CARICA PAPAYA SEEDS-DERIVED COAGULANT FOR WATER TREATMENT

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DEDICATION

This thesis is dedicated to my beloved family, friends and my supervisors that have supported me during my study.

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ABSTRACT

Papaya, or also known as *carica* papaya is a common fruit grown in many tropical climate countries. Following its mass consumption, papaya fruit wastes such as peels and seeds are generated around 15 to 20% of the fruit's weight. Hence, the needs arise to either to reduce waste or reuse it into other forms that can be beneficial. Natural coagulants are gaining interest as they are environmentally friendly compared to chemical coagulants. Therefore, the aim of this study is to utilize discarded papaya seeds in becoming the natural coagulant to treat turbid water. The objective of this study is to characterize physico-chemical and morphological properties of *carica* papaya seed-derived natural coagulant, to determine the optimum operating conditions of *carica* papaya seed-derived natural coagulant in treating synthetic water and to investigate performance efficiency of *carica* papaya seeds-derived natural coagulant in treating different classes of river water. Initially, the collected *carica* papaya seeds were processed by washing, deshelling, drying at 50°C for 24 hours and grinding prior to physico-chemical and morphological characterization. Jar test was conducted based on 2-level factorial design, followed by Response Surface Methodology (RSM) in order to determine the optimum operating conditions of coagulant dosage, pH and initial turbidity on turbidity removal and coagulation activity. For comparison purpose, alum was used. The effectiveness of *carica* papaya seeds-derived natural coagulant was then tested on different classes of rivers. Class III, Class IV and Class V river water was represented by Skudai River, Melana River and Tukang Batu River respectively. The effectiveness of *carica* papaya seeds as coagulant was determined based on the removal of turbidity, chemical oxygen demand (COD), ammoniacal nitrogen, nitrite, nitrate, phosphorus and coliforms. Based on the findings, the deshelled *carica* papaya seeds contained 3.9% moisture content, which resulted towards high yield of 99.2%. The isoelectric point of *carica* papaya seeds derived natural coagulant was at pH 6 while the surface charge was recorded as +0.4 meq/g. The coagulant also contained minimum concentration of iron and sufficiently high protein content of 363 mg/g. Factorial analysis of *carica* papaya seeds-derived coagulant revealed that most main and interaction terms are significant, excluding interaction between pH and initial turbidity on turbidity removal. Based on the RSM analysis, at optimum condition of 196 mg/L dosage, pH 4 and initial turbidity of 500 NTU, the papaya seeds were capable to remove turbidity up to 93% with coagulation activity of 85%. Actual observations using the optimum conditions resulted to 88% turbidity removal and 83% coagulation activity. Meanwhile for alum, at optimum condition of 197 mg/L dosage, pH 6.3 and initial turbidity of 425 NTU, the recorded turbidity removal and coagulation activity was 98% and 98%, respectively. Actual observations using the optimum conditions resulted to 94% turbidity removal and 93% coagulation activity. *Carica* papaya seeds derived natural coagulants were also able to obtain high removal turbidity (87.6%), nitrite (86.2%) and nitrate (82.3%) for river of Class III while for river of Class IV, the natural coagulant obtained higher removal of only turbidity (88.3%) and nitrite (92.2%). This natural coagulant was also able to remove 57.6% and 62.1% of total coliform and *Escherichia coli*, respectively from Class III river water, which then verifies the antimicrobial properties of the studied natural coagulant. In conclusion, *carica* papaya seeds have proved its potential ability in becoming effective natural coagulant and able to treat synthetic kaolin water as well as river water of Class IV and below at designated optimum conditions.

ABSTRAK

Betik, atau nama saintifiknya *carica papaya* adalah buah popular yang ditanam di kebanyakan negara tropika. Berikutan pengambilannya yang banyak, sisa betik seperti kulit dan biji juga dihasilkan dalam anggaran 15 hingga 20% dari berat asal buah. Oleh itu, perlu ada cara sama ada mengurangkan sisa tersebut atau menggunakannya semula dalam bentuk lain yang lebih bermanfaat. Pengental semula jadi semakin popular kerana ia adalah mesra alam sekitar jika dibandingkan dengan pengental kimia. Justeru itu, kajian ini bertujuan untuk memanfaatkan sisa biji betik dengan menjadikannya pengental semua jadi bagi merawat air yang keruh. Objektif kajian ini adalah untuk pengkelasan biji betik dari segi fiziko-kimia dan sifat morfologi, menentukan keadaan operasi yang optimum bagi pengental semula jadi yang dihasilkan dari biji *carica papaya* dalam merawat air sintetik dan mengkaji kebolehan pengental semua jadi yang dihasilkan dari biji *carica papaya* untuk merawat air dari sungai dengan kelas berbeza. Pada mulanya, biji *carica papaya* yang telah dikumpul diproses dengan membasuh, membuang kulit luar, pengeringan pada 50°C selama 24 jam dan dikisar sebelum pencirian fiziko-kimia dan morfologi dijalankan. Ujikaji balang dilakukan berdasarkan reka bentuk faktorial 2-peringkat, diikuti dengan Kaedah Permukaan Tindak Balas (RSM) untuk menentukan keadaan operasi yang optimum bagi faktor dos pengental, pH dan kekeruhan awal terhadap pengurangan kekeruhan dan aktiviti pengentalan. Untuk tujuan perbandingan, alum digunakan. Keberkesanan pengental semula jadi biji *carica papaya* kemudiannya diuji terhadap kelas sungai yang berbeza. Sungai Kelas III, Kelas IV dan Kelas V diwakili oleh Sungai Skudai, Sungai Melana dan Sungai Tukang Batu. Keberkesanan pengental semula jadi oleh biji *carica papaya* ditentukan berdasarkan pengurangan kekeruhan, permintaan oksigen kimia (COD), nitrogen-ammonia, nitrit, nitrat, fosforus dan koliform. Berdasarkan hasil kajian, biji *carica papaya* yang dibuang kulitnya mengandungi 3.9% kandungan lembapan, yang menghasilkan hasil akhir yang tinggi sebanyak 99.2%. Titik isoelektrik pengental semula jadi biji *carica papaya* adalah pada pH 6 manakala cas permukaan direkodkan sebagai +0.4 meq/g. pengental ini juga mengandungi kepekatan besi yang minimum dan mengandungi kandungan protein yang cukup tinggi iaitu 363 mg/g. Analisis faktorial pengental semula jadi biji *carica papaya* menunjukkan kebanyakan terma utama dan interaksi adalah penting kecuali interaksi antara pH dan kekeruhan awal terhadap pengurangan kekeruhan. Berdasarkan analisis RSM, pada keadaan optimum dos 196 mg/L, pH 4 dan kekeruhan awal 500 NTU, biji betik dapat mengurangkan kekeruhan sebanyak 93% dengan aktiviti pengentalan sebanyak 85%. Keputusan sebenar menggunakan keadaan optimum telah mengurangkan kekeruhan sebanyak 88% dan 83% aktiviti pengentalan. Sementara itu untuk alum, pada keadaan optimum dos 197 mg/L, pH 6.3 dan kekeruhan awal 425 NTU, pengurangan kekeruhan dan aktiviti pengentalan yang direkodkan masing-masing adalah 99% dan 98%. Keputusan sebenar menggunakan keadaan optimum telah mengurangkan kekeruhan sebanyak 94% dan 93% aktiviti pengentalan. Pengental semulajadi biji *carica papaya* juga menunjukkan peratus pengurangan yang tinggi bagi kekeruhan (87.6%), nitrit (86.2%) dan nitrat (82.3%) untuk air sungai Kelas III manakala bagi air sungai Kelas IV, pengental semula jadi memperoleh peratusan pengurangan yang tinggi hanya bagi kekeruhan (88.3%) dan nitrit (92.2%). Pengental semula jadi ini juga mampu mengurangkan sebanyak 57.6% kolifom dan 62.1% *Escherichia coli* dari sungai Kelas III, maka ini membuktikan sifat anti-bakteria terhadap pengental semula jadi tersebut. Kesimpulannya, kebolehan biji *carica papaya* untuk menjadi pengental semula jadi telah terbukti dan ia mampu merawat air sintetik dan juga merawat air sungai Kelas IV ke bawah dalam keadaan operasi yang optimum.

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LIST OF ABBREVIATIONS

FTIR	-	Fourier-transform Infrared Spectroscopy
PVSK	-	Polyvinylsulfuric Acid Potassium Salt
BSA	-	Bovine Serum Albumin
Fe	-	Iron
UIRL	-	University Industry Research Laboratory
AAS	-	Atomic Absorption Spectrophotometer
FESEM	-	Field-emission Scanning Electron Microscope
COD	-	Chemical Oxygen Demand
RSM	-	Response Surface Methodology
CCD	-	Central Composite Design
NWQS	-	National Water Quality Standard for Malaysia
E. coli		*Escherichia Coli*

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Coagulation and flocculation processes are widely used in water and wastewater treatment. Its main objective is to remove suspended colloidal particles and to reduce turbidity in water body (Choy *et al.,* 2014). The process usually takes place in a chemical reactor in which the influent water or wastewater enter the basin and it is mix with coagulant agents using a mechanical mixer. The process is followed by sedimentation to remove the particulate through gravity settling (Hammer and Hammer Jr., 2004). There are many types of coagulants available, often used are the chemical-based coagulants such as alum and ferric salts (Saharudin and Nithyanandam, 2014). However, there are also coagulants derived from plant based materials that are rising in popularity and potentially able to replace the use of chemical coagulants in the near future.

1.2 Problem Statement

Conventionally, coagulation process uses coagulants such as aluminium sulphate (alum) and ferric chloride. Despite of its establishment in treating water and wastewater, the uses of these chemical coagulants pose numerous adverse effects due to residual coagulant present in the treated water. The residual coagulant is harmful and can deteriorate one's health upon long period of consumption (Choy *et al.,* 2014). Besides, the operational coast of a treatment using chemical coagulant is also high due to its voluminous end sludge production that requires proper treatment (Antov *et al.,* 2010). Therefore, the cost of chemical coagulant for water treatment puts a strain on developing countries. Due to these aforementioned drawbacks, it is now crucial to shift towards the use of natural coagulant. The use of natural coagulants in water and wastewater treatment have been commonly practiced and it

is evidenced of having environmental advantages. Reviews and current practices indicated that *moringa oleifera* seeds, *nirmali* seeds, tannin and *opuntia ficus* cactus are the most popular precursors for natural coagulants production (Yin, 2010). Continuing efforts to diversify the choice of natural coagulants and to explore other potential natural coagulants would be beneficial in terms of achieving the goal of waste minimization and seeking better water and wastewater treatment approaches.

Carica papaya, commonly called as papaya has been a popular fruit especially in tropical countries like Malaysia. In 2013, Malaysia has been ranked as the second highest papaya fruit export globally, with an export value approximately RM100-120 million per year (Sekeli *et al.,* 2018). Consumption of papaya fruits results to mass production of food wastes, particularly the discarded papaya peels and seeds which is between 15 and 20% of its weight (Hameed, 2008). Hence, actions need to be taken to minimize the quantity of food wastes resulted from the consumption of papaya fruits. Papaya seeds has been studied to have high protein content (Chandran and George, 2015). Consequently, proteins are the coagulating agents in plant-extract coagulant (Chandran and George, 2015). However, to date there are lack of study has been done regarding the study on potential use of *carica* papaya seeds as the natural coagulant. Its chemical characteristics such as surface chage and effeciency in removing turbidity and perform coagulation remain lacking. Therefore, this study is carried out to explore the feasibility of *carica* papaya seeds-derived natural coagulant in treating turbid water.

1.3 Objectives of the Study

The aim of this study is to investigate the potential of *carica* papaya seeds as a natural coagulant in treating polluted water. Therefore, objectives of this study are as the following below.

i. To characterize physico-chemical and morphological properties of *carica* papaya seeds-derived natural coagulant.

ii. To determine optimum operating conditions of pH, dosage and initial turbidity of *carica* papaya seeds-derived natural coagulant and compare them to alum in treating synthetic water.

iii. To investigate performance efficiency of *carica* papaya seeds-derived natural coagulant in treating different classes of river water with regards to the physical, chemical and biological properties.

1.4 Scope of the Study

The study was conducted at Environmental Engineering Laboratory, School of Civil Engineering, Universiti Teknologi Malaysia (UTM). In this study, the material used as natural coagulant was *carica* papaya seed. Primary processing of the crude seeds was done by mixing it with distilled water to produce *carica* papaya seeds-derived natural coagulant.

Physico-chemcial and morphology characterization was done to the *carica* papaya seed powder in which it went through a series of tests which are isoelectric point, protein content, surface charge, metal content, FESEM and FTIR. Next, jar test was done at 250 rpm rapid mixing for 3 minutes, 30 rpm slow mixing for 15 minutes and followed by 30 minutes of sedimentation time. Synthetic water using kaolin was used for the har tests. The factors set for jar test was coagulant dosage, initial turbidity and pH followed by responses which are turbidity removal and coagulation activity. The factorial design for jar test was done at a two level factorial to determine the significant impact between each variables and responses. Following that, higher level factorial was done by response surface methodology method. The natural coagulant was then tested its potential to treat class III, IV and V river water. Skudai river, Melana river and Tukang Batu river was selected as those are class III, IV and V river respectively. This test was conducted using the optimized operational condition obtained from RSM.

1.5 Significance of the Study

Natural coagulants are biodegradable and safe for human health. Furthermore, the sludge produced by natural coagulant are biodegradable and have less volume than the sludge produced by chemical coagulant (Megersa *et al.,* 2014). Established natural coagulants such as *moringa olifiera* and *strychnos potatorum* are derived from plant seeds as the seeds' extract has active coagulant agent capabilities. A thorough literature search indicates that *carica* papaya seeds have not been commercially used in water treatment due to its lack of information and research. Therefore, the significance of this study are listed as following below.

i. This study provides thorough information on the properties of *carica* papaya seeds including physico-chemical such as protein content and surface charge in addition of its morphological properties.

ii. This study provides optimum operating conditions for water treatment using *carica* papaya seeds-derived natural coagulant as well useful data for future research.

iii. This study features food wastes reduction, reduce sludge volume production as well as produce biodegradable sludge.

iv. The study develops a new coagulant for water and wastewater treatment, thus, it diversifies the spectrum of natural coagulant available for commercial water treatment plant use.

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