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Synthesis and characterization of *Dioscorea hispida* sp. tuber starch-polyacrylamide wood coating and its facile inhibitory towards *Pycnoporus sanguineus* and *Coptotermes curvignathus*

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ABSTRACT

A unique, non-leaching and durable novel anti-biocide polyacrylamide-starch coating (pAam-g-S) has successfully been synthesized. In this study, a grafted cationic-functionalized polymeric coating was designed and cross-linked with native starch extracted from *Dioscorea hispida* sp. yam to afford multi-functional anti-fungal and anti-termite coating. Leaching of the disinfectant into the environment was eliminated because no toxic chemicals were used. The copolymerization was successfully carried out to produce various ratios of pAam-g-S coating using modification of starch-gel. Results obtained from Fourier Transform Infrared-Attenuated Total Reflectance (FTIR-ATR) confirmed the monomer pAam was grafted onto the starch backbone as shown by the cross-linked peak at 1642 cm^{-1}. Supported by differential scanning calorimetry (DSC), the highest transition glass temperature was observed at 154 °C. The coating was designed to continuously decontaminate against pathogenic fungus and termite in addition to afford preliminary anti-biocides properties. Facile anti-fungal and anti-termite evaluations were conducted via total weight loss of wood (%) studies using white rot fungus, *Pycnoporus. sanguineus* and termite *Coptotermes curvignathus* respectively. In order to verify the coating performance, gel fractions, morphologies and heat resistant properties were also investigated.

1. Introduction

Wood is a natural polymeric composite which is widely used for home furnishings and construction materials. Although this organic multifunctioning material offers many applications, however unprotected wood is susceptible to wood rotting fungi and termite, which resulted in quality curtailment particular in its mechanical strength [1]. In order to extend the service life, wood products are therefore normally treated with preservatives such as creosote, alkaline copper quaternary (ACQ), and copper azole (CuAz) [2,3]. These chemicals were used as protector due to their impregnation ability into the wood cell and furthermore improve their physical durability. A range of different chemicals are readily available to improve the permanence as well as to help the resistance to decay, insects, weather or fire. Some of the preservative agents are highly toxic that will be phased out in a short period of time as it is largely imposed adverse impact on human health and polluted the environment. Therefore, the quest for alternative phytochemicals with lower environmental and mammalian toxicity has currently become a major concern.

The search for biocides with improved antimicrobial and functional performance has led to the development of several generations of cationic quaternary ammonium salts (QAS) which were widely used to control the bacterial growth in clinical, industrial and marine environments [4]. Quaternary ammonium salts have been used as key components in many disinfectants, fabric softeners, laundry detergents, and antistatic agents [5,6]. QAS has high biocide activity for a wide spectrum of biological species at minimal concentrations and can be easily tailored for desired functionality and alkyl chain length through conventional synthesis method [5–7]. Although the synthetic bioactive such QAS is often demonstrated as a good disinfectants, on the contrary, it is poor

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in degradability which consequent lead to pollution. Alternately, coating with high presence of copper (Cu) [8–10] contents which leached out relatively in high amounts could be toxic in aquatic environments [10,11].

Utilizing essential oil extracted from herbs or plants to suppress mold on surfaces to inhibit the attack of the decay fungi, and to protect against termites on wood has proved to be a powerful alternative. Anti-fungal effects of essential oils extracted from lemongrass, rosemary, tea tree, thyme, cinnamon, anise oil, lime oil, and tangerine oil have been reported for mold growth on wood but on contrary of their good performance it is difficult to extract essential oils as it requires lots of procedures and time consuming, whereas it is not practical to produce the disinfection agent. So far there were no reports on anti-fungal effects on wood by *Dioscorea hispida* sp. yam starch, or their alcaloid (dioscorin) components. However from the previous research [12], it was reported *Dioscorea Hispida sp*. starch gave positive inhibition of several bacterias such as *Staphlococcus Aureus* sp., *Staphlococcus Aureus* sp., *Sacharomyces Cereviae* sp. and *E. Coli* sp.

Owing to this matter, durability and effectiveness become the main focus as self-decontaminating coatings with eco-friendly property is developed. Therefore, natural materials such as starch, cellulose and chitosan have attracted great attention due to their abundant resources, degradability and ease of manipulation. It is noted that natural based material can be decomposed and be used by microbes, plants as well as being compatible to the environment. Hence, alternative has been made by using organic resources which offers greener application without any side effect [13].

Starch tubers are abundant bio-resources which comprises 40–60% of natural amylose and amylopectin. Nonetheless, starch from different wild tubers species are unutilized due to poisonous bioactive alcaloids that are harmful to human [13]. *Dioscorea hispida* sp. or locally known as Ubi Gadong in Malaysia, a poisonous tuber that stores its toxic poison in its rhizome. Approximately there are over 600 *Dioscorea* species found in various parts of the world, especially in tropical and subtropical region [14,15]. *Dioscorea hispida* Dennst. (Dioscoreaceae), another wild tuber despite its toxicity has become a staple food in some tropical regions. Traditionally it has also been used as one of the medicinal remedies to treat constipation. Studies have shown that an alkaloid extract from these tuber causes dizziness, nausea, vomiting, and caused sleepiness in humans [16,17]. Starch from the tuber of *Dioscorea hispida* is edible and can be consumed when the poison (dioscorine) has been removed. It takes five to seven days of soaking in which to ensure full detoxification in flowing water [18–20]. Furthermore, it has been used as remedy in which the tuber was used as crude drug to inflammation [21].

Previously we demonstrated that hydrogel made from *Dioscorea hispida* sp. starch can act as a promising antibacterial to inhibit bacterial activity [12,22–24]. Hence in this research, the chemical and physical characteristics of the *D.hispida* starch based coatings with its anti-fungal and anti-termite were further explored. One-pot reaction method has been used in preparing the coating by grafting starch with polyacrylamide (pAam) was employed [24]. The characterization was made by using Fourier transform infrared spectroscopy (FTIR), Scanning electron microscopy (SEM), Optical microscopy, and Differential Scanning Calorimetry (DSC). Polyacrylamide are known to have excellent impact strength, low curing temperature, and abrasion resistant characteristics [25]. The promising applications for biocide containing this polyacrylamide include foams, coatings and medical devices [26,27]. This research embraced the characterization of this coating to determine its optimum performance including its facile anti-fungal and anti-termite test. The coating was treated on the rubberwood and followed by Feeding Inhibitory test (FI test) as specified in ASTM D2017- (ASTM 1996).

2. Experimental

2.1. Materials

Analytical grade chemicals were used in this studies. All so tions without any further purification were prepared using distill water. The *dioscorea hispida* sp yam was obtained from Terenggar Malaysia. The polyacrylamide (Sigma Aldrich) was used witho further purification. As for the cross-linking agent and initiat *N*,*N*′-methylenebisacrylamide (MBA) (Merck 8) and potassium p sulfate (KPS) (Merck) were used. A Denver 215 model pH meter a a Heildolp MR3001 model magnetic stirrer were also used duri the experiments. Retsch PM200 model grinder was used to gri the starch compound into fine powder with diameter of appro imately (5 nm). A polyscience 9006 model refrigerating-heati circulator was also used during the starch based hydrogels synth sis. This refrigerating-heating circulator was used to ensure t all chemical process such as radicals and crosslinking polymeri tion were performed without any effects from the surroundi physically and chemically.

2.2. Preparation of starch and starch stock solution

Past research stated *Dioscorea hispida* (*D.hispida*) tuber has be recognized as a poisonous plant in which its tuber contains to poison and can be only consumed after the poison is prope removed [28]. The wild yam tubers were peeled and rinsed bef being pulverized using a home blender. The suspension was k in a container and left overnight. After 24hr, the upper layer of t suspension was removed while the lower layer was collected a dried in the oven for 3 days. The dried starch was then pulveri until 1??m diameter using ultron grinder.

2.3. *Synthesis of* dioscorea hispida *sp starch/polyacrylamide coating*

About 2 g of *D. hispida* sp. starch was mixed in 10 mL (5 w/ of sodium hydroxide solution with constant stirring at 300 rpm ambient room temperature to form gelatinized starch mixtures 1 h. Later, gelatinized starch mixtures were added with 0.25 g M and initiator. The flask was stoppered well and the contents we stirred and refluxed with monomer polyacrylamide at const temperature of 60 °C at 400 rpm. In order to establish crosslinki an inert condition has to be applied by flowing nitrogen into t reflux. This condition was adhered to avoid the formation of bu bles in the casted coating and also to enhance crosslinking betwe the monomer and starch. The mixtures were then into molded pe dishes and dried at room temperature. The coating obtained we 50% translucent and labelled with various ratios of monomer a starch.

2.4. Characterization of the hydrogels

FTIR-ATR analysis was conducted to characterize the coati films using Perkin-Elmer Spectrum BX-II Model FTIR spectroph tometer. Samples were dried to a constant weight in an oven 50 °C for 24 h before being used and certain peaks of the samp were recorded in the range between 4000 cm^{-1} and 400 cm^{-1}, a resolution of 4 cm^{-1} as an average of 50 scans.

The surface of the samples were observed with a JEOL J 6300F Scanning Electron Microscope (SEM) operated at an acc eration voltage of 5 kV. In addition, further surface analysis we done by using optical scanning digital microscope. The samp were pinned on a mounting board and surface topography was analyzed with an enhanced 1.3 megapixels (20×–220× resolution) AM4515ZT Optical Scanning Microscope operated with the adjustable polarization.

Rubberwood was used as the test sample in this study. The mass and dimensions of the wood block specimens ($16 \times 16 \times 10\,\text{mm}^3$ cubes) accurately determined. The wood blocks were placed in beaker, covered with a coarse mesh, and weighed down. Subsequently, polymeric polymer particle suspension (New Preservative) with various the concentration (0, 1, 3, 5 & 10%) w/v of PVOH and starch extract will be poured over the block. The beaker was subjected to a pressure treatment consisting of a partial vacuum of 17.3 kPa for 25 min, followed by pressurization at 790 kPa for 45 min. Specimens were first removed and the excess liquid was wiped off. The wood blocks were then weighed to determine the mass of the retained suspension, and the undelivered polymeric particles were recovered consecutively. This is due to further confirm the delivered mass of polymeric particles. The samples were dried overnight (40 °C), cut longitudinally into four wafers (two interior and two exterior), and reweighed. The wafers then will be sterilized in an autoclave for 15 min at 120 °C.

2.5. *Resistance of particle boards to fungal decay*

The decay resistance against the white rot fungus, *P. sanguineus*, was carried out in the laboratory using the method specified in ASTM D2017-81 (ASTM 1996). The efficacy of the treatment was assessed based on the per cent of weight loss caused by fungal degradation. Eight test blocks, 16 × 16 × 10 mm, were cut from each treated and untreated boards. The blocks were stabilized in an air-conditioning room with temperature maintained at 25 ± 2 °C and 65 ± 5% relative humidity until they reached constant weight. The test bottles were prepared according to ASTM D2017-81 (ASTM 1996). Rubberwood feeder strips of dimensions 3 × 20 × 30 mm were laid flat on the soil surface in the test bottles. The bottles were loosely capped steamed and sterilized at 121 °C for 30 mins. After cooling and keeping overnight, the feeder strip in each bottle was later inoculated with the white rot fungus. The fungus was allowed to grow and cover the feeder strip before the pre-weighed test block was introduced. The bottles together with the contents were left in an incubating room with temperature maintain at 25 ± 2 °C and (70 ± 5)% relative humidity. At the end of 12 weeks, the test blocks were removed from the bottles and all mycelium adhered on the surface of the blocks were brushed off. They were again left in the conditioning room until their weights were constant. The percent weight loss was represented in equation 1 where Wa were calculated from the conditioned weight before and Wb after exposure was obtained.

$$\frac{Wa - Wb}{Wa} \times 100 \qquad (1)$$

2.6. *Resistance of particleboards to termite attack*

The test on resistance of treated boards against termite (*C. curvignathus*) was carried out in the laboratory in accordance with ASTM D3345-74 (ASTM 1998). Eight blocks of 25 × 25 × 10 mm were randomly cut from each of the untreated and treated boards and conditioned in the air-conditioning room until they reached constant weights. The weights were measured and the blocks were placed in test bottles filled with sand. The test bottles and the sand were prepared according to ASTM D3345-74 (ASTM 1998). The bottles, together with their contents, were sterilized at 120 °C for two hours. Approximately 1.0 ± 0.05 g termites comprising 10% soldiers and 90% workers were introduced in each of the test bottles. The bottles were covered with black paper and kept at room temperature 26 ± 1 °C for four weeks. The activities of the termites were observed and the mortality recorded at the end of 1st, 2nd and 4th week of exposure. At the end of four weeks, the blocks were removed, cleaned and conditioned in a conditioning room until their weights were constant. The resistance to termite attack was calculated based on percentage weight loss from the conditioned weight before W1 and after exposure W2. The percentage mortality of termites presented in *equation* 2 as calculated based on the number of dead (No) and the original number (Ni).

$$\frac{No}{Ni} \times 100 \qquad (2)$$

3. Results and discussion

3.1. *Synthesis of polyacrylamide and* Dioscorea hispida *sp. starch (pAam-g-S) coating*

A proposed mechanism for synthesis of pAam-g-s (polyacrylamide-g-starch) coating, where acrylic radical polymerization with starch is a chain reaction process as shown in Fig. 1 consists of three main steps: initiation, propagation and termination [27,28]. Firstly, hydroxyl free radicals are formed on the starch backbone, a process initiated by KPS. Then, the pAam monomer reacts with the hydroxyl free radicals resulting in propagating a new polymer chain (branch) that is covalently anchored to the starch. The free radical site is then transferred to the newly formed branch. Subsequently, more pAam monomers may covalently bind to the free radical sites of the branch [29–31]. The propagation of the branch continues until termination occurs either by crosslinking of two growing starch chains with MBA or by a disproportionation mechanism [32]. Propagation and termination may also occur by a chain transfer to monomer, initiator, dead polymer, or to impurities. This shows that starch plays a major role in the synthesis of S-g-pAam coating. Firstly, it provides high density hydroxyl groups. Secondly, starch serves as the backbone of the coating networks, which determines the mechanical properties and machinability of the produced material.

3.2. *Fourier transformed infrared (FTIR)*

FT-IR spectra of the S-g-pAam coating and the starch are shown in Fig. 2. As can be seen, the S-g-pAam hydrogel and starch showed an absorption peak at $3274\,\text{cm}^{-1}$ and $3198\,\text{cm}^{-1}$ respectively due to the hydrogen bonded $-$OH groups of starch. Both reported peaks around $2931–2928\,\text{cm}^{-1}$ that referred to the $-CH_2-$ asymmetric stretching of $-CH_2OH$ groups in starch. For S-g-pAam coating, a broad peak appeared in the range of $1655.06\,\text{cm}^{-1}$, which assigned to the C=O stretching vibration of $CNH_2C{=}O$ groups of grafted pAam with starch. Sharp peaks were observed at $1424\,\text{cm}^{-1}$ and $1415\,\text{cm}^{-1}$ in both pAam and S-g-pAam spectra which contributed from the carboxylate symmetric stretching of COO^- groups [33]. The peaks observed at $1655–1651\,\text{cm}^{-1}$ and $1415\,\text{cm}^{-1}$ prove the existence of carbonyl groups in coating after grafting polymerization. In comparison with the original starch, the FT-IR spectrum of S-g-pAam coating exhibits the absorption at $1077\,\text{cm}^{-1}$ for the C—O stretching while the vibration of $-CH_2OH$ groups decreased due to the conjugation compared to the peak at $1077\,\text{cm}^{-1}$ (starch) [34]. This result was considered as previous researcher postulated that grafting polymerization reaction only occurred at the primary hydroxyl groups of starch. However, the existence of carboxyl groups is also possible due to the blending of pAam monomer or its homopolymer. As a consequence exhaustive washing procedure was conducted by immersing the coating in a 0.01 mol/L of NaOH for two days followed by freeze dry. The treated coating displays similar FT-IR absorption with the untreated sample, which further

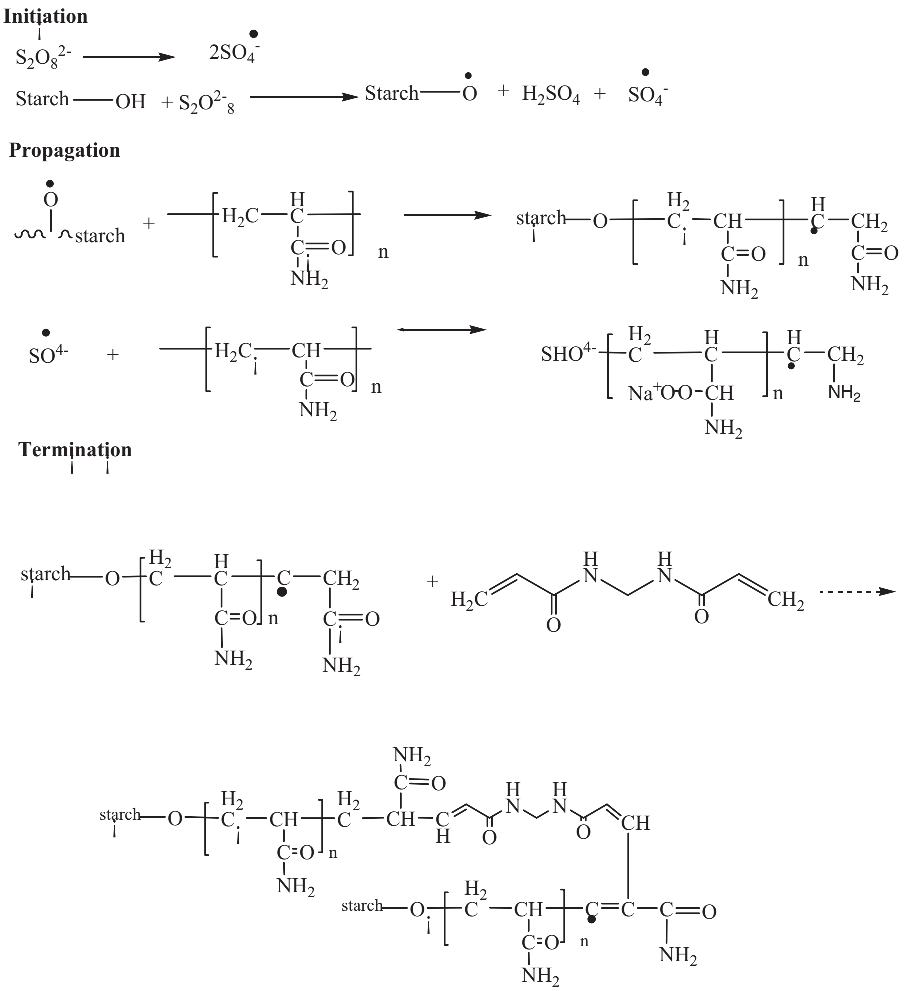

Fig. 1. Proposed mechanism for synthesis of polyacrylamide grafted dioscorea hispida sp starch enhanced with potassium persulfate (KPS) as the initiator and N
methylenebisacrylamide (MBA) as the crosslinked agent.

confirmed that pAam was successfully grafted to starch instead of blending with starch.

3.3. *Scanning electron microscopy*

Typical SEM photographic image in Fig. 3 shows that the coating are translucent, soft, and smooth with a slippery surface. From the previous study [35] suggests that the hydrogels had a highly porous network structure. As a higher mole ratio of polyacrylamide to starch was used, the strength of the final product is so poor that the coating can hardly be shaped. The SEM images in Fig. 3 showed non porous network structure with a maximum of 10 μm has been produced. Surface morphology of different ratios of starch/acrylamide complexes showed that the amount of starch used directly affected the surface topography of the coating ratios (3b, 3c and 3d). As can be seen, the coating with a ratio of 2:1 gave the most translucent and homogeneous surface compared to the coating gel with a higher amount of starch (Fig. 3c and d).

3.4. *Optical scanning microscope*

The images produced by Optical Scanning Microscopy in Fig. 4 displayed non-porous network topography on the surface of the starch based coating film with a maximum magnification of 200 μm. It also confirmed the resultant coating was uniform and homogeneous, with slightly porous surface with an average roughness of 155.3 μm (Fig. 4). Surface morphology of different rat
of starch/polyacrylamide complexes showed that the amount
starch used directly affected the smoothness of the grafted coati
complexes 4a, 4b and 4c. Fig. 4a showed the ratios of grafted co
ing pAam-g-s 2:1 while Fig. 4b and c showed the ratios of graft
coating pAam-g-s 1:2 and 3:5 respectively. From the figures topo
raphy, it significantly displays a homogeneous surface with ve
limited porosity. The porosity of the coating has been successfu
controlled by the incorporation of Tween-80 surfactant with t
synthesized coating pAam-g-s. The process was likely to preve
the pores from absorbing too much water and hindered oxidati
from occured on the surface of the coated material. It has be
reported [36] that the basic pH of the monomer aids in produci
micro porous aggregates that can enhance the mechanical prop
ties of the synthesized coating. Another important aspect duri
synthesis of coating between starch and pAam is that the mixtu
should not have any phase separation in order to obtain a ma
mum homogeneity. Film coating with a ratio of 2:1 gave the mo
homogeneous and smooth morphology compared to the other tw
coating ratios with a higher amount of starch as shown in Fig. 4

3.5. *Differential scanning calorimetry (DSC)*

The differential scanning calorimetry analysis (DSC) compou
gave thermograms of starch and S-g-pAam coatings at differe
ratios a (starch), b (2: 1), c (1: 2), and d (3: 5) as shown in Fig. 5. It w

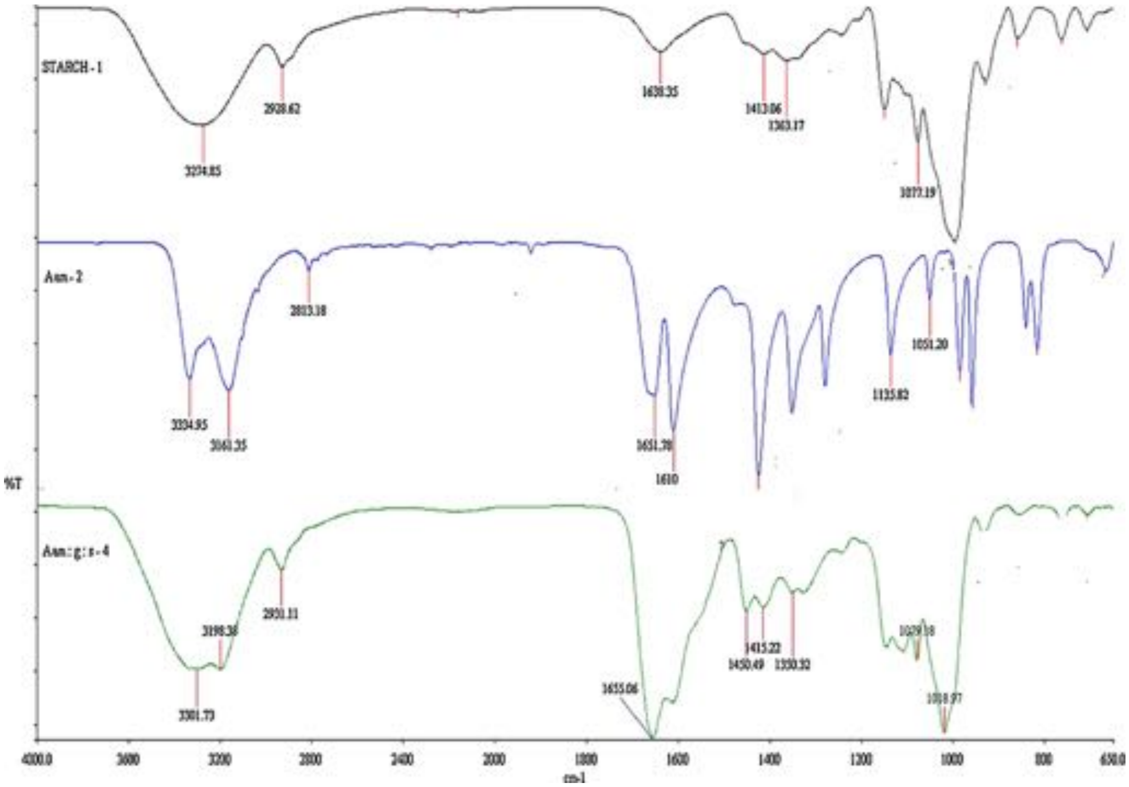

Fig. 2. FTIR spectra of monomer (pAam), cross-linked agent (MBA), Starch (comonomer),and grafted coating film (S-g-pAam).

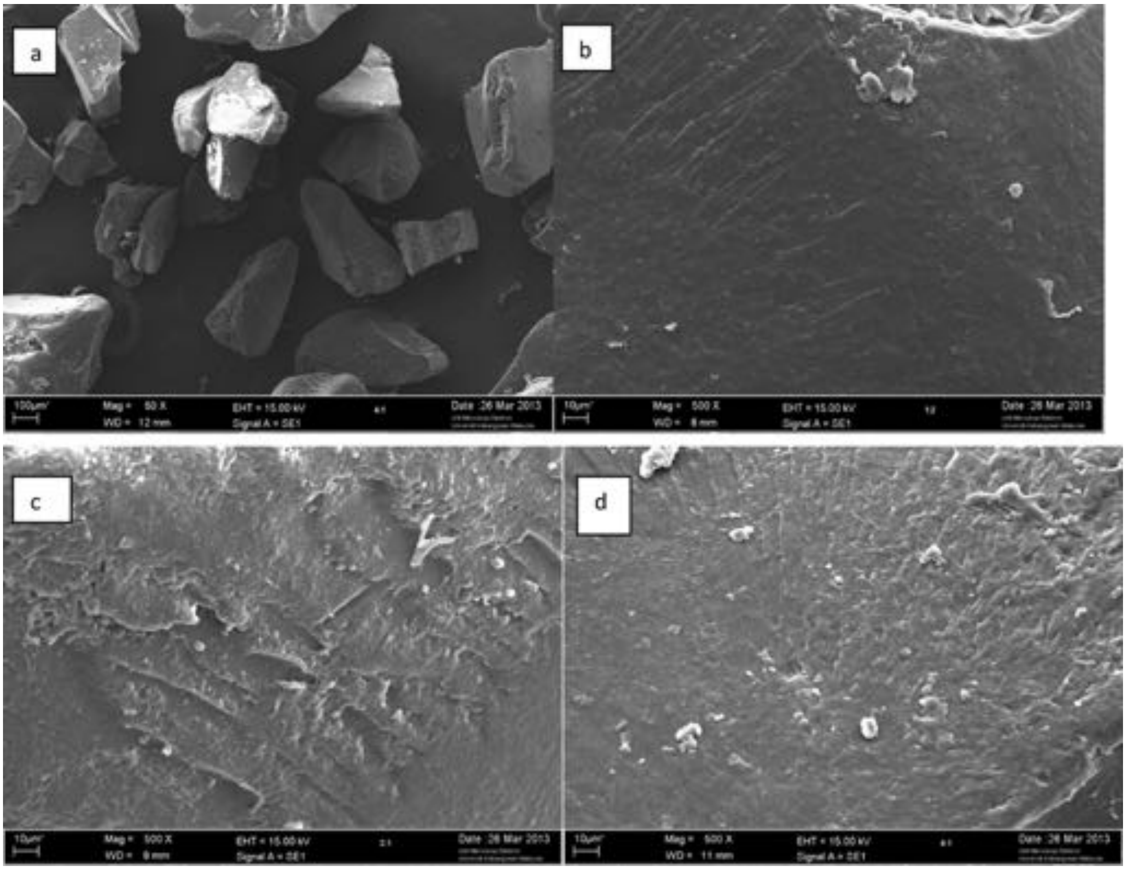

Fig. 3. Micrographs of a) *Dioscorea hispida* sp. starch granules b) polyacrylamide: starch (2:1) c) polyacrylamide: starch (1:2) and d) polyacrylamide: starch (3:5).

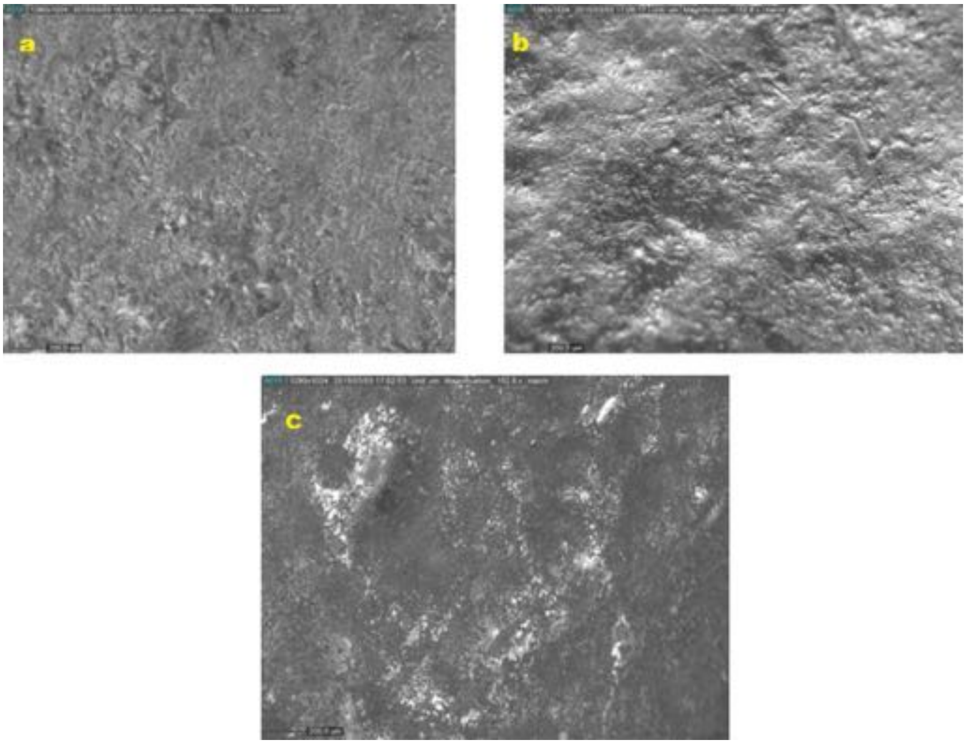

Fig. 4. Micrographs upon 150 times magnification (200 μm) of three pAam: starch ratios (a) 2:1 (b) 3:5 (c) 1:2.

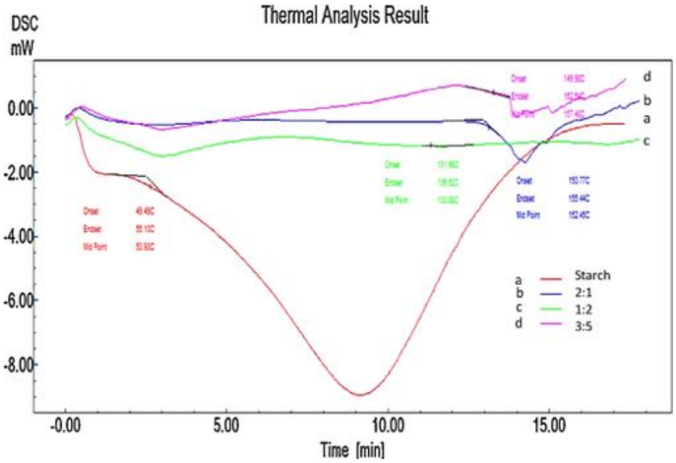

Fig. 5. Thermograms of different ratios of the coating sample: (a) starch powder only, coating ratio of pAam: starch (b) 2:1, (c) 1:2, (d) 3:5.

noted the differences in starch and monomer ratios significantly influenced the glass transition temperature (T_g) of the coatings. These results indicated many multistep taking places including the dehydration of carbohydrate chains and the breaking of C—O—C glycosidic bonding of the starch chain occur in the range 0 °C.–60 °C. However, there are prominent differences on the transitional glass temperature between the grafted pAam and starch. It has higher transitional glass temperature range compared to the original starch (T_g) which is 18.08 °C whereas the grafted coating samples for ratio 1:2, 2:1 and 3:5 (T_g) in the range of 138.88 °C, 152.45 °C and 157.48 °C respectively. It is concluded that the grafted coating film (S-g-pAam) were thermally stable which coincided with the amount of starch existed in the networks. On the other hand, the starch not only strengthens the networks but also acts as heat barrier which further enhances the thermal stability of the coatings.

3.6. *Coating effect towards white rot fungus* Pycnoporus sanguineus *and termite* Coptotermes curvignathus

3.6.1. *Effect towards white rot fungus* Pycnoporus sanguineus

White rot fungi is the sole microorganisms that efficien
degrade all the components of plant cell walls, both carbohydra
and lignin. As such species, e.g., *Pycnoporus sanguineus, Ceri*
riopsis subvermispora and *Trametes versicolor* have been studi
in detail and used as model organisms for this complex proce
These spesies could lead to severe damages to wood used
export and consequently affect the economical side. Apart fr
that, C. curvignathus termite also has been affected in the ag
cultural, silvicultural and horticultural sectors. In past resear
they reported that in agriculture, it is a serious pest of rubberwo
(*Hevea brasiliensis)* grown on peat soils in Indonesia and Thaila
These funguses have been threatening the rubber tree by attac
ing trunks and as well the roots. Although on land that has be
long planted or replanted with rubber, where the incidence of p
attack appears to be higher [37].

The inhibitory effects of grafted starch coating and their co
ponents on molds and the white-rot decay fungus *P. sanguine*
and termite *C. curvignathus* are shown in Fig. 6a and c. It is e
dent that the grafted coating S-g-pAam, exhibited both fungista
and fungicidal activities against the test molds. *Dioscorea hispi*
sp starch proved to be a stronger inhibitor to the test molds
various concentration. The synthesized starch based coating w
coated on wood samples by dipping method to investigate its in
bition ability on the growth of the decay fungus, *P. sanguineus.* T
samples tested shown in Fig. 6b and c was varied with three diffe
ent ratios of polyacrylamide and starch which is 1:2, 2:1 and 3
to observe its preliminary inhibition towards fungus *P. sanguine*
and invasion of termite *C. curvignathus* respectively. From Fig.
(iii), it can be concluded that the ratio starch up to 5 g, gave t
most effective inhibitory characteristic. The inhibition effect co
be related to the existence of dioscorine-type alkaloids in the tu
which gave remarkable disinfection effects [12,38]. The results

Fig. 6. (a) Rubberwood before coated with pAam-g-S coating while (b) Coated rubberwood affected by white rot fungi *P Sanguineus* with various ratios pAam: starch i) 2:1, ii) 1:2, and iii) 3:5. (c) Coated rubberwood attacked by termites *C. Curvignathus* while (d) Various ratios of coated rubberwood affected by *C. Curvignathus* with pAam: starch i) 2:1, ii) 1:2, and iii) 3:5.

Table 1
Mean weight loss of untreated and treated rubberwood after 12 weeks of exposure to *P. sanguineus.*

	Weight loss (%) ± SD				
	Concentration of dioscorea hispidagrafted polyacrylamide preservative (w/v)				
Rubberwood	0 (control)	01:01	01:03	01:05	01:10
	33.25 ± 7.33	15.45 ± 4.53	5.43 ± 0.98	5.99 ± 0.68	5.17 ± 0.65

in agreement with previous research, where they demonstrated the hydrogels made with additional of *D hispida* sp. starch gave highly resistant to some bacteria and fungi [12,39,40] The presence of a cyclic chain in the disc-type molecule with nitrogen bonding with the carbon group (C—N) gives antioxidant ability, including anti-biocide properties against certain fungal and bacterial species (Table 1) [41,42].

From the preliminary result shown in Fig. 6, the anti-fungal and anti-termite were further investigated by conducted the total weight lost (%) and feeding inhibitory (FI) test. The purpose of the investigation was to study the effect of starch content towards the inhibition potential over *P Sanguineus* and *C. Curvignathus*. For optimum result, starch content of the coating ratio were increasing from 1 g up to 10 g whereby polyacrylamide was remained constant with 1 g. Fig. 7 shows the observation of the total weight loss towards white rot fungi *P. sanguineus*. Found that the control (0%) of rubberwood which has not been coated, gave the highest weight loss (%) with 33.25 ± 7.33, attacked by *P. sanguineus.* However, convincing result was obtained for sample with concentration ratios of 1:1 (pAam-starch) where it able to reduce up to 15.45 ± 4.53 for the total weight lost (%) of rubberwood. The concentration ratios of 1:3 (pAam: starch) provided the optimum inhibition of the fungus. Result showed a moderate amount is required 3% of the starch ratio provided the best protection against *P. sanguineus.* Some of the pestiferous alcaloids that naturally exist in plant can inhibit the growth, cause morphological and physiological changes and affect

Table 2
Effect of wood extracts on feeding inhibition (FI) and lethal concentration (LC50) on *C. curvignathus*.

	Ratio of *D. hispida* sp. grafted polyacrylamide preservative (w/v)				
	0 (Control)	1:1	1:3	1:5	1:10
Feeding Inhibition (%) ± SD	15.32	47.56	99.21	98.32	100.0

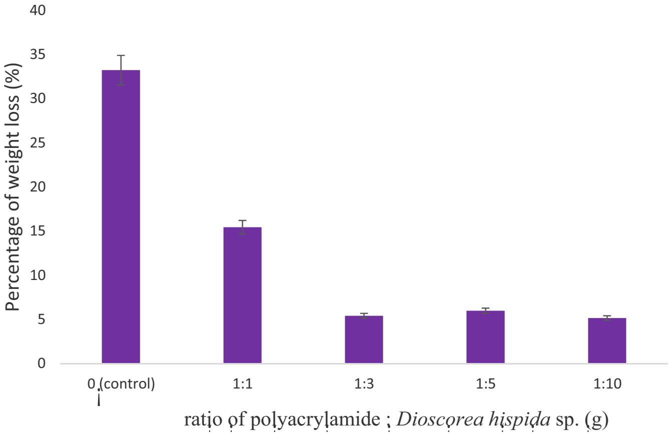

Fig. 7. Graph total percentage weight loss (%) of rubberwood treated with various ratio of *dioscorea hispida* sp. starch towards white rot fungi *P Sanguineus*.

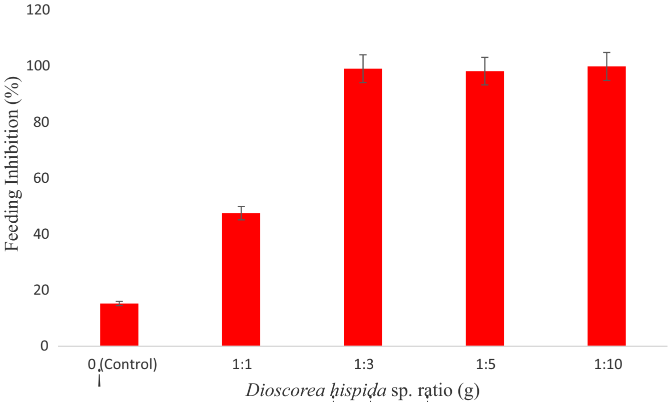

Fig. 8. Feeding Inhibition (%) of rubberwood towards termite *C. Curvignathus* as a function of *Dioscorea hispida* sp. ratio (g).

the reproduction of basidiomycetes. Fungal species and strains differ in their sensitivity toward certain chemical molecule such as nitrogen N in the protection mechanisms involved. Although heavy metals such as Hg, Cu, or Ni were relentlessly used in development of antifungal wood preservatives, however the utilization of these toxic inorganic metals consequently harmful to human and environment due to their leaching out from the sample [43].

3.6.2. Effect of wood extracts on feeding inhibition (FI) and lethal concentration (LC50) on C. curvignathus.

Termites serve a great role in recycling plant and woody materials, as they decompose the cellulose and help to break down approximately one third of the annual production of dead wood. Unfortunately, they are also highly destructive insect due to their wood eating habits. They destroy structural and non-structural building materials, finished goods, plants and agricultural crops and also other domestic goods such as paper, cloth, carpets and other cellulosic materials [42,44]. Hence this section discusses the effectiveness of *Dioscorea hispida* sp. wood coating as a function of *C. curvignathus* (Table 2).

Fig. 8 displayed effect of wood extracts on feeding inhibition (and lethal concentration (LC50) on C. curvignathus. Control (0 was attacked by *C. curvignathus* shows 15.32% feeding inhibito As the ratio of concentration increase to 1:1 (pAam-g-starch) t increment of (%) ± SD feeding inhibition is evident at 47.56%. comparison for ratio 1:3 and 1:4 the percentage for feeding in bition is vigorously increased up to 99.21 and 98.32%, respective As shown in tabulated data, the ratio 1:3 concentration of pAa starch gave optimum feeding inhibitory by termites *C. curvignath* It is expected that by increasing starch to 10 equivalent ratio total feeding inhibitory upon termites are obtained. These resu are clearly supporting previously discussed in section (i).

Contemporary protection methods include both physical a chemical approaches. Physical methods include physical barri such as stainless steel mesh or gravel aggregates, heat, freezing, a microwaves have been used to control the termite invasion [45]. example, Termimesh^{TM} a commercial stainless steel mesh is n commonly employed as one of the termite barriers. Chemical b riers include the use of chemical termiticides in the soil around t structure to be protected. On the other hand, chemical treatme of wood is a common and effective method which is widely us to prevent termite damage. Although this approach is found wo able however, some of the chemicals used are toxic and probl occurs when this poisonous compound leach out or mishandled. order to alleviate these concerns, it is necessary to look for alt natives to minimize the use of synthetic and harmful chemica Bio-pesticides, which are extracted or purified substances fr plants potentially promising replacements due to advantages su as their minimal toxicity, widespread availability and relatively l cost.

4. Conclusion

Starch grafted polyacrylamide (S-g-pAam) coating was synt sized using *N*,*N*′-methylenebisacrylamide as a cross-linking ag and its potential inhibition was examined. There were absorpt in the FTIR spectrum of the coatings that significantly differ fr the peaks corresponding to their individual components. Thus shows that the functional groups in the structure of starch and po acrylamide change significantly. The cross-linking peak of sta and polyacrylamide was expected at the frequency absorpt 1655 cm^{-1} of Fourier Transformation Infrared. Topography a surfaces of the synthesized S-g-pAam coating were determi via Scanning Electron Microscope (SEM) in the 10 μm magnifi tion and Optical Scanning until 220 x micron resolution. It show homogeneous, smooth and translucent morphology that applica for coating system. Differential Scanning Calorimetry (DSC) sho a convincing results towards thermal degradation of grafted co ing pAam-g-S. Coating with ratio pAam: S 3:5 shows the high transition glass temperature observed at 157 °C. Further inves gation is made, to determine the effectiveness of native sta *Dioscorea Hispida* sp extract upon total weight loss (%) of rubb wood towards white rot fungi *P Sanguineus* and feeding inhibit (FI) of *C. curvignathus*. Results showed disinfection test of t infectants (white rot fungus *Pycnoporus sanguineus* and termite *curvignathus*) occurred at an optimum sample ratio which was 1 pAam:starch. This formulation gave total inhibitory to both of t infectants. Based on the result obtained, S-g-pAam coating has t potential to be used as novel organic preservatives and biope cides which gave major decontaminating factor for prolonged the structure of rubberwoods.

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