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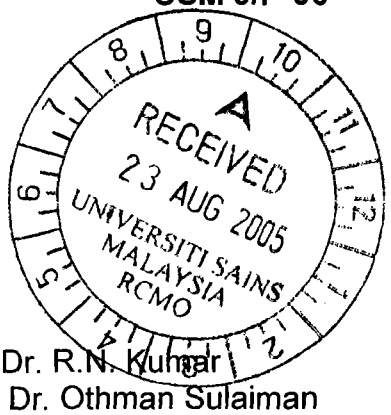

BAHAGIAN PENYELIDIKAN & PEMBANGUNAN
CANSELORI
UNIVERSITI SAINS MALAYSIA

Laporan Akhir Projek Penyelidikan Jangka Pendek

1. Nama Penyelidik: Dr. Rokiah Hashim
   Nama Penyelidik-penyelidik lain (Jika berkenaan): Dr. R.N. Kumar
   : Dr. Othman Sulaiman

2. Pusat Pengajian/Pusat/Unit: Teknologi Industri, USM

3. Tajuk projek: "Performance and durability of UV cured surface finish on preservative treated wood"

4. a) Penemuan Projek/Abstrak

Abstract

The study investigates the effect of wood preservatives on the curing and performance of ultraviolet (UV) curable coatings. The preservatives used were basileum, boric acid, and borax pentahydrate. The analysis was divided into two parts; first by incorporating the wood preservative (Basileum) in the coating material and secondly impregnating the wood with preservatives (basileum, boric acid, borax pentahydrate) and evaluates its the effects of application on the curing of UV coating. The results from the pendulum hardness showed that when the concentration of the basileum increase the UV curing will be decreased. This was further confirmed from the FTIR study showing the wavelength of the basileum and the photoinitiator were apparently the same. The study showed that 2% of basileum did not interfere in the UV curing as has been determined from the adhesion, film pencil hardness, and gel content. From the second analysis, the results showed that the mortality and the wood consumption of termites were proportional to the concentration of basileum whereas for wood treated with borax pentahydrate and boric acid showed higher mortality but in low wood consumption. For the soil block test, all the three preservatives showed reduction in wood consumption as the concentration of the preservatives increases. The presence of preservatives showed lower in the adhesion and film hardness on the wood surface. There was no change in the wood coating after 6 cycles of the cold check test.

b) Senaraikan Kata Kunci yang digunakan di dalam abstrak

UV curable coatings
Preservative
Basileum
Boric acid
Borax Pentahydrate
Pendulum hardness
Gel content
Termites test

5) Output dan Faedah Projek

a) Penerbitan (termasuk laporan/kertas seminar)
(Sila nyatakan jenis, tajuk, pengarang, tahun terbitan dan di mana telah diterbit/dibentangkan)

Sila lihat
(Draf untuk penerbitan dilampirkan)

b) Faedah-faedah lain seperti perkembangan produk, Prospek Komersialisasi dan pendaftaran paten)
(Jika ada dan jika perlu, sila guna kertas berasingan)

Tiada

c) Latihan Gunatenaga Manusia

i) Pelajar Siswazah :

ii) Pelajar Prasiswazah: Putri Tamyez

Effect of wood preservatives on the performance and curing of ultraviolet curable coating

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Abstract

The study investigates the effect of wood preservatives on the curing and performance of ultraviolet (UV) curable coatings. The preservatives used were basileum, boric acid, and borax pentahydrate. The analysis was divided into two parts; first by incorporating the wood preservative (Basileum) in the coating material and secondly impregnating the wood with preservatives (basileum, boric acid, borax pentahydrate) andevaluates its the effects of application on the curing of UV coating. The results from the pendulum hardness showed that when the concentration of the basileum increase the UV curing will be decreased. This was further confirmed from the FTIR study showing the wavelength of the basileum and the photoinitiator were apparently the same. The study showed that 2% of basileum did not interfere in the UV curing as has been determined from the adhesion, film pencil hardness, and gel content. From the second analysis, the results showed that the mortality and the wood consumption of termites were proportional to the concentration of basileum whereas for wood treated with borax pentahydrate and boric acid

showed higher mortality but in low wood consumption. For the soil block test, all the three preservatives showed reduction in wood consumption as the concentration of the preservatives increases. The presence of preservatives showed lower in the adhesion and film hardness on the wood surface. There was no change in the wood coating after 6 cycles of the cold check test.

Introduction

Rubberwood or Malaysian Oak is one of the main timber species used for furniture. Due to its susceptibility to fungal attacks, rubberwood must be treated with preservatives prior to its use (Hong et al. 1982). Boric acid and borax pentahydrate are among commercially used preservatives for rubberwood. Basileum was commercially used preservatives for the plywood industry normally added into the glue mix. For furniture use, rubberwood was normally coated to enhance its surface appearance. Furniture coatings must fulfill special requirements since their surfaces have to be odorless and free of any long term emittable substances. The surface finished rubberwood is then cured with either conventional curing or ultraviolet cured (UV). Ultraviolet curable system have many advantages (Bongiovanni, et al. 2002). It has high gloss, good resistance towards abrasion and has immediate cure. The key to perfect furniture is excellent marketable raw material, well preserved systems on the wood, and finally a glossy and good film properties on the surface of the wood. Several studies have showed growth capabilities of fungal such as blue stain with different surface coatings (Sharpe and Dickinson, 1992; Homan and

Militz, 1995). Few research that has been done investigating the influence of wood characteristic on the properties and durability of ultra violet cured coating on wood substrates, particularly rubberwood (Feist and Ross, 1995; Petric, et al. 2003). Rubberwood has been taken serious attention for being a great demand in a huge mass production of knockdown furniture in Malaysia. Apart from that, preservation on this species has been in great consideration not only to produce an excellent surface coating, but also in improving the utilization efficiency of wood. Subsequently furniture produced will have a higher long span. The knowledge on compatibility of certain preservatives with surface finishes are still lacking.[2,5,6] This study therefore prelimanary investigates the effects on performance and durability of the ultraviolet cured surface finishes on the preservative treated wood. The properties studied include gel content, cold check test, film hardness on wood surface and glass plates, adhesion on wood surfaces and finally evaluating its resistance towards termites attack.

Materials and methods

The study were carried out in two ways. First by incorporating the wood preservative in the coating material. This was done using basileum at 2%, 6%, 10%, 12% and along with the control. Secondly by impregnating the wood with preservatives. Fresh rubberwood samples were obtained from a nearby mill. The samples were air dried prior treatment. using selected preservatives by vacuum treatment for 30 minutes in a dessiccator. The preservatives used were boric acid, borax pentahydrate and basileum. The wood samples were sanded

prior surface coating with known grade. The samples were then coated using selected UV cured surface coating. Several evaluation tests will then carried out which include adhesion tape test (ASTM D3359-780 , Film hardness by pencil test on wood surface (ASTM 3363-74) and temperature change resistance (ASTM D1211-74). In investigating the effect on durability, parts of the UV cured surface finish on preservative treated will be exposed to soil burial test. Selected wood preservatives will also be incorporated with the selected UV cured wood finishes and performance will be based on gel content, film hardness on glass plate and FTIR

Preparation of coating formulations and application on wood and glass surface

The formulations were 10 parts of polyester Acrylate (Ebecryl 810), 5 parts HDDA (1,6-Hexanedioldiacrylate), 0.4 parts of Irgacure 651 and 0.2 parts of Irgacure 184. The photoinitiators were obtained from CIBA specialty Chemical (UCB Asia Pacific Sdn. Bhd.). Each percentage of basileum was added separately for comparison. Samples of lacquer were drawn onto glass plates and onto rubberwood surface in layers of 40μm thick with a spiral coater. The wood samples were sanded smoothly with sand paper grit no. 80. This application was done in an illuminated room with yellow light, in order to eliminate uncontrollable effects of daylight. This was then followed by the exposure to a medium pressure mercury vapour lamp of Portacure 1000 in 200 W/in at a line speed of 10-15 n/min in 5 passes.

Pendulum hardness test on glass plate surface (DIN 53157)

Pendulum hardness Erischen, Model 299/300 tester was used to measure the Koenig pendulum hardness of the cured film. The pendulum hardness test was carried out according to DIN 53157 It is the time taken for the pendulum to reduce its angle of swing from 6° to 3°. The result is expressed as % pendulum hardness as shown below:

% Pendulum hardness = [(No. of oscillations for damping from 6° to 3° for sample)/ (No. of oscillations for damping from 6 to 3 for standard glass)] x 100

Evaluation on gel content

The films which has been taken out from the glass plate were then washed with acetone and dried in the oven at for 5-10 minutes to ensure all the water evaporates. After that the cured polymer was placed in a Soxhlet apparatus and extracted with toluene, acetone, and ethanol in a ratio 4:1:1 for 3 hours. The extracted samples were then air dried and further dried in the oven until constant weight. The weight loss caused by the extraction was expressed as the percentage of the initial weight was the gel content and was assumed as the degree of polymerization.

Identification of wavelength of Basileum

Spectrophotometer (UV/VIS) model UV 160A Shimadzu was used to identify the wavelength of the basileum.

FTIR

The FTIR test was carried out to identify how much reduction of acrylate monomer has occurred or how much has the film cured in 0%, 2%, 6% and 10% basileum. Scanning is carried out from 4000 cm^{-1} (2.5μ) to 400 cm^{-1} (25.0μ). The FTIR used is Nicolet's AVATAR 360 E.S.P.TM FTIR spectrometer system.

Laboratory evaluation of rubberwood to termites resistance

Subterranean termites were collected from the nearby University campus using the bridge method(Tamashiro et al. 1973). Three types of preservatives used; basileum, borax pentahydrate and boric acid. Each preservative was prepared in 5 different concentrations (0%,2%, 6%, 10% and 12% along with the control). Rubberwood test block of size 2x2x1.5 cm. Were then impregnated respectively with the various preservatives at different concentration. For each concentration 10 replicates of wood blocks were used. Each replicate was then coated with the UV cure finishes. The experiment was set up in a jar size 6.5cm diameter and height 12 cm. Each jar contained 40g of washed beach sand, screned at 40mm and 16 mm, oven dried at 100°C and autoclaved to ensure free from contaminants. After that 6 ml of distilled water was added to provide moisture to the termites. Then the test blocks were introduced into the jars. Finally 100 workers and 5 soldiers were added to each jar. The assembled jars

were then placed in a large moisturized and damp container where occasionally water was added.

Exposure to the soil

Samples were exposed to the burned soil for 2 months. Each sample has 15 replicates. Ovendry weight was obtained prior to exposure and finally after exposure. Rubberwood samples treated with UV surface coating were used as control.

Adhesion tape test on wood surface

The adhesion tape test on wood surface was carried out according to ASTM D3359-78. In this experiment an area of free blemishes and minor surface imperfections is selected. The panel on a firm base are placed and under illuminated magnifier the parallel cuts are made through the film to the substrate on one steady motion using just sufficient pressure using a cutting tool Cross Hatch Cut Model 295. Two complete laps of tape are removed and discarded. An additional length is removed at steady rate and a piece is cut about 3 in (75mm) long. The center of the tape 1 inch(25mm) wide semi transparent pressure sensitive tape with an adhesion strength of 40±2.1g/mm width is placed over the grid and in the area of the grid smooth into placed by a finger. To ensure good contact with the film the tape is rubbed firmly with the eraser of the end of a pencil. The colour under the tape is a useful indication of when the good contact has been made. The tape is removed by seizing the free

end and rapidly pulled off at as close to an angle of 30° as possible. The grid area were inspected using the magnifying glass which is an illuminated magnifier to be used while making individual cuts and examining the test area.

Temperature change resistance of UV films applied to wood

The test was done according to ASTM D 1211-74. Two replicates of each concentration of basileum, boric acid and borax pentahydrate were used. The failure end point is defined as the cycles on which innumerable fine lines appear or on which a total of four checks (25 to 50mm) in length appear. Two replicates of each concentration was used for basileum, boric acid and borax pentahydrate.

Film hardness by pencil test

Film hardness test on wood surface was done according to ASTM D 3363-74. A set of equivalent, calibrated wood pencils meeting the following scale hardness is provided. The difference between two scratch hardness is where the hardest pencil that will not rupture the film and is recorded at each point.

Results and Discussion

The study has been divided into: The UV coating part on the glass plates, durability of the wood part of the wood and the coating properties using UV curing on the wood surface. Study on the UV curing on the glass plate focussed only on basileum.

Influence on the film hardness on glass plates

When the concentration of basileum increases, the pendulum hardness decreases to 55%.7%.

Effect of basileum concentration on the pendulum hardness

The results shows that as the percentage of the basileum increased lesser pendulum swings and therefore results in lower film hardness (Figure 1). From the ANOVA study showed no signicant difference was seen for 2% and 6% concentration of basileum. that the effect of basileum concentration is significant at 10 and 12 %.

Effect of basileum concentration on the gel content

Figure 2 shows the results on the effect of basileum on the gel content. The results shows that as the concentration of basileum increase, the gel content of the film decreases. However with the addition of 2% basileum , the results was comparable with that of the control. The effect on gel content was statistically significant with the addition of 12 % concentration of basileum.

Identification of absorption spectra of basileum , Irgacure 651 and Irgacure 184

Basileum showed an absorption peak of 385nm, and referring to Ciba Geigy Specialty Chemicals Inc, the UV absorption peak of Irgacure 651 is 330-340

and Irgacure 184 are 240-250 and 320-335nm as shown in Table 1. The reduction of coating properties with the presence of basileum in curing of UV using acrylate polyester. A further evaluation was done by identifying the wavelength of basileum. The wavelength of basileum is in the same range of wavelength of the photoinitiators. The results showed that Basileum competes UV light with the photoinitiator and therefore reducing the efficiency of the photoinitiator. With the increase percentage of basileum, the film did not polymerize which eventually lowers the quality of coating.

Residue of acrylate monomer unsaturation in the cured film

The results showed that 2% basileum did not interfere in the polymerization and the 2% treated film has polymerized like the control. This was based on the evaluation from FTIR (Figure 3-6) indicating as the concentration of the basileum increase, the residue of the acrylate monomer also increases with a bigger area of curve. and could affect the quality of UV coating.

Influence on the decay resistance of the coated samples after treatment

In the second part, the results showed a lower trend in the wood consumption and higher trend in the mortality of termites for samples treated with boric acid and borax pentahydrate. However, for basileum treated wood, high wood consumption and high mortality of termites were observed. For basileum, the method of incorporating the preservative into the wood by adding it into the UV

formulation and coated on the wood surface could contribute to this. (Refer to Figure 7-13)

Coating properties on the wood surface

All the three preservatives showed lower trend of pencil hardness, film adhesion on the wood surface and also on the soil block test. The effect of change in high and low temperature on the surface coating, the number of cycles passed in this experiment is 6 cycles and no failures such as cracks on the applied film after visual observation were observed. This means that the surface coating for all the 3 types of preservatives used were able to withstand the exp[osure to the sudden change of low and high temperature and a good resistance to checking and cracking of UV systems.

Conclusion

When the concentration of the basileum increase the UV curing will be decreased. The study showed that 2% of basileum did not interfere in the UV curing. The mortality and the wood consumption of termites were proportional to the concentration of basileum whereas for wood treated with borax pentahydrate and boric acid showed higher mortality but in low wood consumption. For the soil block test, all the three preservatives showed reduction in wood consumption as the concentration of the preservatives increases. The presence of preservatives showed lower in the adhesion and film

Sharpe, P.R. and Dickinson, D.J. 1992. The ability of Aureobasidium pullulans to penetrate wood surface coatings. The International Research Group on Wood preservation. IRG/WP/1557-92

Acknowledgement

We would like to acknowledge Universiti Sains Malaysia for the short term grant, Borax Ltd. USA for kindly providing the boron based preservatives and ISM Materials Protection Sdn. Bhd. for providing the basileum preservatives.

Table 1 Absorption peak of basileum and photoiniators

Basileum	385nm
Irgacure 651	330-340nm
Irgacure 184	320-335nm

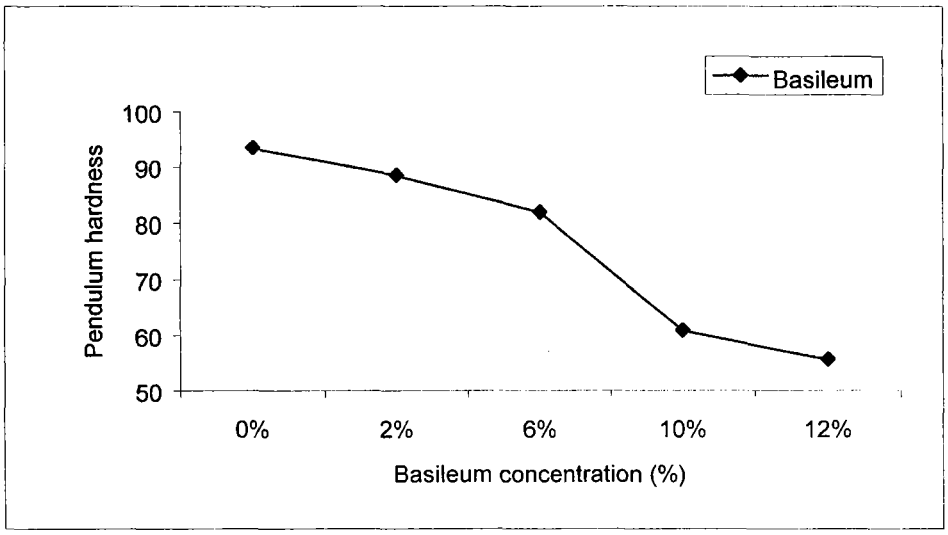

Figure 1 Effect of basileum concentration on pendulum hardness

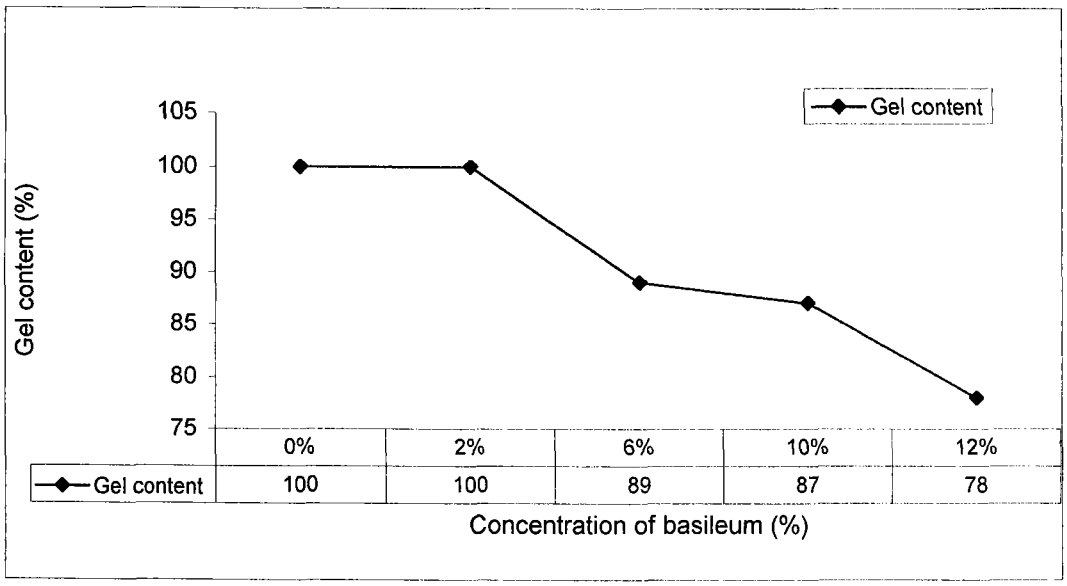

Figure 2 Effect of concentration of basileum on gel content

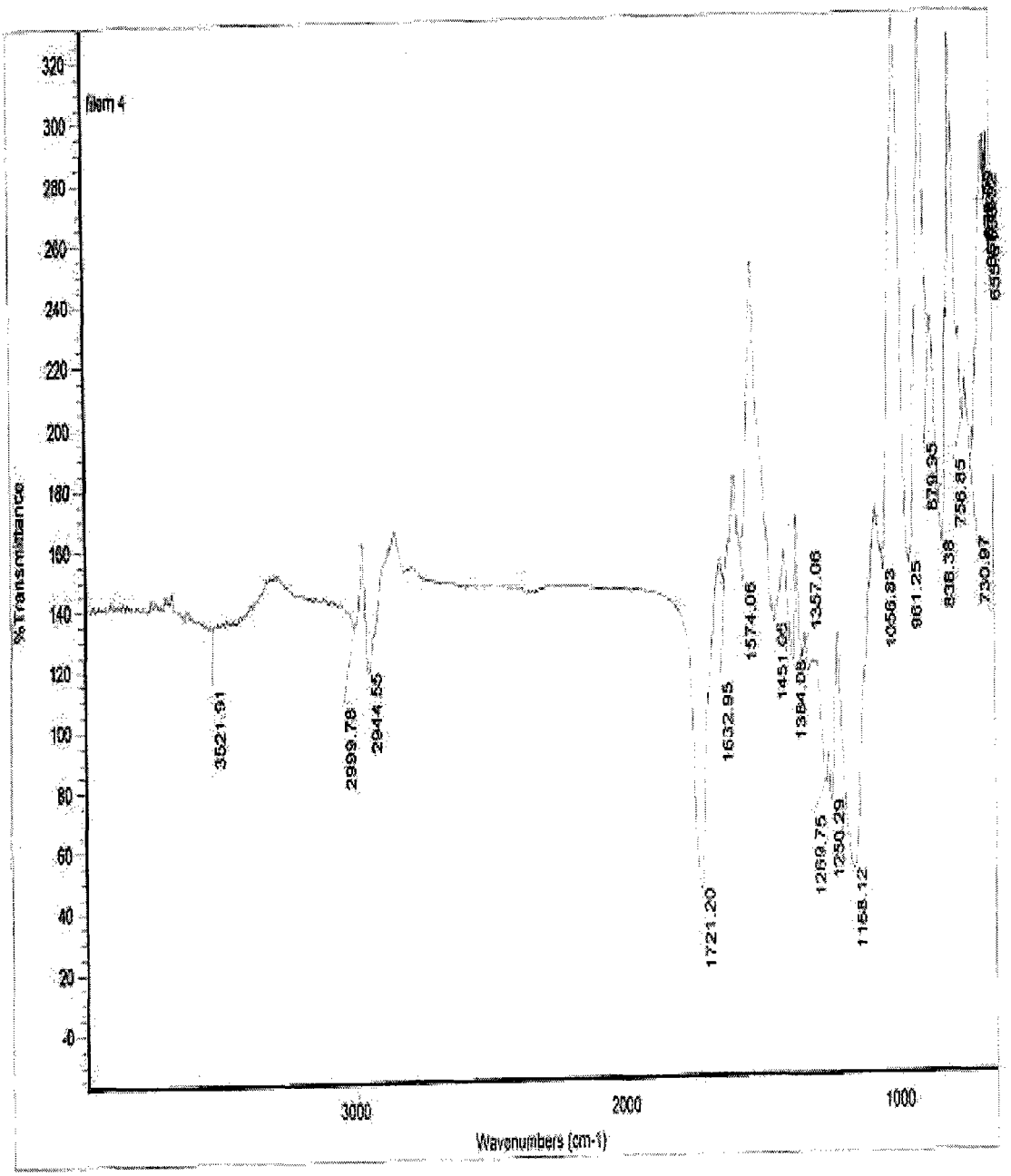

Figure 3 FTIR Acylate residue as a control in the cured film

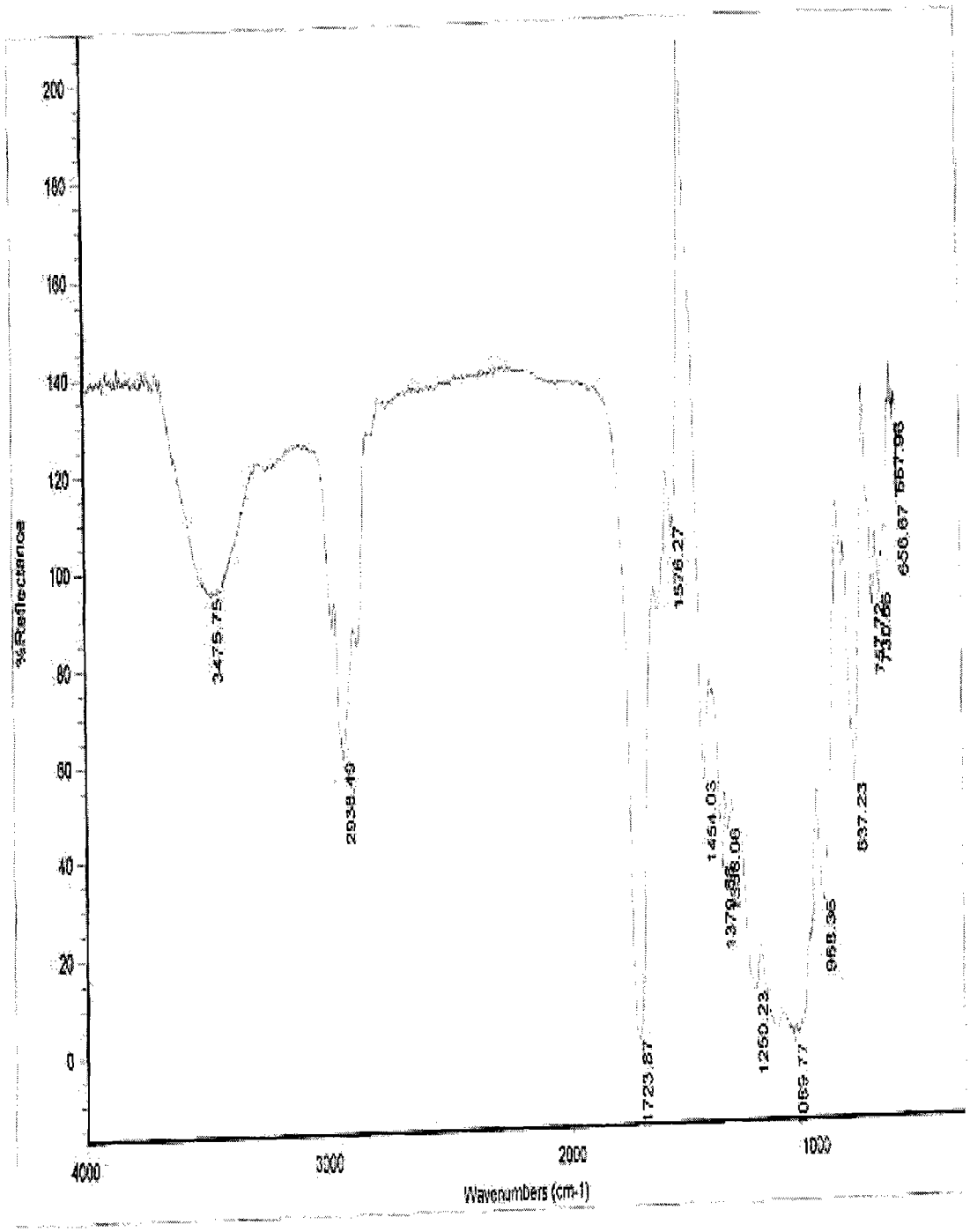

Figure 4 FTIR Acrylate residue with the presence of 2% basileum in the cured film

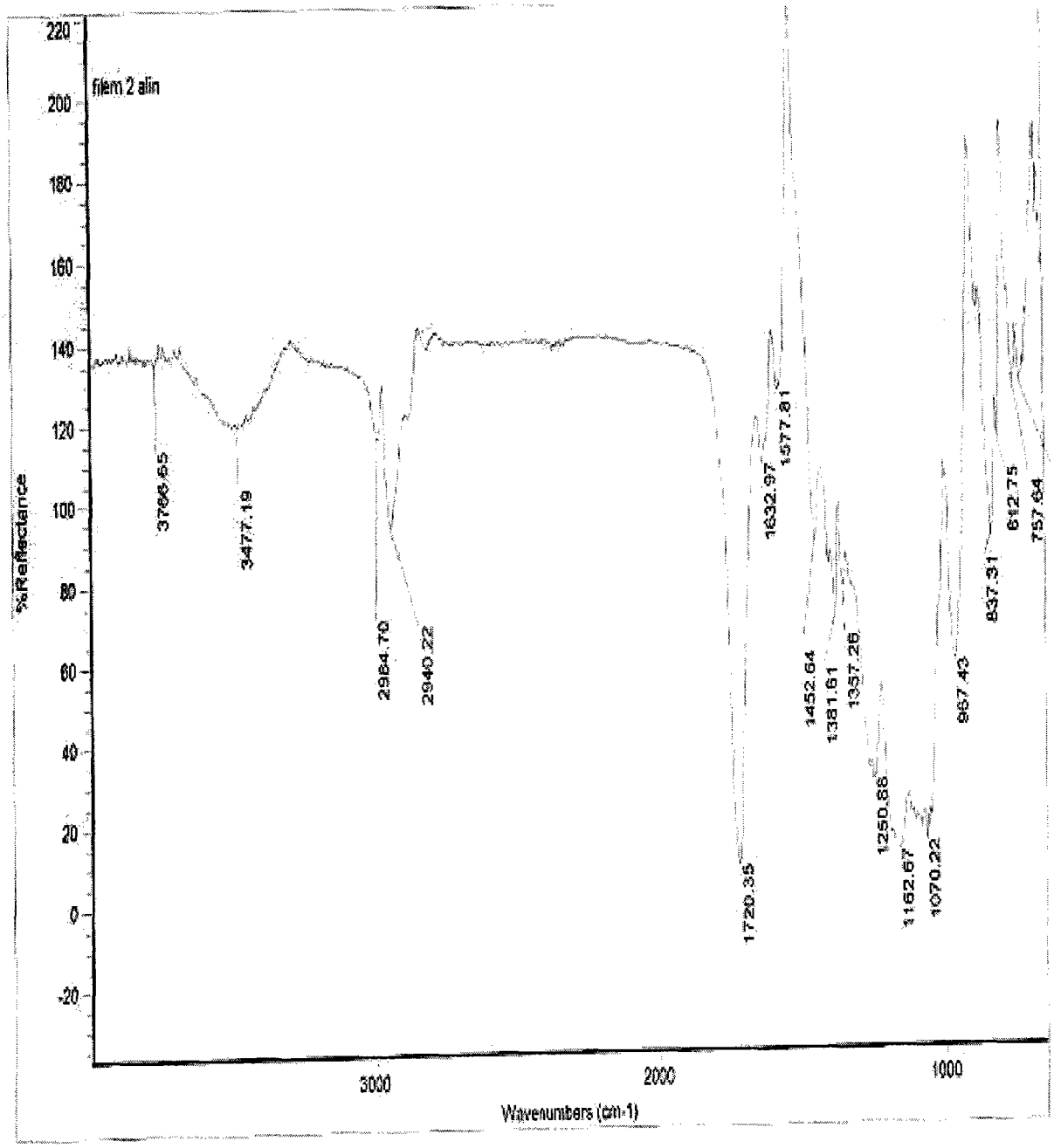

Figure 5 FTIR Acrylate residue with the presence of 6% basileum in the cured film

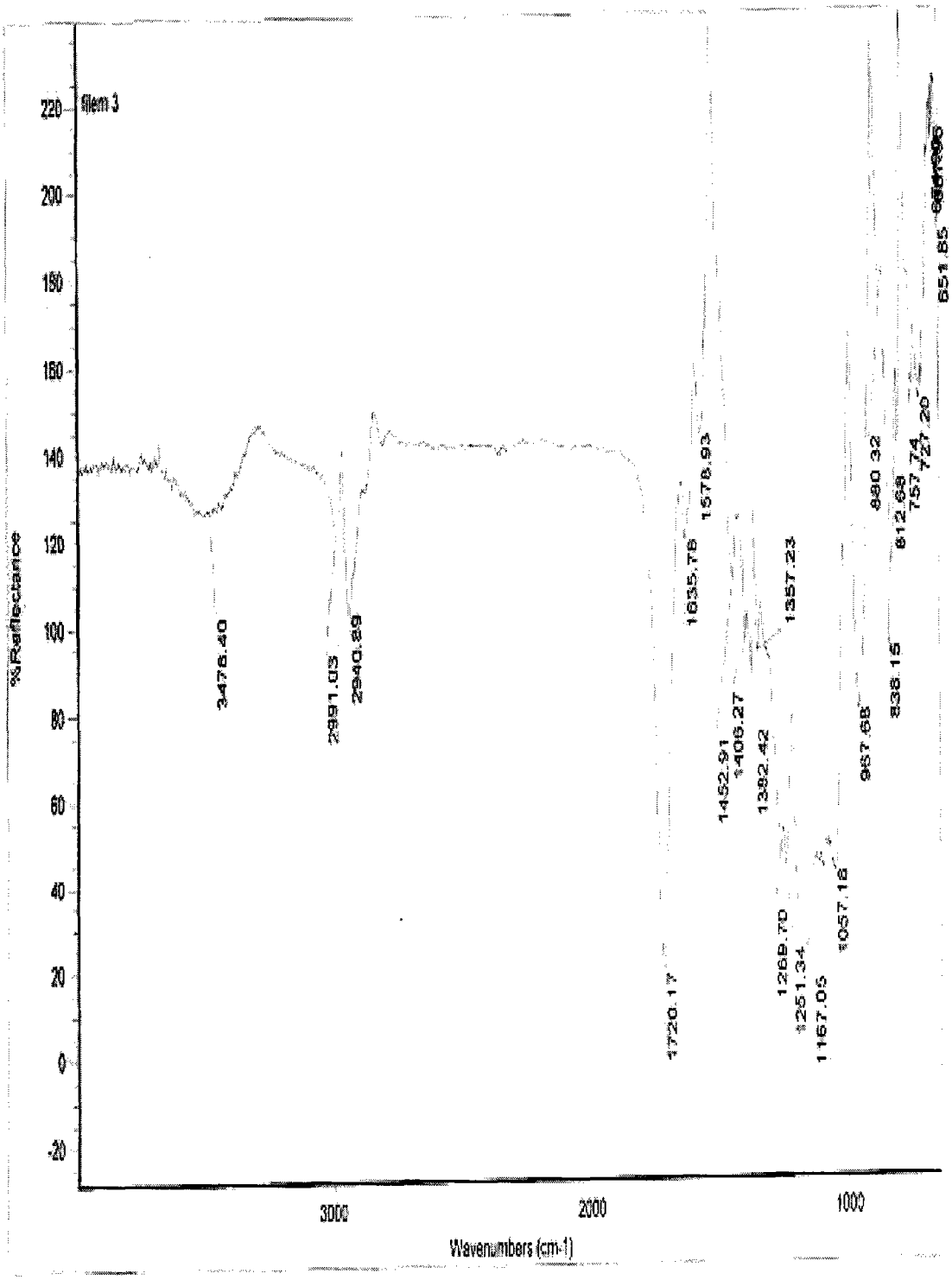

Figure 6 FTIR Acrylate residue with the presence of 10% basileum in the cured film

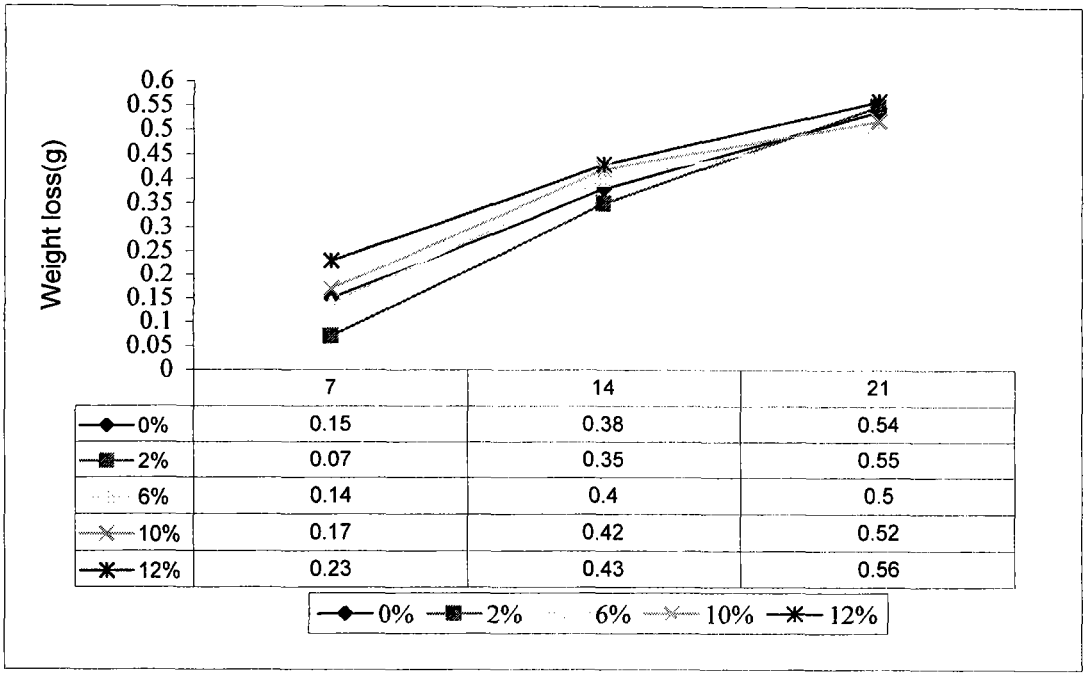

Figure 7 Mean wood consumption after exposure of wood blocks treated with basileum

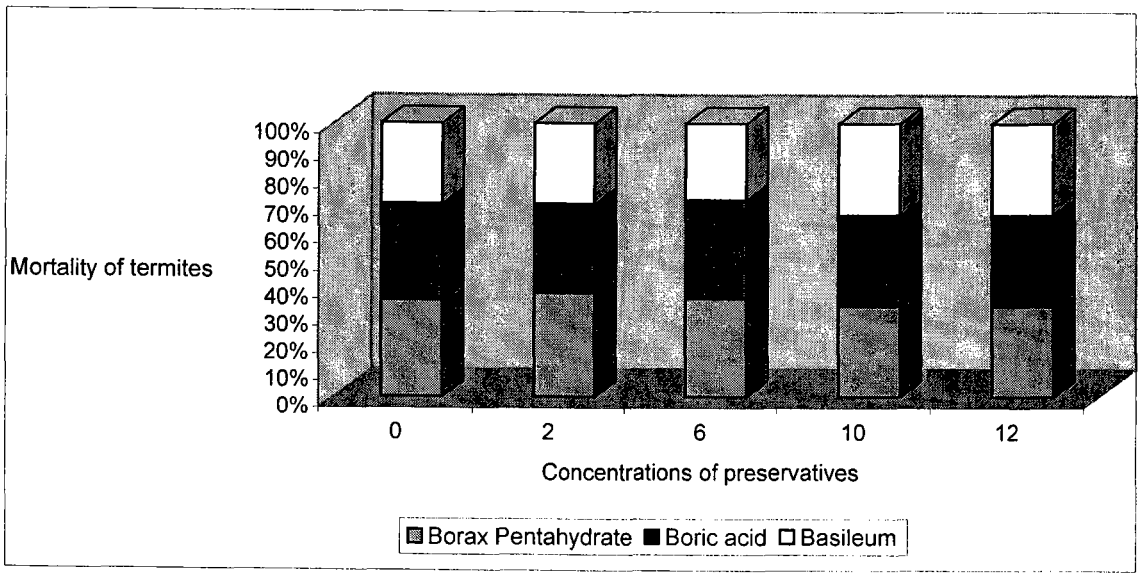

Figure 8 Mean mortality of termites after 3 weeks

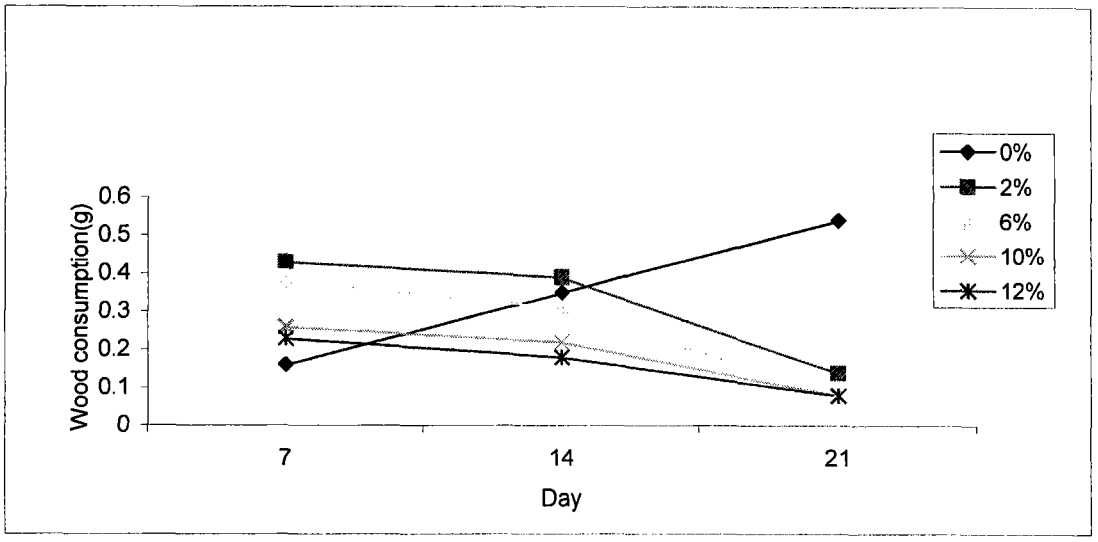

Figure 9 Mean wood consumption (g) after exposure of wood blocks treated with boric acid

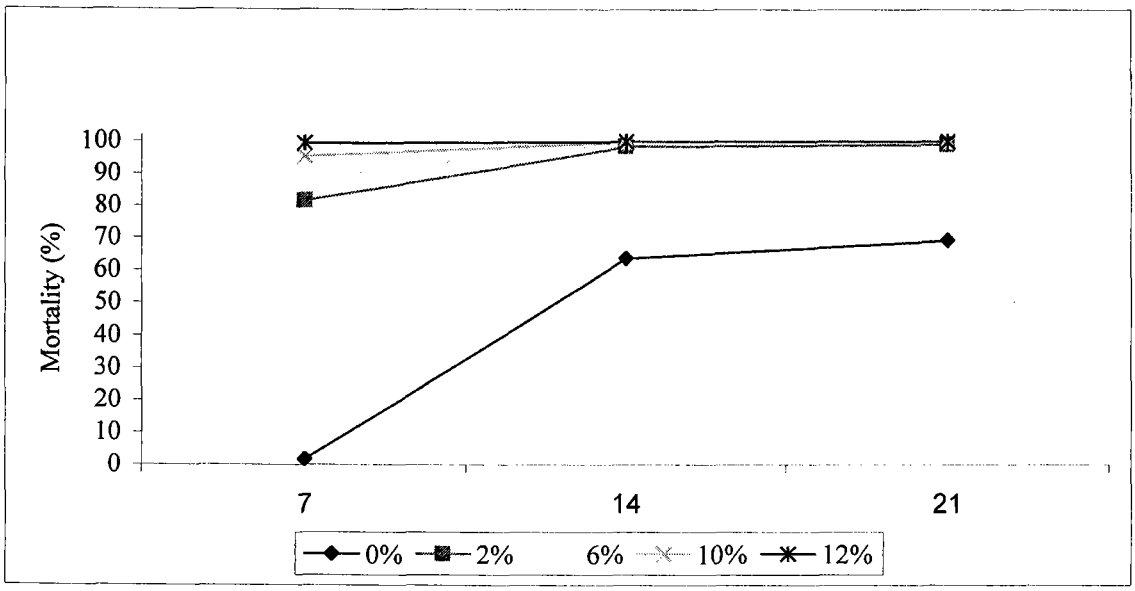

Figure 10 Mean mortality of termites for wood blocks treated with boric acid

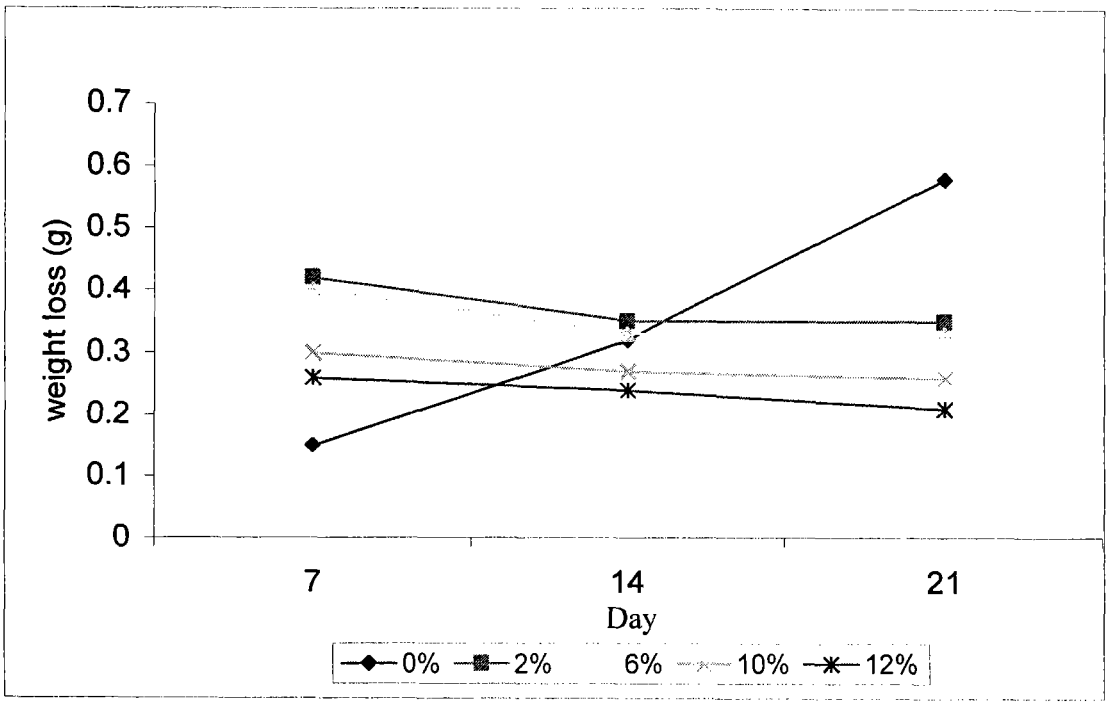

Figure 11 Mean wood consumption (g) for wood block treated with borax pentahydrate

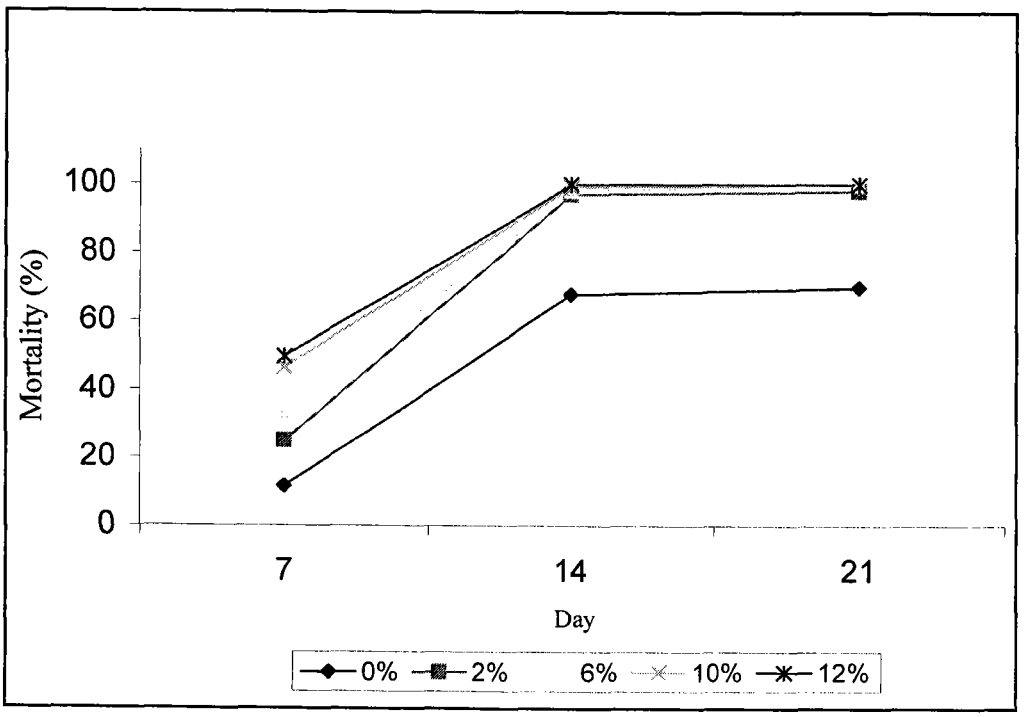

Figure 12 Mean mortality of termites after subjected to wood block treated with borax pentahydrate

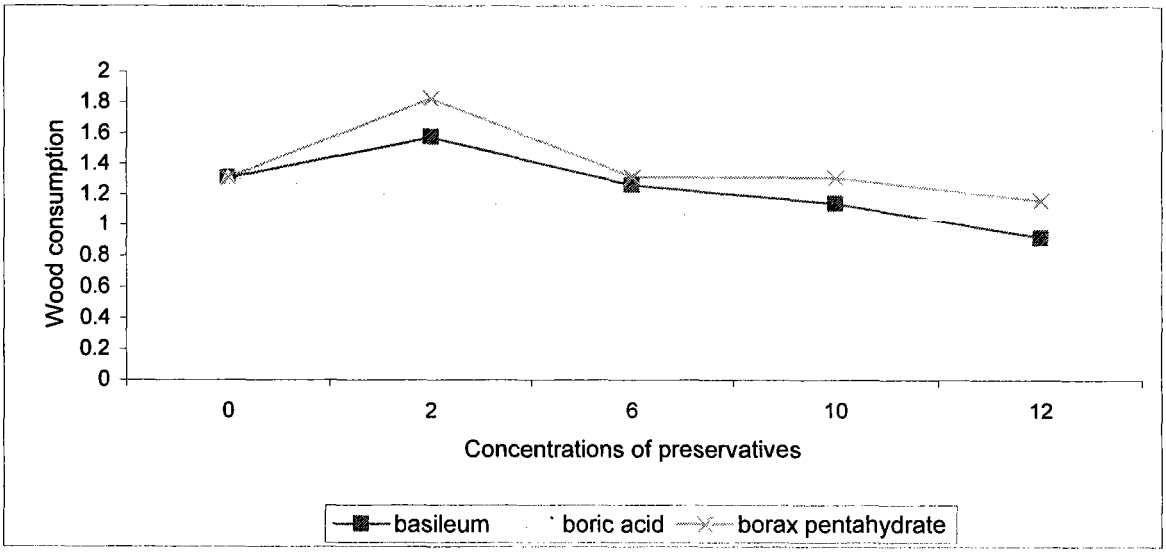

Figure 13 Mean wood consumption (g) after soil block test