ability to produce awide range of tints and shades, with the same dye material

(Anitha *et al*, 2007).In addition of their environmental friendly nature many natural dyes have anti allergic and deodorizing properties (Lee *et al*, 2010).Due to the fact that natural dyes can often inhibit the growth of microorganisms traditionally, different plants have been used as natural dyes in textile and carpet industries and it is believed that these dyes are less allergic and more stable than the chemical ones (Mehrabian et al., 2000).Demand of natural dyes is increasing continuously (Samanta and Agarwal, 2009) as their production and application does not require strong acids and alkalies (Bhuyan *et al.,* 2004).Although there is an increasing demand for natural dye, problems with the use of natural dyes in textile dyeing are the colour yield, complexity of the dyeing process, reproducibility results, limited shades, blending problems and inadequate fastness properties (Kiran &Kapoor., 2007).The natural dye extracts selected for this study is the betacyanin and curcumin pigments from the red pitaya and turmeric respectively.

2.4 Natural and Synthetic Dye

The demand for the synthetic dyes is high because it satisfies dyers demand as it has simple and reproducible application processes and they can also be manufactured at reasonable price (Sengupta and Singh, 2003).But with the invention of synthetic dyes in 1856, the prominence of natural dyes s lacked
because the synthetic dyes had some advantages over natural dyes like colour fastness, g ood reproducibility of shades, brilliance of colour and easy to use(Gulrajani *et al.,* 2011). However, the disadvantages of using these synthetic dyes can never be denied. Wastewater from textile industry contains quite a number of other polluting matters including toxic waste, acids and bases as well as inorganic matters. Release of these harmful substances pollutes the water source nearby such as the rivers and directly affects the health of the consumers (Manpreet, 2013). Application of synthetic dyes can have detrimental effects not only on the surrounding but also to the workers. Synthetic dyes are known to be carcinogenic and its adverse effect to human health increases the awareness of many.

2.5 *Bamboo Yarn*

The most important factor that determines the properties of yarn is the type and ratio of fibre used in the blend (Erdemlu & Ozipeck, 2011). Fibres are twisted and spun to required thickness and length to create yarn. The strength and hardness of the yarn also depends on the twist that it undergoes. Bamboo fibre has high air permeability and water absorption properties due to its micro gaps in its structure (Wallace, 2005). Bamboo clothing is an excellent organic choice that has many benefits and advantages as compared to cotton (Erdumlu & Ozipeck, 2011). Also, bamboo based fabrics are known to have antibacterial properties with a low amount of creasing and piling (Karahan et al., 2006)It is found that pure bamboo clothes can dry twice as fast as cotton ones as it is able to absorb moisture fast.This results from the voids present in the cross section of bamboo.Since the process producing the bamboo yarn is more labour intensive and costly, this type of manufacturing process of bamboo fibre for clothing is rarely used. However, due to its biodegradable properties, bamboo yarn has started to edge into the textile market recently.

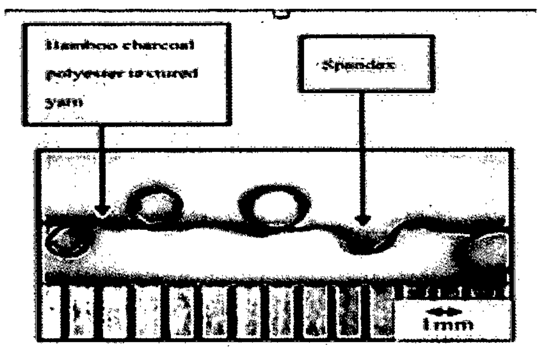

Figure 2-1: Complex yarn with a spandex expansion multiple of 3. a yarn wrap count of 2.5turns/cm, rotor twister speed of 10000rpm

2.6 *HylocereusPolyrhizus (Red-fleshed pitaya)*

Due to strong consumer demand for more natural products, new plant-derived colorants for the food industry are being developed(Herbach*et al.,* 2006). Therefore, natural food colouring by application of intensively pigmented plant products is increasingly superseding artificial dyes. *Hylocereus polyrhizus* commonly known as red-fleshed pitaya or dragon fruit belongs to the family of Cactaceae and order of Caryophyllales.

The fruits known as red pitaya or pitahaya, which means "the scaly fruit", in Latin America, belong to the cacti family which is native to the tropical forest regions of Mexico and Central and South America. The red-fleshed dragon fruit is becoming popular in Malaysia due to its unique shape, attractive red colour and high functional properties. Compared to most cactus pears, pitayas are devoid of glochids, exhibit an exceptional red-purple hue and feature significantly higher betacyanin contents. The deep purple colour of the pulp is contributed by a set of pigments known as the betalains which are nitrogen-containing pigments (Harivaindaran *et al.,* 2008), made up of the red-violet betacyanins and yellow betaxanthins with maximum absorptivity at 535 and 480 nm, respectively (Herbach*et al.,* 2006). According to Stintzing *et al.*, (2002) and Wybraniec and Mizrahi (2002), dragon fruits are totally devoid of betaxanthins and there are at least seven identified betacyanins in the *Hylocereus* genus namely: betanin, isobetanin, lhyllocactin, isophyllocactin, betanidin, isobetanidin and bougainvillein-R-I where all have identical absorption spectra that contribute to the deep purple coloured pulp. The seed of dragon fruit contains 50% essential fatty acids, i.e., 48% linoleic acid (C18:2) and 1.5% linolenic acid (C18:3) (Ariffin *et al.,* 2008). Thus, dragon fruit has potential for use as a source of functional ingredients to provide nutrients that may prevent nutrition-related diseases and improve physical and mental well-being of the consumers.

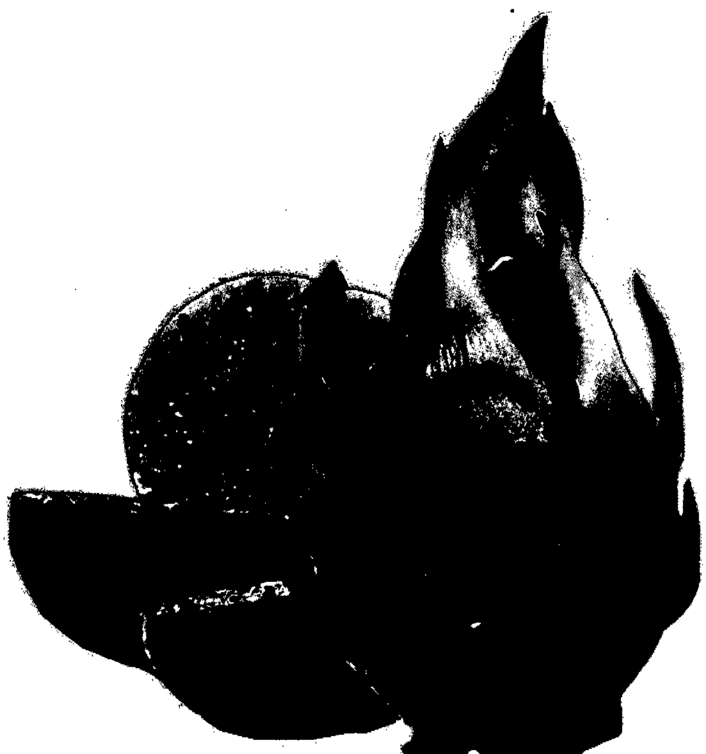

Figure 2-2: Red Dragon Fruit

2.7 Betacyanin Pigment

Betacyanin, a group of of reddish to violet betalin pigments they are common in many flowers and fruits. It can be classified into four kinds: betanin, amaranthin, gomphrenin and bouginvillein (Cai et al., 1999).Despite the numerous number of anthocyanin containing food colorant extracts, there is just one single betacyanin source, that is in the red beet (Beta vulgaris L. sp. vulgaris), which has been approved in the market (Castellar et al.,2003).Red beetroots (Beta vulgaris) are the main commercial source of betacyanins which available in the concentrated and powder form. However, red beetroot contains geosmin and pyrazines that are responsible for the unpleasant peatiness of this crop as well as high nitrate concentrations associated with the formation of carcinogenic nitrosamines, there is a demand for alternative compounds (Mohammer et al., 2005).Nevertheless, a high molar absorbency index of betacyanins and their potential as colorant are equivalent for synthetic colorants (Strack et al., 2003). In contrast to red beetroot, red-fleshed pitaya fruit does not have this negative sensorial impact. As an alternative, betacyanins from red-fleshed pitaya fruit may be a potential source on top of red beetroots.

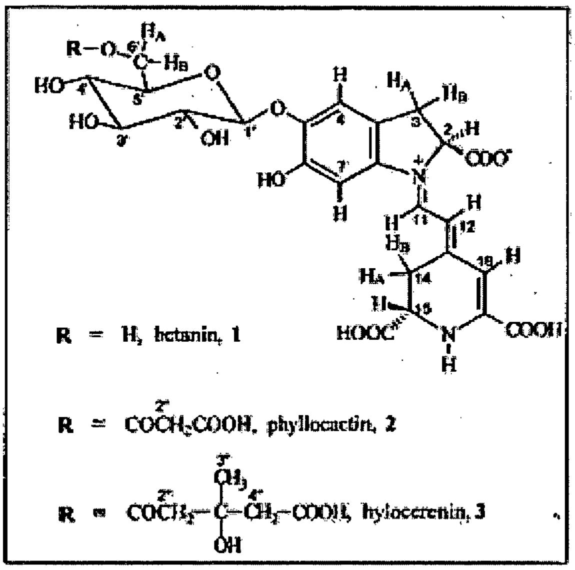

Figure 2-3: Chemical Struture of Analysed Betacyanin in *Hylocereus Polyrhizus*

As betacyanins and anthocyanins are chemically related, the methods of anthocyanin extractions can therefore be applied for betacyanin extraction (Sajilata & Singhal, 2006). Compared to polar anthocyanins, betacyanins pigments are more hydrophilic. To explain, they can dissolve in three common polar solvents (namely, water, methanol and ethanol) and their mixtures; to certain extent, water and organic acids are miscible (Schoefs, 2004).Although water extraction is simple, a highly efficient and low cost method for crude betacyanin extraction led to a difficult separation of betacyanin and water-soluble protein components (Cai et al., 1998).

2.8 Curcuma Longa (Turmeric)

Turmeric is a spice that comes from the root Curcuma longa, a member of the ginger family, Zingaberaceae (Pierce, 1999).*Curcuma longa* L. is an important source of spice used as a cosmetic, and colouring agent has also been used in Indigenous System of Medicine(Kiran & Kapoor, 2007). Turmeric consists of various molecularconstituents, including three gold-coloredalkaloidal Curcuminoids: curcumin, desmethoxycurcumin and bisdemethoxy curcumin (Umbreen et al., 2008).The curcuminoid content, responsible for color,depends upon the turmeric variety and, within avariety, on the maturity at harvest. It may bepresent to the extent of 3-5% in turmeric(Umbreen et al., 2008). Curcumin is an oil soluble pigment, practically insoluble in water at acidic and neutral pH, soluble in alkali (Umbreen et al., 2008). The powerful anti-oxidation property of curcumin has an important role in keeping curry for a long time without it turning rancid. In the present study in vitro, test confirmed the antimicrobial activity of turmeric extract against ten different bacterial strains(Terahara *et al.,* 1998).Safety evaluation studies indicate that both turmeric and curcumin are well tolerated at a very high dose without any toxic effects. Thus, both turmeric and curcumin have the potential for the development of modern medicine for the treatment of various diseases (Chattopadhyay et al., 2004). Several research reports the extraction procedures of turmericnecessary for characterization and dyeing. The procedure islargely divided into water-based extraction.Extensive investigation over the last five decades has indicated that curcumin reduces blood cholesterol (Aggarwal et al., 2008).

Figure 2-4: Turmeric

2.9 Curcumin Pigment

Curcumin (diferuloylmethane) is a yellow pigment present in the spice turmeric (Curcuma longa) that has been associated with antioxidant, anti-inflammatory, anticancer, antiviral, and antibacterial activities as indicated by over 6,000 citations.

It has extensive absorption around 420 nm in organic solvent, but its absorbance strongly decreased in aqueous solution (Bo Tang et al., 2002).Curcumin (C), main coloring substance in *Curcuma longa* and two related compounds, demethoxycurcumin (DMC) and bisdemethoxycurcumin (BDMC), are altogether known as curcuminoid (Revathy et al., 2011).

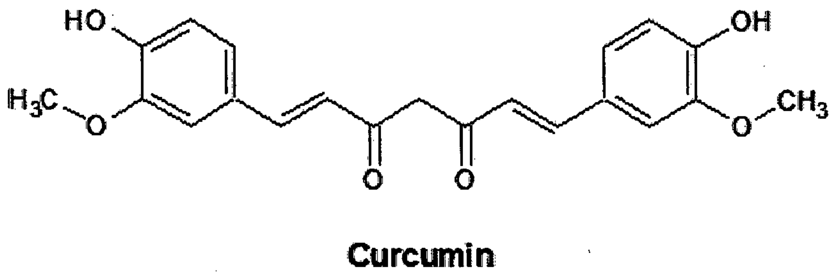

Figure 2-5: Curcumin Chemical Structure

Research has shown curcumin to be a highly pleiotropic molecule capable of interacting with numerous molecular targets involved in inflammation. Based on early cell culture and animal research, clinical trials indicate curcumin may have potential as a therapeutic agent in diseases such as inflammatory bowel disease, pancreatitis, arthritis, and chronic anterior uveitis, as well as certain types of cancer. Because of curcumin's rapid plasma clearance and conjugation, its therapeutic usefulness has been somewhat limited.

2.10 Adsorption Process

Adsorption is the process of binding of molecules or particles to a surface. The binding to the surface is usually weak and reversible. Adsorption phenomena are operative in most natural physical, biological, and chemical systems, and adsorption operations employing solids such as activated carbon and synthetic resins are used widely in industrial applications and for purification of waters and wastewaters(Klimiuk et al., 2006).There are various conventional methods of removing dyes includingcoagulation and flocculation, oxidationor ozonation and membrane separation.However, these methods are not widely used due to their highcost and economic disadvantages. Adsorption has been considered as the most versatile and viable method and is widely used. The equilibrium adsorption data usually were described by means of Langmuir or Freundlich equation. It could be used for comparison of adsorption behaviour for tested adsorbents or for various experimental conditions (Klimiuk et al., 2006). Below are the list of literature reviews involved in the study of adsorption isotherm with the adsorbents and adsorbates involved accordingly.

Table 2.1, 2.2 and 2.3 shows the adsorption isotherm used in each case and it can be concluded that Langmuir adsorption isotherm is one of the most commonly used equation as compared to Langmuir in order to determine maximum adsorption that occurs in each study.

From the list of papers that I have studied, there are no studies on adsorption of natural dye on bamboo yarn, taking the natural dye as adsorbate and bamboo yarn as the adsorbent. Most of the journals discuss on the adsorption of dyes from wastewater, effluent and also from the solute itself. Comparison between the Langmuir and Freundlich isotherm enables this research to be carried out to identify which isotherm is suitable for this research as this two isotherms are most commonly used.

Table 2-1:Langmuir Isotherm and Freundlich Isotherm

Title and Process	Author
The Effectiveness of Surfactants Adsorption onto Chitin and Dye-modified Chitin **Adsorbent: Chitin** **Adsorbate:Anionic (Borutosol KRN, Siarczanol N-2) and noninonic (Rokafenol N-8) surfactants**	Klimuik et al., (2005)
Freundlich and Langmuir Adsorption Isotherms and Kinetics for the Removal of Tartrazine from Aqueous Solutions using Hen Feathers **Adsorbent: Hen feathers** **Adsorbate: Tartrazine**	Mittal et al., (2006)
Equilibrium Studies for Acid Dye Adsorption onto Chitosan **Adsorbent: Chitosan** **Adsorbate: Acid Greeb 25, Acid Orange 10, Acid Orange 12, Acid Red 18, Acid Red 73**	Wong et al., (2003)
Equilibrium and Kinetic Studies for Adsorption of Direct Blue 71 Aqueous Solution by Wheat Shells **Adsorbent: Wheat shells** **Adsorbate: Direct blue 71**	Bulut et al., (2006)
Anionic Dye Removal from Aqueous Solutions using Modified Zeolite : Adsorption Kinetics and Isotherm Studies **Adsorbent: Zeolite** **Adsorbate: Azo dyes**	Alver et al., (2012)
Adsorption Isotherm Models for Basic Dye Adsorption by Peat in Single and Binary Component Systems **Adsorbent: Moss peat** **Adsorbate: Basic red 22, Basic blue 3, Basic yellow 21**	Allen et al., (2004)
Comparison of Optimized Isotherm Models for Basic Dye Adsorption by Kudzu	

Adsorbent: Dried Kudzu **Adsorbate: Basic red 22, Basic yellow 21**	Allen et al., (2002)
Equilibrium and Kinetic Modelling of Adsorption of Reactive Dye on Cross-linked Chitosan Beads **Adsorbent: Chitosan beads** **Adsorbate: Reactive red 189 dye**	Chiou et al., (2002)
Adsorption from Aqueous Solution onto Natural and Acid Activated Bentonite **Adsorbent: Acid activated Bentonite** **Adsorbate: Methylene blue**	Laila et al., (2012)
A Comparative Evaluation for Adsorption of Dye on Neem Bark and Mango Bark Powder **Adsorbent: Neem Bark and Mango Bark Powder** **Adsorbate: Malachite Green**	Ruchi et al., (2011)
Adsorption of Dye by Using the Solid Waste from Leather Industry as an Adsorbent **Adsorbent: Leather waste** **Adsorbate: Acid red 131 dye**	Jitendra et al., (2013)
Dyeing adsorption isotherm and equilibrium modelling characteristics of enzymatic and caustic pre-treated Lyocell fibres **Adsorbent: Lyocell fibres** **Adsorbate: Reactive dyes**	Pan et al., (2011)

Table 2-2:Langmuir Isotherm

Title and Process	**Author**
Decolourization of a textile vat dye by adsorption on waste ash	

Adsorbent: Ash from burning brown coal **Adsorbate:Vat dye Ostanthren Blue GCD (C.I. Vat Blue 14)**	Miodrag et al., (2010)
Langmuir Isotherm Models applied to the Multicomponent Sorption of Acid Dyes from Effluent onto Activated Carbon **Adsorbent: Activated carbon type F400** **Adsorbate: Acid red 114, Acid blue 80, Acid yellow 117**	Keith et al., (2000)

Table 2.3: Freundlich Isotherm

Title and Process	**Author**
Kinetic and Isotherm modelling of Adsorption of Dyes onto Rusk Husk Carbon **Adsorbent: Rusk Husk Carbon** **Adsorbate:Crystal Violet, Direct Orange, Magenta Dye**	Verma et al., (2010)

2.11 Langmuir Isotherm

An adsorption isotherm is a graphical representation showing the relationship between the amount adsorbed by a unit weight of adsorbent (e.g. activated carbon) and the amount of adsorbate remaining in a test medium at equilibrium(Kulkarni *et al.,* 2011)The Langmuir Isotherm best describes chemisorption processes. Langmuir visualised the dynamic equilibrium between adsorbate molecules in the gas phase at a pressure p, and the adsorbed entities in the surface layer, the fraction of the sites covered being$\boldsymbol{\theta}$. This isotherm also described adsorbate-adsorbent systems in which the extent of adsorbate coverage is limited to one molecular layer at or before a relative pressure of unity is reached. The equation is nevertheless obeyed at moderately low coverage by a number of systems, and can be readily extended to describe the behaviour of binary adsorbate systems. The equation of Langmuir isotherm is as below: