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# AN INVESTIGATION ON THE EFFECTIVENESS OF PREPOLYMERIZATION, DRYING AGENTS AND PROTECTIVE COATING ON THE CHARACTERISTICS OF LACQUERWARE*

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## Abstract

Thitsi (Myanmar Lac) sample was collected from Kawlin Township, Sagaing Region during October and November, 2012. The physico-chemical characteristics of raw and prepolymerized (purified) Thitsi such as colour, odour, ash, viscosity, boiling range, pH and specific gravity were determined. Moreover, chemical constituents such as moisture and volatile matter, thitsiol, nitrogenous matter, gummy matter and fatty or oily matter were investigated. Bamboo lacquerwares were prepared by applying raw and purified Thitsi several time and hardened in the underground cellar. Effect of number of coating and drying agents on the hardening time of Thitsi-coat on lacquerwares were investigated at the relative humidity (70 – 87)% and the temperature (27.1 – 31.8)ºC of the underground cellar. Evaluation of the quality of the prepared lacquerwares was studied by investigating the pencil hardness, cross hatch, adhesion, coating thickness, specular gloss, immersion resistances, resistance to steam at 100ºC, and weathering resistance were determined. The best quality of lacquerware was achieved by restricted increased number of coatings and lacquerwares coated six or seven times occupied the perfectness. Although drying agents can accelerate the polymerization time, it can impair the properties of lacquerware. Thitsi coated lacquerwares are safe and adaptable for use in house-hold purposes and can also be kept in special environments for several years without diminution of their aesthetic attraction. Additionally, the quality of lacquerware was upgraded by applying a protective coating to give a high gloss lacquerware with a lesser number of consecutive lacquer coatings (two coats) and the upgraded ware could be employed for exterior uses.

**Keywords:** Thitsi, kurome lacquer, prepolymerize, underground cellar, specular gloss

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## Introduction

Lacquer used in Myanmar is called "Thitsi", literally meaning wood varnish. It is the sap of *Melanhorrea usitata*, a tree native to Southeast Asia. Lacquer tree grows wild up to elevations of three thousand feet in the drier forests of Myanmar. There seems to have been no attempt to cultivate it using plantation management techniques (Fraser-Lu, 1996).

Thitsi consists of phenolic matter, water, gum, nitrogen containing matter and laccase, all of which are known to be necessary for hardening of Thitsi. No organic solvent evaporates during the drying process, only water. Because of the self-drying system, natural lacquer is an eco-friendly product that is expected to be useful in the future as a coating material (http://www. intechopen.com). Thitsi was first used as an adhesive for fixing gold foil, chipped porcelain, or attaching arrowheads to the wooden shaft. Then, with the accumulation of experience and awareness, Thitsi was applied to bamboo, wood and other furniture. It is still used in daily life in crafts and industrial equipment (http://www.jsaweb.recent-advances-in-research-on-lacquer-allergy. html).

Indeed, lacquerware has many of the characteristics of modern plastic. It is light, waterproof, easily moulds and dries to a hard state. It can be applied to virtually any surface: plain or carved wood, bamboo, paper, fabric, even metal and stone. It stiffens, strengthens and preserves the surface to which it is applied. It is decorative, inexpensive, hygenic and can be painted, moulded, and carved. When polished, it takes on a flawless sheen (Fraser-Lu, 1996).

The objectives of this study were to get the scientific data concerning with Myanma Thitsi and lacquerwares, eco-friendly products and to investigate the upgraded lacquerware for exterior uses.

## Materials and Method

### Materials

Thitsi sample was collected from Kawlin Township, Sagaing Region during October and November. Matured stalks of bamboo (Wa-ya) (*Gigantochloa rostrata Wong*) from Yangon Region were used as the substrates to prepare the lacquerwares. Turpentine oil and linseed oil were also obtained from Kemiko Cosmetics and Chemical Dealers, Yangon Region. UPG protective coating was provided from United Paint Group Co., Ltd, Yangon Region.

## Methods

### Purification or Prepolymerization of Thitsi

Raw Thitsi was homogenized by a make-shift homogenizer. About 500 g. of Thitsi was taken and homogenized in a make-shift homogenizer for 0.5 hr., 1 hr., 1.5 hr. and 2 hr. respectively. After that, it was filtered by using a filter cloth. During filtration and homogenization, heating was made by halogen lamp (1000 W.) from 1 ft. above the homogenizer and filtering medium to facilitate the flow of Thitsi and evaporation of water.

### Determination of Physico-chemical Characteristics of Raw and Purified Thitsi

Physico-chemical characteristics like ash content, viscosity, boiling range, pH and specific gravity were determined by ASTM D29, D562, D850, pH meter and D1963 respectively.

### Determination of Constituents of Raw and Purified Thitsi

Constituents of Thitsi samples such as moisture and volatile matter, thitsiol content, nitrogenous matter, gummy matter and fatty or oily matter were determined by ASTM D29, and Pearson, 1908.

### Characterization of Functional Groups of Thitsiol

The various functional groups of thitsiol of purified Thitsi were examined by Fourier Transform Infrared Spectroscopy (FT-IR, Perkin Elmer, 8400, Shimadzu).

## Preparation of Bamboo Lacquerwares

### Preparing the Bamboo Substrates

Air-dried matured stalks of bamboo (Wa-ya) (*Gigantochloa rostrata Wong*) substrates were cut into 2 inches in length and 1 inch in width and polished with abrasive paper to smooth the surface and cleaned to free from dust and dirt.

### Lacquering and Hardening in Local Underground Cellar

The prepared bamboo substrates were lacquered with raw Thitsi and purified Thitsi. Lacquering was made carefully with a flat brush in all the prepared lacquerware to form a thin layer of uniform coating. Then, the coated materials were hardened in the underground cellar. After each coating, the freshly dried coat was rubbed with an abrasive paper (paper No. 400 and 600) to get a smooth surface. The specimen was said to be dried if no tackiness was felt by a finger press on the lacquered surface. As a preliminary study, standard deviation for hardening time of raw Thitsi-coat on bamboo substrates was firstly determined.

### Determination of Physico-chemical Properties of Processed Lacquerwares and Export Quality Myanma Commercial Lacquerwares

Physico-chemical properties of lacquerwares such as pencil hardness, cross hatch, adhesion, coating thickness, specular gloss, water immersion resistance, salt immersion resistance, resistance to steam at 100ºC, acid immersion resistance, alkali immersion resistance and weathering resistance were determined.

### Characterization of Morphological Features of Lacquer Film

The morphological feature of seven times coated lacquer film was studied on the original film and also after weathering test by Scanning Electron Microscope (SEM) (JSM – 5610).

### Study on the Effect of Drying Agents on the Hardening Time

Purified Thitsi was blended with varying amounts of turpentine to enhance the hardening time. 10 g. each of purified Thitsi was blended with varying amounts of turpentine oil such as 0.025 g., 0.05 g., 0.075 g. and 0.1 g. and stirred for 30 min. under sunlight. Then the respective mixtures were painted on bamboo substrates. The above procedure was again conducted with linseed oil, another drying agent.

### Determination of Physico-chemical Properties of Lacquerwares Coated by Thitsi Mixed with Drying Agents

Physical and chemical properties of coated lacquerwares by purified Thitsi mixed with respective drying agents were determined.

### Study on the Effect of Protective Coating on Myanma Lacquerwares for Exterior Uses

High performance heavy duty, protective coating was prepared by mixing 4:1 ratio of 2K polyurethane top coat clear (HPU 90200) and hardener coat (HPH 65200), and 10 – 20% (%w/w) of thinner (UT 91). The protective coating was coated on the hardened lacquerwares and dried for 3 hr. at room temperature. Then, weathering effect on the protective film coated lacquerwares was inspected.

## Results and Discussion

As shown in Table (1), it was observed that the colour of Thitsi changed from deep brown to black due to the purification process. The colour of Thitsi represented their quality. Thitsi samples possessed a peculiar sweetish odour. It was also found that ash content of purified Thitsi sample was slightly increased by the purification process and also it was clearly observed that the viscosity of Thitsi increased markedly, whereas specific gravity was decreased. Thus, purified Thitsi became lighter than that of raw Thitsi. But the boiling range of purified Thitsi did not change apparently. pH of Thitsi samples were 5.6. By the purification process, their physico-chemical characteristics did not entirely deviate. These physico-chemical characteristics of Thitsi were within the range of literature values of Thitsi.

**Table1:** Physico-chemical Characteristics of Raw and Purified Thitsi

| Sr. No. | Characteristic | Thitsi Sample | | Literature Value* |
|---|---|---|---|---|
| | | **Raw** | **Purified** | |
| 1 | Colour | deep brown | black | grayish – black |
| 2 | Odour | peculiar sweetish | peculiar sweetish | peculiar sweetish |
| 3 | Ash (%w/w) | 0.074 | 0.089 | 0.041 – 0.130 |
| 4 | Viscosity (cP.) | 3482 | 8000 | 200 – 14100 |
| 5 | Boiling Range (ºC) | 50 – 83 | 53 – 82 | 18.8 – 387.7 |
| 6 | pH | 5.6 | 5.6 | 4 – 6 |
| 7 | Specific Gravity | 1.012 | 0.996 | 0.985 – 1.013 |

* Data – http://www.material-safety-data-sheet-lacquer.html

Constituents of raw and purified Thitsi are displayed in Table (2). Due to the purification process, the contents of thitsiol and nitrogenous matter were increased whereas the remaining constituents, moisture and volatile matter, gummy matter and fatty or oily matter of raw Thitsi were decreased. Moisture and volatile matter content decreased from 10.0 %w/w to 5.0 %w/w and Thitsiol content increased from 80.0 %w/w to 87 %w/w. Decrease in moisture and volatile matter content and fatty or oily matter and increase in nitrogenous matter of Thitsi facilitate the hardening, meanwhile increase in thitsiol content impair the hardening, but it could provide the best gloss and high resistance to physical and chemical attacks. The quality of Thitsi depends on its content of Thitsic acid, now termed thitsiol. The best quality lacquer contains the highest percentage of thitsiol.

**Table 2:** Constituents of Raw and Purified Thitsi

| Sr. No. | Constituent | Thitsi Sample | | Literature Value* (Japanese Urushi) |
|---|---|---|---|---|
| | | **Raw** | **Purified** | |
| 1 | Moisture and Volatile Matter (%w/w) | 10.0 | 5.0 | 20 – 30 |
| 2 | Thitsiol (%w/w) | 80.0 | 87.0 | 60 – 70 |
| 3 | Nitrogenous Matter (%w/w) | 1.0 | 2.0 | 1.5 – 5 |
| 4 | Gummy Matter (%w/w) | 4.5 | 3.0 | 4 – 10 |
| 5 | Fatty or Oily Matter (% w/w) | 0.5 | 0.3 | 0 – 1 |

*Data - http://www.jsaweb.recent-advances-in-research-in-lacquer-allergy.html

To improve the quality of lacquerware products and to speed up the polymerization time, raw Thitsi were prepolymerized or purified. Table (3) shows the effect of prepolymerization time on the moisture and volatile matter content and thitsiol content of Thitsi. It was found that moisture and volatile matter content decreased meanwhile thitsiol content increased with increased prepolymerization time. The most suitable prepolymerization time was observed at 1 hr. because of the needs for the reliable Thitsi to be of minimum moisture and volatile matter content, 3 – 5% w/w. At this prepolymerization time, the highest thitsiol content was found to be 87%w/w.

**Table 3:** Effect of Prepolymerization Time on the Moisture, Volatile Matter and Thitsiol Contents of Raw Thitsi

| Sr. No. | Constituent | Prepolymerization Time (hr.) | | | | | Remarks |
|---|---|---|---|---|---|---|---|
| | | **0.0** | **0.5** | **1.0*** | **1.5** | **2** | |
| 1 | Moisture and Volatile Matter (%w/w) | 10.0 | 8.0 | 5.0 | 1.0 | 0.0 | 1. Thitsi should have minimum moisture and volatile matter content (3 – 5)%w/w. |
| 2 | Thitsiol (%w/w) | 80.0 | 84.0 | 87.0 | 88.0 | 88.0 | 2. All constituents are essential for hardening of Thitsi. |

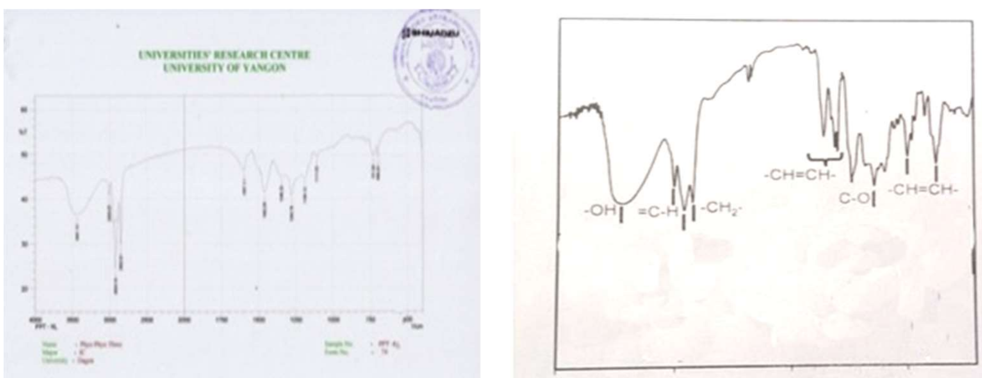
*Most suitable condition,
Remark (1) - http://www.development.of.a.fast.drying.lacquer.based.on.raw.lacquer.sap. Pdf
Remark (2) - http://www.intechopen.com

Various functional groups of thitsiol from Thitsi were examined by FTIR and it proved that the sample was Thitsi. As shown in Table (4), the frequency at 3441$cm^{-1}$ represented the presence of phenolic groups which has O – H stretching vibration assignment. The frequency at 3009 $cm^{-1}$ corresponded to the presence of = CH – group of the aromatic system. The band at 2924 $cm^{-1}$ frequency indicated the saturated alkyl group which has – $CH_2$ – asymmetric stretching vibration and the frequency at 2852 $cm^{-1}$ of sample showed the saturated alkyl group which has –$CH_2$ – symmetric stretching vibration. The band at 1280 $cm^{-1}$ frequency represented the characteristics of O – H in-plane bending vibration of phenolic group whereas at the frequency of 731 $cm^{-1}$ corresponded to the O – H out-of-plane bending vibration of phenolic group. The infrared spectrum of thitsiol obtained was found to be the same with urushiol from Japanese urushi virtually.

**Table 4: FTIR Absorption Frequencies of Functional Groups of Thitsiol from Purified Thitsi**

| Sr. No. | Observed Frequency ($cm^{-1}$) | Literature Frequency* ($cm^{-1}$) (Urushiol) | Band Assignment | Remarks |
|---|---|---|---|---|
| 1 | 3441 | 3431 | O – H stretching vibration | Phenol |
| 2 | 3009 | 3012 | = CH – stretching vibration | Aromatic ring |
| 3 | 2924 | 2926 | – $CH_2$ – asymmetric stretching vibration | Saturated alkyl group |
| 4 | 2852 | 2853 | – $CH_2$ – symmetric stretching vibration | Saturated alkyl group |
| 5 | 1280 | 1310-1200 | O – H in-plane bending vibration | Phenol |
| 6 | 731 | 750-650 | O – H out-of-plane bending vibration | Phenol |

* http://www.atsem09-owjung.pdf




**(a)** **(b)**

**Figure 1:** FTIR Spectra of (a) Thitsiol and (b) Urushiol

It was studied that standard deviation for hardening time of raw Thitsi-coat on bamboo substrates hold 0.58 hr.. For further studies, this deviation time covered on the hardening time of raw and purified Thitsi-coat on bamboo lacquerwares.

Total hardening time of coat of raw and purified Thitsi on bamboo lacquerwares are shown in Table (5). It was found that, high moisture and volatile matter content and high nitrogenous matter content of Thitsi facilitate the hardening whereas high thitsiol content curtails the hardening. The presence of nitrogenous constituent was essential for the drying of Thitsi. It was also found that the hardening time of Thitsi coats were slightly decreased with consecutive increased number of coatings. Moreover, high relative humidity of underground cellar diminished the hardening time.

Since, purification or prepolymerization accelerated the polymerization of thitsiol monomer to the lacquer dimer, trimer, ……, oligomer and polymer, it can be clearly observed that the hardening time of coated lacquerwares with purified Thitsi in all the coating was greatly shorter than the wares coated with raw Thitsi.

For the same of number of coatings (i.e. eight coats), hardening time was very much shorer, 216.3 hr. for purified Thitsi compared to 315 hr. for raw Thitsi.

**Table 5:**Total Hardening Time of Coat of Raw and Purified Thitsi on Bamboo Lacquerwares

| **Thitsi Sample** | **Hardening Time (hr.) of Coats of Thitsi** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **1st coat** | **2nd coat** | **3rd coat** | **4th coat** | **5th coat** | **6th coat** | **7th coat** | **8th coat** |
| Raw | 60.3 | 106.6 | 151.3 | 195.1 | 227.5 | 257.8 | 287.0 | 315.0 |
| Purified | 36.3 | 66.3 | 94.6 | 120.8 | 146.6 | 171.0 | 194.3 | 216.3 |

Physical properties of bamboo lacquerwares coated with raw and purified Thitsi from Kawlin Township are described in Table (6). It can be observed that the increase in number of consecutive coatings, resulted in harder the scale of hardness. From these data, the hardness values of lacquerwares initially from four to eight times were the highest (i.e. 6H) and the commercial product, export quality Myanma lacquerware had also 6H. Cross hatch and adhesion qualities of Thitsi (raw/purified) coated on bamboo substrates were completely perfected, 100%.

It was observed that the wet film thickness of each coating in all lacquerwares occupied 120 μm. The dry film thicknesses of coated lacquerwares with purified Thitsi were much thicker than that coated with raw Thitsi in all consecutive lacquer coatings because of purified Thitsi had high viscosity.

Determination of the specular gloss of processed lacquerwares is an essential test for assessment of their quality. Because of purified Thitsi had higher thitsiol content than raw Thitsi, it was observed that the gloss values of coated lacquerware with purified Thitsi were much higher than the wares coated with raw Thitsi. Rather high gloss values, >80G.U. were obtained starting from five times coated lacquerwares with purified Thitsi. The highest gloss value, 100 G.U. was obtained in eight times coating for purified Thitsi.

Moreover, the gloss value of processed lacquerwares painted with purified natural Thitsi were higher than the gloss value of commercial product, export quality Myanma lacquerware. It was also found that the gloss values increased with increase in number of consecutive coatings. This test confirmed that the thitsiol content of Thitsi could greatly influence the specular gloss of lacquerwares. Therefore, Thitsi products can last hundreds of years while retaining their glossiness, smoothness and elegance.

**Table 6:** Physical Properties of Coated Lacquerwares with Raw and Purified Thitsi

| **Sr. No** | **Coat on Lacquerware** | **Physical Property** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Pencil Hardness** | | **Cross Hatch (%)** | | **Adhesion (%)** | | **Dry Film Thickness (μm)** | | **Specular Gloss (GU)** | |
| | | Raw | Purified | Raw | Purified | Raw | Purified | Raw | Purified | Raw | Purified |
| 1 | 1st coat | 4H | 4H | 100 | 100 | 100 | 100 | 26 | 43 | 28.5 | 45.5 |
| 2 | 2nd coat | 5H | 5H | 100 | 100 | 100 | 100 | 52 | 86 | 33.2 | 54.6 |
| 3 | 3rd coat | 5H | 5H | 100 | 100 | 100 | 100 | 78 | 129 | 45.8 | 63.8 |
| 4 | 4th coat | 6H | 6H | 100 | 100 | 100 | 100 | 104 | 172 | 59.0 | 70.6 |
| 5 | 5th coat | 6H | 6H | 100 | 100 | 100 | 100 | 130 | 215 | 71.8 | 85.6 |
| 6 | 6th coat | 6H | 6H | 100 | 100 | 100 | 100 | 156 | 258 | 80.1 | 94.8 |
| 7 | 7th coat | 6H | 6H | 100 | 100 | 100 | 100 | 182 | 301 | 87.7 | 98.2 |
| 8 | 8th coat | 6H | 6H | 100 | 100 | 100 | 100 | 208 | 344 | 93.0 | 100.0 |
| 9 | Myanma Export Product | 6H | | 100 | | 100 | | - | | 98.1 | |

Wet film thickness of Thitsi = 120 □m, H = Hard pencil

Chemical properties of bamboo lacquerwares coated with raw and purified Thitsi from Kawlin Township are described in Table (7). It was observed that after the treatment of water, salt and steam, the resultant gloss values of lacquerwares were higher than the wares before treatment in respective mediums in all coatings and also the gloss value of the export quality commercial product. In these tests, the increased in consecutive coatings, resulted in higher the gloss value and increased to withstand the chemical and heat resistances.

It was found that the gloss values of lacquerwares were slightly decreased by acid and alkali treatments (1-3 G.U.) than the original gloss values but they were still higher than the gloss values of commercial product. Although the gloss value of wares slightly decreased after determination of acid immersion resistance they could be said that they were rather resistant to acid solution because no cracking, blistering, rusting and water spotting were observed.

**Table 7:** Gloss Values of Coated Lacquerwares with Raw and Purified Thitsi in Different Mediums

| **Sr. No** | **Coat on Lacquerware** | **Specular Gloss of Thitsi-Coat on Lacquerware (G.U) after Chemical Treatment** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Water Immersion (2 months)** | | **5% NaCl Immersion (2 months)** | | **Steam Treatment (6 hr)** | | **5% HCl Immersion (1 month)** | | **5% NaOH Immersion (1 month)** | |
| | | Raw | Purified | Raw | Purified | Raw | Purified | Raw | Purified | Raw | Purified |
| 1 | 1st coat | 35.5 | 57.2 | 37.5 | 58.8 | 39.4 | 56.2 | 26.2 | 45.1 | 20.8 | 37.5 |
| 2 | 2nd coat | 43.4 | 63.0 | 40.4 | 65.1 | 45.2 | 65.4 | 31.5 | 51.8 | 25.9 | 45.0 |
| 3 | 3rd coat | 57.2 | 72.2 | 56.3 | 73.5 | 59.3 | 74.5 | 44.1 | 61.7 | 38.1 | 55.2 |
| 4 | 4th coat | 68.8 | 79.1 | 70.2 | 80.8 | 71.5 | 82.3 | 57.2 | 68.8 | 50.9 | 61.8 |
| 5 | 5th coat | 78.7 | 87.9 | 81.4 | 91.3 | 82.6 | 90.5 | 70.0 | 83.7 | 63.2 | 76.3 |
| 6 | 6th coat | 89.6 | 96.8 | 89.9 | 99.8 | 92.4 | 98.3 | 77.8 | 91.4 | 71.8 | 85.4 |
| 7 | 7th coat | 96.2 | 99.9 | 97.9 | 100.0 | 98.1 | 100.0 | 85.1 | 97.0 | 80.5 | 91.2 |
| 8 | 8th coat | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 91.4 | 100.0 | 87.2 | 95.9 |
| 9 | Myanma Export Product | 98.9 | | 99.2 | | 99.8 | | 89.6 | | 45.9 | |

Gloss values of coated lacquerwares with different raw and purified Thitsi after weathering effect are shown in Table (8). From this test it was found that the gloss value of lacquerwares gradually decreased with prolonged exposure time to UV radiation. Because of decreased in gloss value, the appearance of the wares was unsatisfactory but their qualities were acceptable, and they could not be scratched with a finger nail. There was no chalking, cracking, blistering, rusting, water spotting and dirt retention too.

Thus, hardened Thitsi film is an excellent coating material due to its lustre and stiffness, but its drawback is that it is sensitive to light, especially UV radiation. Part of the polymerized thitsiol was decomposed and may be volatile, leaving the film in a heterogeneous condition when the film was exposed to UV radiation. After assessing the weathering resistance which is equivalent to nine years and five months, the gloss value of processed wares were higher almost double the value than the gloss of commercial products. Thus, the processed wares could sustain the exterior weather condition.

**Table 8:** Gloss Values of Coated Lacquerwares with Raw and Purified Thitsi after Weathering Test

| Sr. No. | Exterior Weather | | Specular Gloss of Thitsi-Coat on Lacquerware (G.U.) | | |
|---|---|---|---|---|---|
| | **hr. Used** | **Affected yr.** | **Raw Thitsi** | **Purified Thitsi** | **Myanma Export Product** |
| 1 | - | - | 86.5 | 96.8 | 98.1 |
| 2 | 164 | 0.68 | 76.2 | 83.5 | 85.3 |
| 3 | 352 | 1.47 | 65.8 | 77.1 | 69.5 |
| 4 | 776 | 3.23 | 43.7 | 70.3 | 52.1 |
| 5 | 1088 | 4.53 | 38.8 | 62.7 | 46.2 |
| 6 | 1492 | 6.22 | 35.6 | 58.3 | 39.7 |
| 7 | 1812 | 7.55 | 32.9 | 50.0 | 28.9 |
| 8 | 2192 | 9.13 | 30.8 | 43.4 | 19.6 |
| 9 | 2264 | 9.43 | 27.1 | 37.9 | 12.1 |

SEM photomicrograph of original lacquer film and SEM microphotograph of the film after weathering test which include the exposure to UV radiation are shown in Fig (2). SEM image of seven times coated original lacquer film was packed densely and a well-defined surface texture with an equally smooth surface with only very few minute grains which was responsible for its excellent durability. When the film was exposed to UV radiation, the lacquer film might absorb UV and suffer from photo-oxidative degradation and part of the polymerized thitsiol was decomposed and volatilized. So, SEM photographs of lacquer films after weathering effect showed well-defined microstructure with irregular scratches, large nodules and turning marks.


**(i)** **(ii)**

**Figure 2:** SEM Photographs of Kawlin Thitsi Coated Lacquer Film
(i) Seven Times Coated Original Lacquer Film
(ii)Seven Times Coated Lacquer Film after Exposing to Weathering Test Equivalent to Nine Years and Five Months

In order to speed up the polymerization time of Thitsi-coat on lacquerwares, turpentine and linseed oil were used as drying agents and their hardening effect was studied. Effect of turpentine and linseed oil on the hardening time of Thitsi-coat on lacquerwares is described in Tables (9) and (10) respectively. It was observed that the most suitable ratio of Thitsi and turpentine was found to be 1:0.005, which gave the shortest hardening time, and the most suitable ratio of Thitsi and linseed oil was 1:0.0075. It was found that drying oils truly enhanced the polymerization time of Thitsi-coat on lacquerwares. The hardening time of Thitsi-coat on lacquerwares decreased by mixing Thitsi with appropriate amount of drying agents because solvent drying agent, turpentine accelerated the polymerization ability of Thitsi by evaporation of water, and drying oil, linseed oil speeded up to harden Thitsi by a chemical reaction in which the components crosslinked by the action of oxygen.

**Table 9:** Effect of Turpentine on the Hardening Time of Thitsi-Coat on Lacquerwares

| Sr. No. | Ratio of Thitsi and Turpentine | Hardening Time of Thitsi-Coat on Lacquerware (hr.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1st coat | 2nd coat | 3rd coat | 4th coat | 5th coat | 6th coat | 7th coat | 8th coat |
| 1 | 1:0.0000 | 36.25 | 30.00 | 28.33 | 26.25 | 25.75 | 24.42 | 23.25 | 22.00 |
| 2 | 1:0.0025 | 32.00 | 27.67 | 26.00 | 24.50 | 23.00 | 22.25 | 21.33 | 19.83 |
| 3 | 1:0.0050* | 26.67 | 22.17 | 21.50 | 20.33 | 18.50 | 17.17 | 16.25 | 15.50 |
| 4 | 1:0.0075 | 30.33 | 26.50 | 24.17 | 23.83 | 21.25 | 20.67 | 19.58 | 18.67 |
| 5 | 1:0.0100 | 49.00 | 46.67 | 38.33 | 34.83 | 30.50 | 29.17 | 27.25 | 26.67 |

* Most suitable ratio of Thitsi and turpentine

**Table 10:** Effect of Linseed Oil on the Hardening Time of Thitsi-Coat on Lacquerwares

| Sr. No. | Ratio of Thitsi and Linseed Oil | Hardening Time of Thitsi-Coat on Lacquerware (hr.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1st coat | 2nd coat | 3rd coat | 4th coat | 5th coat | 6th coat | 7th coat | 8th coat |
| 1 | 1:0.0000 | 36.25 | 30.00 | 28.33 | 26.25 | 25.75 | 24.42 | 23.25 | 22.00 |
| 2 | 1:0.0025 | 26.50 | 24.15 | 23.33 | 21.67 | 20.75 | 18.00 | 17.25 | 16.17 |
| 3 | 1:0.0050 | 23.00 | 22.75 | 21.67 | 19.17 | 17.25 | 16.17 | 15.83 | 14.33 |
| 4 | 1:0.0075* | 21.50 | 19.17 | 18.50 | 16.83 | 14.67 | 13.50 | 12.83 | 12.00 |
| 5 | 1:0.0100 | 27.50 | 25.17 | 24.83 | 22.17 | 21.50 | 19.83 | 18.17 | 16.83 |

* Most suitable ratio of Thitsi and linseed oil

Pencil hardness of lacquerwares coated by purified Thitsi mixed with drying agents are shown in Table (11). It was observed that the pencil hardness of lacquerwares coated by purified Thitsi mixed with linseed oil was harder than that mixed with turpentine. It was also found that the hardness degree increased with increase in number of consecutive coatings. These hardness values were lower than the wares painted by purified Thitsi alone. Thus, drying agents improved the polymerization time but; these agents impaired the hardness of lacquerwares.

**Table 11:** Pencil Hardness of Different Types of Thitsi Coated Lacquerwares

| Sr. No. | Coat on Lacquerware | Pencil Hardness of Thitsi-Coat on Lacquerware | | |
|---|---|---|---|---|
| | | PTK + T (1 : 0.0050) Thitsi-Coat | PTK + LO (1 : 0.0075) Thitsi-Coat | Purified Thitsi-Coat |
| 1 | 1st coat | F | H | 4H |
| 2 | 2nd coat | F | H | 5H |
| 3 | 3rd coat | F | 2H | 5H |
| 4 | 4th coat | F | 2H | 6H |
| 5 | 5th coat | H | 3H | 6H |
| 6 | 6th coat | 2H | 3H | 6H |
| 7 | 7th coat | 3H | 4H | 6H |
| 8 | 8th coat | 4H | 4H | 6H |

PTK = Purified Thitsi from Kawlin Township, T = Turpentine oil, LO = Linseed oil, F = Fine pencil, H = Hard pencil

Cross hatch and adhesion of lacquerwares coated by purified Thitsi mixed with drying agents are described in Table (12). It revealed that the cross hatch and adhesion of painted lacquerwares by purified Thitsi mixed with turpentine and linseed oil were 100%. Thus the application of drying agents in lacquering process did not influence the cross hatch and adhesion strength of processed lacquerwares.

**Table 12:** Cross Hatch and Adhesion of Different Types of Thitsi Coated Lacquerwares

| Sr. No. | Coat on Lacquerware | Cross Hatch and Adhesion of Thitsi-Coat on Lacquerware (%) | | |
|---|---|---|---|---|
| | | PTK + T (1 : 0.0050) Thitsi-Coat | PTK + LO (1 : 0.0075) Thitsi-Coat | Purified Thitsi-Coat |
| 1 | 1st coat | 100 | 100 | 100 |
| 2 | 2nd coat | 100 | 100 | 100 |
| 3 | 3rd coat | 100 | 100 | 100 |
| 4 | 4th coat | 100 | 100 | 100 |
| 5 | 5th coat | 100 | 100 | 100 |
| 6 | 6th coat | 100 | 100 | 100 |
| 7 | 7th coat | 100 | 100 | 100 |
| 8 | 8th coat | 100 | 100 | 100 |

Table (13) shows the specular gloss values of lacquerwares coated by purified Thitsi mixed with drying agents. It was observed that the gloss values of coated lacquerwares by purified Thitsi mixed with linseed oil were higher than the wares that mixed with turpentine. However, these gloss values of lacquerware were slightly lower than the ware coated with original purified Thitsi. Although the drying agents promoted the polymerization time of Thitsi, it slightly lower the gloss of lacquer film.

**Table 12:** Specular Gloss of Different Types of Thitsi Coated Lacquerwares

| Sr. No. | Coat on Lacquerware | Specular Gloss of Thitsi-Coat on Lacquerware (G.U.) | | |
|---|---|---|---|---|
| | | PTK + T (1 : 0.0050) Thitsi-Coat | PTK + LO (1 : 0.0075) Thitsi-Coat | Purified Thitsi-Coat |
| 1 | 1st coat | 37.8 | 39.2 | 45.5 |
| 2 | 2nd coat | 45.3 | 45.9 | 54.6 |
| 3 | 3rd coat | 54.8 | 58.6 | 63.8 |
| 4 | 4th coat | 62.0 | 69.8 | 70.6 |
| 5 | 5th coat | 74.2 | 78.5 | 85.6 |
| 6 | 6th coat | 83.5 | 87.0 | 94.8 |
| 7 | 7th coat | 91.7 | 94.8 | 98.2 |
| 8 | 8th coat | 94.6 | 95.2 | 100.0 |

Specular gloss values of coated lacquerwares by purified Thitsi mixed with respective drying agents after chemical treatments and weathering effect are shown in Tables (14), (15) and (16) respectively. From these Tables, it was found that the gloss values of painted lacquerware by purified Thitsi mixed with linseed oil were higher than that mixed with turpentine. But, these gloss values of lacquerware were slightly lower than gloss values of lacquerware coated by purified Thitsi alone.

**Table 14:** Specular Gloss of Coated Lacquerwares by Purified Thitsi mixed with Turpentine (1: 0.005) after Chemical Treatments

| Sr. No. | Coat on Lacquerware | Specular Gloss of Thitsi-Coat on Lacquerware (G.U) | | | | |
|---|---|---|---|---|---|---|
| | | Water Immersion (2 months) | 5% NaCl Immersion (2 months) | Steam Treatment (6 hr) | 5% HCl Immersion (1 month) | 5% NaOH Immersion (1 month) |
| 1 | 1st coat | 37.2 | 37.4 | 37.5 | 33.8 | 31.7 |
| 2 | 2nd coat | 43.0 | 43.1 | 43.3 | 40.3 | 39.1 |
| 3 | 3rd coat | 52.8 | 52.1 | 53.4 | 49.8 | 46.3 |
| 4 | 4th coat | 59.6 | 59.8 | 59.3 | 57.1 | 54.9 |
| 5 | 5th coat | 69.5 | 69.8 | 69.2 | 65.4 | 61.2 |
| 6 | 6th coat | 80.1 | 81.2 | 81.0 | 76.5 | 69.1 |
| 7 | 7th coat | 87.5 | 87.8 | 88.0 | 86.2 | 79.8 |
| 8 | 8th coat | 91.6 | 92.0 | 91.6 | 92.1 | 87.5 |

**Table 15:** Specular Gloss of Coated Lacquerwares by Purified Thitsi mixed with Linseed Oil (1 : 0.0075) after Chemical Treatments

| Sr. No. | Coat on Lacquerware | Specular Gloss of Thitsi-Coat on Lacquerware (G.U) | | | | |
|---|---|---|---|---|---|---|
| | | Water Immersion (2 months) | 5% NaCl Immersion (2 months) | Steam Treatment (6 hr) | 5% HCl Immersion (1 month) | 5% NaOH Immersion (1 month) |
| 1 | 1st coat | 39.5 | 40.8 | 39.1 | 36.6 | 33.7 |
| 2 | 2nd coat | 52.8 | 53.2 | 49.5 | 45.8 | 42.8 |
| 3 | 3rd coat | 57.3 | 58.1 | 56.7 | 53.7 | 49.2 |
| 4 | 4th coat | 63.4 | 63.0 | 64.0 | 63.0 | 60.4 |
| 5 | 5th coat | 74.8 | 74.1 | 75.1 | 70.3 | 66.3 |
| 6 | 6th coat | 84.4 | 86.6 | 85.4 | 82.5 | 74.1 |
| 7 | 7th coat | 89.2 | 90.5 | 89.9 | 89.1 | 82.6 |
| 8 | 8th coat | 92.6 | 93.8 | 92.4 | 93.4 | 89.1 |

**Table 16:** Specular Gloss of Coated Lacquerwares by Purified Thitsi mixed with Drying Agents after Weathering Effect

| Sr. No. | Exterior Weather | | Specular Gloss of Thitsi-Coat on Lacquerware (G.U.) | | |
|---|---|---|---|---|---|
| | hr. Used | Affected yr. | PTK + T (1 : 0.0050) Thitsi-Coat | PTK + LO (1 : 0.0075) Thitsi-Coat | Purified Thitsi-Coat |
| 1 | - | - | 91.7 | 94.8 | 96.8 |
| 2 | 164 | 0.68 | 81.3 | 82.1 | 83.5 |
| 3 | 352 | 1.47 | 70.8 | 73.4 | 77.1 |
| 4 | 776 | 3.23 | 62.4 | 65.3 | 70.3 |
| 5 | 1088 | 4.53 | 52.6 | 56.4 | 62.7 |
| 6 | 1492 | 6.22 | 47.2 | 50.6 | 58.3 |
| 7 | 1812 | 7.55 | 40.8 | 44.1 | 50.0 |
| 8 | 2192 | 9.13 | 30.1 | 35.2 | 43.4 |
| 9 | 2264 | 9.43 | 24.7 | 30.8 | 37.9 |

Fast drying resulted in an opaque and non-uniformly hardened film when the rate of water evaporation from the Thitsi coated surface did not harmonize well with the hardening rate, i.e., the oxygen-absorbing rate to form a uniform and transparent hardened film. Thus, application of drying agents diminished both physical and chemical properties of lacquerware because these drying agents quickly dried the Thitsi. (Monreal, 1985)

With the aid of protective coating, lightly coated lacquerwares, (i.e. only two or three coats) could be upgraded in lustre. Besides, they withstood attacks from weathering as heavily coated lacquerwares. Gloss values of coated lacquerware with thin film protective layer after weathering effect are shown in Table (17).

It was observed that the gloss values of all consecutive lacquer coating did not decrease by weathering effect. The protective coating prevented the exposure of the lacquer film to UV radiation and the decomposition of polymerized thitsiol, and thus the gloss values, 100 G.U. remain constant after exposure to UV radiation which is equivalent to nine years and five months. Therefore, lacquerwares can be used for exterior uses like outdoor decorations for hotel, restaurants and parks, etc., by providing with high performance protective coating.

By this experiment, application of protective coating over the lacquered surface not only enhanced the using of lacquerwares for outdoor purposes but it also saved the required time and amount of Thitsi needed as lacquerwares are coated by natural purified Thitsi only.

**Table 17:** Gloss Values of Coated Lacquerwares with Protective Coating after Weathering Effect

| Sr. No. | Exterior Weather | | Specular Gloss of Thitsi-Coat on Lacquerware (G.U.) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | hr. Used | Affected yr. | 1st coat | 2nd coat | 3rd coat | 4th coat | 5th coat | 6th coat |
| 1 | - | - | 90.6 | 100 | 100 | 100 | 100 | 100 |
| 2 | 164 | 0.68 | 90.6 | 100 | 100 | 100 | 100 | 100 |
| 3 | 352 | 1.47 | 90.6 | 100 | 100 | 100 | 100 | 100 |
| 4 | 776 | 3.23 | 90.6 | 100 | 100 | 100 | 100 | 100 |
| 5 | 1088 | 4.53 | 90.6 | 100 | 100 | 100 | 100 | 100 |
| 6 | 1492 | 6.22 | 90.6 | 100 | 100 | 100 | 100 | 100 |
| 7 | 1812 | 7.55 | 90.6 | 100 | 100 | 100 | 100 | 100 |
| 8 | 2192 | 9.13 | 90.6 | 100 | 100 | 100 | 100 | 100 |
| 9 | 2264 | 9.43 | 90.6 | 100 | 100 | 100 | 100 | 100 |

**(a)**

**(b)**

**Figure 3:** Smooth and Glossy (a) Bamboo Lacquerwares (b) Lacquerware Cups

**Figure 4:** Wolff-Wilborn Pencil Tester

**Figure 5:** Cross Hatch Cutter


**Figure 6:** Wet Film Thickness Comb

**Figure 7:** Dry Film Thickness Tester

**Figure 8:** Tri-micro Gloss Meter

**Figure 9:** QUV Accelerated Weathering Tester

## Conclusion

The constituents and properties of Thitsi vary with the age of tree, grown region and collected season. Quality of Thitsi depends on its thisiol content. Moreover, the best quality Thitsi can give the lustrous lacquerwares, possessing outstanding qualities with marvelous gloss, good chemical resistance and high durability. Purification of Thitsi produces fine lacquer. Thus purified Thitsi can provide further appropriate seasoning, viscosity and glossiness when laid upon any surfaces.

Lacquer could not set by the aid of heat, sun light and dry air and hence, polymerization of Thitsi should be allowed to take place in the dark underground cellar to dry the lacquerwares. Purification process saved the time required for polymerization of raw Thitsi and also gave high quality lacquerwares. In addition, the prepolymerization was to hopefully be used to prepare a fast drying Thitsi on a large scale and promote the application of Thitsi as an industrial paint. Using appropriate amount of solvent and drying oil reduced the hardening time of Thitsi but slightly affect the some properties of lacquerwares (with the exception of cross hatch and adhesion). Using large amount of these drying agents retarded the polymerization time and impaired the quality of lacquerwares.

Processed lacquerwares had hardness and good adhesive power so they can keep their aesthetic appearance. From the point of chemical strength, lacquerwares had ability to resist not only water, salt and steam but also withstand acid and alkali. But, their drawback was found on the exposure to UV radiation. The properties of lacquerwares especially glossiness could increase by using them in various environments and different conditions. The good quality lacquerware obtained by restricted increased number of coating and it was noted that six or seven times coated lacquerwares with pure Myanma Thitsi occupied the perfectness. Since thin film protective coating on harden lacquerwares (only second times coated wares) prevents photo-oxidative degradation and decomposition of polymerized thitsiol, they could be used for exterior application under UV radiation. Therefore, Myanma lacquerwares could be upgradeable for various outdoor decorations like synthetic materials. Thitsi, a renewable resource and an eco-friendly biopolymer material, can be used in special environments and can also be kept for several years without declining their true attractiveness.

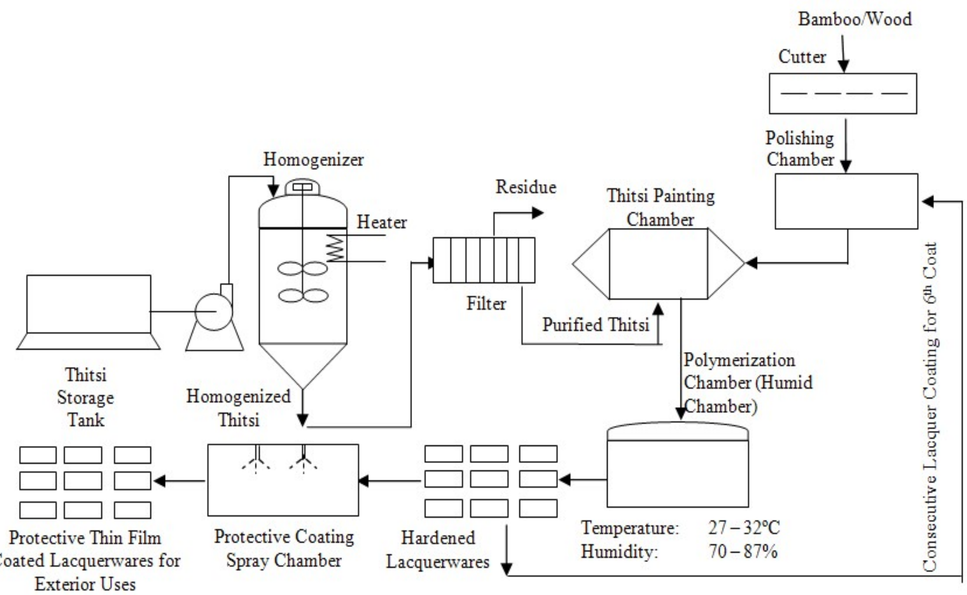



**Figure 10:** Process Flow Diagram for the Production of Protective Thin Film Coated Lacquerwares

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