



The Effect of Borax Addition as Buffering Agent on Storage Stability of Melamine-Formaldehyde Resin in the Production of High-Pressure Laminates

Abdul Halim Muslem¹, Rahmi^{1*}, Midia Fujiani²

¹Department of Chemistry, Universitas Syiah Kuala, Banda Aceh, 23111, Indonesia

²PT TACO Anugrah Corporindo, Serang, 42186, Indonesia

*E-mail: rahmi@unsyiah.ac.id

Article History

Received: 5 April 2023; Received in Revision: 21 June 2023; Accepted: 22 June 2023

Abstract

High-pressure laminates (HPL) is one of the applications of thermosetting resins for wood-based materials as protective and decorative panels covering building furniture. Melamine-formaldehyde (MF) resin is one of the resins that plays a role in the production of high-pressure laminates with providing glossy look on HPL and also water repellent properties. Beside the advantage, This resin has short storage age because of low stability in room temperature during storage process. This lead to turbid look and high viscosity due to physico-chemical interaction occurs between species accompanied by a decrease in pH. This study aims to prolong and improve the storage stability of melamine-formaldehyde resin by adding borax as a buffering agent. Synthesis of MF resin was conducted by polymerization and condensation steps followed by the addition of borax at concentrations of 0, 0.5, 1, 1.5, and 2% when the endpoint was reached. The characterization of the resin includes the analysis of the physical and chemical parameters of the resin and the analysis of the functional groups of the resin by FT-IR. Storage stability study of MF resin was carried out by daily visual observation and determination of daily changes in pH and viscosity. MF resin was further used in the production of high-pressure laminates. High-pressure laminates characterization includes quality analysis based on SNI ISO 4586-7:2017 and analysis gloss level. In this study, 1.5% borax MF resin had the highest storage stability, namely 11 days. HPL quality analysis complies with SNI ISO 4586-7:2017 standards. High-pressure laminates of 1.5% borax MF resin has the highest gloss level, which is 115. This study is expected to be an opportunity for high-pressure laminates industry to overcome the short storage issue of melamine-formaldehyde resin.

Keywords: high-pressure laminates, melamine-formaldehyde resin, storage stability, borax, buffering agent

1. Introduction

Along with the times, furniture has become one of the industrial sectors with a high level of demand in Indonesia. The community's need for furniture and furniture continues to increase in terms of quality and quantity. Based on Indonesian Furniture and Craft Industry Association data (HIMKI, 2022), the furniture industry experienced an increase in exports of US\$3.14 billion in January-November 2021. This value rose 28.93% from the 2020 realization of US\$2.43 billion. Wood is one of the main materials used in the manufacture of furniture and furniture. Wood has several advantages such as being strong and durable, easy to shape, abundant in nature, and inexpensive (Popescu, 2017). However, besides these advantages, wood has several disadvantages, such as being easily weathered, flammable, not resistant to moisture, and can be moldy (Thompson et al., 2014). Therefore, to improve the physical and

mechanical performance of wood-based furniture, we need resin as coating materials (Bulian & Graystone, 2009).

Resins are complex mixtures of solid or semi-solid organic compounds with high viscosity, obtained naturally from plants or synthetically. Synthetic resins are a type of resin that is produced industrially and belongs to the thermosetting polymers, namely polymers that can irreversibly change the resin from a viscous liquid form to a solid crystalline form when it goes through a curing process or high-temperature heating (Motavalli, et al., 2010). Synthetic resins, especially formaldehyde-based resins, are widely applied as raw materials for the manufacture of adhesives and coating materials such as in the manufacture of medium-density fiberboard, super phenolic board, particle board, and high-pressure laminates (HPL) (Santos et al., 2021) (Henriques et al., 2018).

High-pressure laminates is a decorative and protective material for covering home furniture such as cabinets, cupboards, tables, chairs, and wall surfaces with various motifs and patterns. High-pressure laminates are composed of several papers, namely kraft paper as the core of HPL, decoration paper that provides decorative looks and patterns, and overlay paper as a protector and provides durability (Martins et al., 2015). Thermosetting resins such as phenol-formaldehyde resins and melamine-formaldehyde resins also play a role in HPL production. Kraft paper is impregnated with phenol-formaldehyde resin so that it has the properties of resilience and flexibility for HPL. Decoration paper and overlays are impregnated with melamine-formaldehyde resin which gives it rigidity and is transparent and glossy (Magina et al., 2016). Melamine-formaldehyde resin or also known as melamine resin is a thermosetting polymer used as a construction material, such as in the manufacture of wood particle board and medium density fiberboard (MDF), adhesives or industrial adhesives, molding compounds, coating materials, and laminating materials for furniture, and HPL (Ullah et al., 2014). Melamine-formaldehyde resin is formed from a polymerization reaction between melamine and formaldehyde monomers. The polymerization reaction of melamine-formaldehyde resin consists of two stages, namely methylation and condensation. (Lan, et al., 2019).

Melamine-formaldehyde resin is used in lamination fabrication because it has several performance and advantages such as its properties, durability, resistance to heat and fire, water repellent, and provides the luster and glossy properties (Farmakis et al., 2020). But besides that, melamine resin has a short shelf life, which is around one to three days. Melamine resin can begin to separate from the mixture, changing from clear to cloudy due to physico-chemical interaction between species from resin accompanied by a decrease in pH under storage conditions (Jahromi, 1999). This causes the HPL produced to have an opaque appearance (Henriques et al., 2017). Therefore, additives are needed to increase the storage stability of melamine resin so it remains clear. Research has been carried out to increase the storage life of melamine resin such as the addition of comonomers in the form of caprolactam and ethylene glycol to increase the storage stability of melamine resin up to 23 days (Lan et al., 2019). The addition of benzoguanamine can increase the stability of melamine resin for up to 10 days, (Diethelm et al., 1973), (Hiroaki et al., 1970),

and (Henriques et al., 2017). Besides that, it can also be done to control the pH of melamine resin so that it does not decrease. Based on patent results, borax is proven to act as a buffering agent in increasing the storage stability of melamine-urea-formaldehyde resin (Nayedenov, 2012). The focus of this research is the addition of a buffering agent in the form of borax to increase the storage stability of melamine-formaldehyde resin in the production of high-pressure laminates.

The use of borax as a buffering agent in melamine-formaldehyde (MF) resin for enhancing the storage stability in the production of high-pressure laminates (HPL) has never been reported in the literature, where the storage stability of MF resin is a major concern in HPL production as it tends to undergo physico-chemical interaction between species during storage process leading to opaque appearance and other quality issues. Therefore, in this work we investigated the use of borax as a buffering agent in MF resin. Borax has been used as a buffering agent in various industries, including the food and pharmaceutical industries, to stabilize pH and prevent degradation of products during storage (Isac-Garcia et al., 2016) (Pratiwi et al., 2020). The use of borax in MF resin for HPL production demonstrates the potential of industrial additive to solve a long-standing problem in a different industry. This finding could have significant implications for the HPL industry, leading to the development of more stable and reliable MF resins, and ultimately, higher-quality HPL products.

This research was conducted by synthesizing melamine-formaldehyde resin with borax additives of 0, 0.5, 1, 1.5, and 2%. After that, the characterization of the melamine-formaldehyde resin with the synthesized borax additive was carried out, namely the analysis of resin quality standards based on physical and chemical parameters, and analysis of the functional groups of melamine-formaldehyde resin using FTIR instruments. The storage stability study of the resin was carried out by conducting daily observations of the resin, namely the pH, viscosity, and visual parameters of the melamine resin. The age of the resin is determined based on the storage time of the resin until the resin becomes cloudy and separates from the mixture. The synthesized melamine-formaldehyde resin with borax additives is then used in the production of HPL and an analysis of the HPL quality is carried out based on SNI ISO 4586-7 standards.

2. Methodology

2.1. Materials

The materials used were melamine monomer (99.8%; Shandong shuntian chemical group, China), formaldehyde (37%; Hwatsi chemical Pvt, India), diethylene glycol (Merck 803131), urea (46%; Nitrea), NaOH (98%; Asahimas Chemical), borax pentahydrate (technical grade; Etimaden Turkiye). Decoration paper, production treated kraft paper, impregnation additives, aluminum foil, and oil were provided by PT. TACO Anugrah Corporindo, Indonesia.

2.2. Synthesis of Melamine-Formaldehyde Resin

Resin melamine-formaldehyde (MF) was synthesized from the melamine monomers, formaldehyde, and water with molar ratio F/M of 1.58 and molar ratio F/W of 0.35 in a reactor flask, condenser, agitator, and thermometer in a fume hood. The agitator turns on at a speed of 2.5 rpm. DEG used 0.03% w/w. NaOH 6% w/w be added for maintaining pH in the range of 8.5-9.5. The water bath and coil are ignited to raise the temperature in the reactor flask. The temperature of the reactor flask was maintained at 90°C-95°C. The water tolerance value of resin against water at 20°C is determined using a measuring cup until it reaches a ratio of 1:3. The endpoint is determined when the water tolerance value has been obtained. Cooling process walks by adding urea 0.03% w/w into the reactor flask. At a temperature of 75°C, the corresponding variable borax is 0, 0.5, 1, 1.5, and 2 % w/w were added to the reactor flask. The agitator is left running and at 40°C, the resin synthesis apparatus can be disassembled (Henriques et al., 2017).

2.3. Analysis of Physical and Chemical Parameters of MF Resin

The synthesized melamine-formaldehyde (MF) resin with borax additive was analyzed for quality standards based on physical and chemical parameters such as water tolerance, solid content, gel time, viscosity, pH, and density. The pH of melamine-formaldehyde resin with borax additive can be measured with a pH meter, resin viscosity is measured using a viscometer and viscop. The solid content of the resin is determined by weighing 1.1 grams of the resin sample in three aluminum foil containers for a sample, then heated at 120°C for four hours. The value of the solid content of the resin can be determined as the percentage difference

between the initial mass and the final mass after drying. The solid content value can be calculated using the Equation 1.

$$SC (\%) = \left(\frac{m_2 - m_0}{m_1} \right) \times 100 \quad (1)$$

Remark:

SC : solid content

M₀ : mass of aluminum foil container

m₁ : mass of added resin

m₂ : mass of aluminum foil container containing resin after heating.

Water tolerance can be determined by weighing three grams of resin sample in a test tube, then adding water at 20°C until the resin becomes cloudy. The volume of water added to the resin until it becomes cloudy and saturated is determined as the water tolerance value. The water tolerance value can be calculated using Equation 2.

$$WT (\%) = \left(\frac{m_2 - m_1}{m_1} \right) \times 100 \quad (2)$$

Remark:

WT : water tolerance

m₁ : mass of resin

m₂ : mass of the mixture of resin and added water

Gel time can be determined by heating the resin on a hot plate that has been coated with aluminum foil at a temperature of 170°C. The time until the resin becomes gel and sticky is determined as the value of gel time.

2.4. Storage Stability Study of MF Resin

Storage stability analysis of melamine-formaldehyde resin with borax additives was carried out by observing visually every day until the resin turned cloudy and separated from the mixture. In addition, daily changes in pH and viscosity of the resin were also calculated for 10 days. The pH was determined by pH meter (710 A Thermoelectron Orion) and the viscosity was measured by Thermo scientific Haake viscometer.

2.5. FT-IR Analysis of MF Resin

Resin melamine-formaldehyde with borax additives was casted into resin films on a glass surface with a thickness of 1 mm and then dried using an oven at 50°C until the mass is constant. The melamine-formaldehyde resin film obtained was then analyzed for functional groups using a Fourier transform infrared spectroscopy (FT-IR) instrument, namely

Bruker Vertex 70 spectrophotometer (Henriques et al., 2017).

2.6. Impregnation of MF Resin

15 sheets of decorative paper with a size of 36 cm x 36 cm were prepared. Each of the three sheets of decorating paper was impregnated with five resin samples of synthesized melamine-formaldehyde (MF) resin with borax additive (0, 0.5, 1, 1.5, & 2 %) on the treating manual plate. Melamine-formaldehyde resin is first added with an impregnation additive. Decorating paper that has been dipped in resin melamine-formaldehyde with borax additive was flattened using an iron rod until achieved resin content (RC) appropriate. The impregnated decoration paper was then dried in a dryer for 1 minute at 120°C. Volatile content (VC) determined by redrying decorating paper after the impregnation and drying process was put into the oven at 120°C for 10 minutes. Resin content (RC) can be calculated by Equation 3.

$$RC (\%) = \left(\frac{m_1 - m_0}{m_1} \right) \times 100 \quad (3)$$

Remark:

RC : resin content

m_0 : mass of decorative paper before impregnation and drying

m_1 : mass of decorative paper after impregnation and drying

The volatile content (VC) value can be calculated by Equation 4.

$$VC (\%) = \left(\frac{m_1 - m_2}{m_1} \right) \times 100 \quad (4)$$

Remark:

VC : volatile content

m_1 : mass of decorative paper before impregnation and drying

m_2 : mass of decorative paper after drying again in 120°C

2.7. Production of HPL from MF Resin

Impregnated decorative paper and treated kraft paper were prepared with arrangement of three sheets of kraft paper and one sheet of decorative paper for one HPL arrangement. The paper was arranged with the decoration paper position on top then a molding gloss plate was placed as a printer then the decoration paper was arranged again, as well as three kraft papers. Repeat the arrangement of the paper to the end. Between one HPL kraft paper and another kraft paper, plastic is added so that later it doesn't stick. The HPL

composition was then pressed with a pressure of 5.5 Bar at 130°C for approximately 40 minutes.

2.8. Cutting HPL from MF Resin

The pressed HPL was then cut to a size of 30 cm x 30 cm and the back was sanded using a sanding machine. The sanded HPL was then cut into several pieces with a size of 5 cm x 30 cm for the flexibility test, three pieces measuring 5 cm x 5 cm for testing the gain of weight, gain of thickness, and surface rating, two pieces measuring 30 cm x 25 cm for hot oil and hot water test.

2.9. Analysis of HPL Gloss Level from MF Resin

HPL pieces measuring 30 cm x 30 cm was determined the gloss value using a gloss meter (GM-6 Landtek 60 Degree). At first, the gloss meter was calibrated by placing it in its container. The gloss meter is then placed on the HPL in a flat condition and not tilted.

2.10. Analysis of HPL Quality from MF Resin

Pieces of HPL from melamine-formaldehyde resin with borax additive are prepared for analysis of HPL quality with several physical parameters based on Standard SNI ISO 4586-7: 2017, namely, gain of weight (GOW), gain of thickness (GOT), surface rating, flexibility, and analysis of hot oil and hot water. Gain of weight (GOW), gain of thickness (GOT), and surface rating can be determined by boiling three pieces of 5 cm x 5 cm HPL for three hours, initial and final thickness and initial and final mass after the boiling test are measured as GOW and GOT values.

GOT determination of HPL is done by measuring the thickness of the four sides of the HPL. The results of high-pressure laminates after boiling were observed to determine the surface rating with a value of 1-5. Flexibility can be determined by bending the tip of the HPL piece 30 cm x 5 cm per one cm from the tip to the fracture. The flexibility value is the length of the HPL that is bent until it breaks. Hot oil analysis was carried out by placing a pot filled with hot oil at a temperature of 185°C on a 25 cm x 30 cm HPL piece for 20 minutes and hot water analysis was carried out by placing a pot filled with boiling water on a 25 cm x 30 cm HPL piece for 20 minutes. The surface of the high-pressure laminates resulting from hot oil and hot water analysis was observed to determine the value of hot oil and hot water analysis with

a value of 1-5. Ratings for hot oil, hot water, and surface ratings for boiling test results based on the SNI ISO 4586-7: 2017 standard are given as follows.

Score one is given if damage occurs to the surface or bubbles. Score two is given if a significant change in glossy or color occurs. Score three is given if a slightly change in glossy or color occurs. Score four given if the change of the gloss or color occurs slightly, which only looks on some content. Score five is given if no change occurs. The value of gain of weight can be calculated by the following equation

$$GOW (\%) = \left(\frac{w_2 - w_1}{w_1} \right) \times 100 \quad (5)$$

Remark:

GOW : gain of weight

w_1 : mass of HPL sample pieces before heating

w_2 : mass of the HPL sample pieces after being heated

The value of gain of thickness can be calculated by the following equation

$$GOT (\%) = \left(\frac{T_2 - T_1}{T_1} \right) \times 100 \quad (6)$$

Remark:

GOT : gain of thickness

T_1 : thickness of the HPL sample before heating

T_2 : thickness of the HPL sample after heating

3. Results and Discussion

3.1. Synthesis and Characteristics of MF Resin

Melamine-formaldehyde (MF) resin with borax additives was synthesized through a condensation polymerization reaction or so-called polycondensation under alkaline conditions (pH 9-10) and a temperature of 85-95°C. There are two stages of the reaction, the first stage is the methylation reaction, which is the reaction between melamine monomers and formaldehyde monomers to form methylol melamine. Melamine and formaldehyde methylation can form hexa methylol melamine molecules because a melamine structure has three primary amine groups that can bind two formaldehyde molecules so that melamine molecules can bind six formaldehyde molecules to form hexa methylol formaldehyde. The next stage is a condensation reaction between melamine with other methylol melamine or also with free

formaldehyde. This condensation reaction will form melamine-formaldehyde polymer chains with ether bridges and release water molecules. This polymerization reaction is influenced by the molar ratio between formaldehyde and melamine, raw material purity, pH, and temperature. Schematic of the synthesis of melamine-formaldehyde resin with borax additives can be seen in Figure 1.

The first step in the synthesis of melamine-formaldehyde resin is formaldehyde, DEG, and water is put into the reactor flask. NaOH 6% w/w was added to adjust the pH of the system in an alkaline atmosphere with a pH value of 9-10. The water bath is turned on to increase the temperature. When melamine is added, a new melamine-formaldehyde polymerization reaction is started. The optimum melamine-formaldehyde methylation and condensation reactions can occur in an alkaline condition with a pH of 9-10 and a temperature of 90-95°C. The endpoint of the melamine-formaldehyde polymerization reaction is determined by the water tolerance value of the resin to water at 20°C.

The water tolerance you want to look for is 100-200% with resin/water ratio of 1:3. After water tolerance is obtained, cooling is done by turning off the water bath and refilling the water with cold water. Urea is also added to accelerate the cooling process because endothermic reaction. Additive borax (0, 0.5, 1, 1.5, & 2 %) was also added during the cooling process so that it could dissolve in the solution-based melamine-formaldehyde resin system. Melamine-formaldehyde resin with borax additive was then characterized by several physical and chemical parameters. Analysis of the physical and chemical parameters of melamine-formaldehyde resin with borax additives can be seen in Table 1.

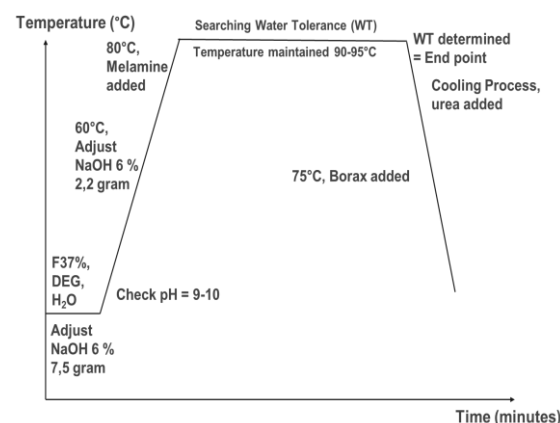


Figure 1. The schematic of the synthesis of melamine-formaldehyde (MF) resin with borax additives

Water tolerance value in the resin mixture shows as a percentage of the amount of water that acts as a solvent before it separates into two phases under equilibrium conditions. Solid content value shows as the percentage of the amount of non-volatile material left in the resin mixture when the solvent has evaporated completely. Gel time value indicates the time required for a resin to turn into a gel form. The shelf life of MF resin was determined by daily visual observation of the resin. Based on the results of physical and chemical parameters obtained, the five melamine-formaldehyde resins with borax additives qualified the quality standards of melamine-formaldehyde resins for HPL production.

3.2. Storage Stability Study of MF Resin

Melamine-formaldehyde (MF) resin with borax additive 0, 0.5, 1, 1.5, & 2 % was carried out for storage stability by observing daily visuals of the resin and changes in pH and viscosity every day for 10 days. Based on the calculation of the daily change in pH of the resin, the 0% MF borax resin decreased in pH from 8.72 to 8.38 while the four MF resins with borax additive did not experience a significant decrease in pH. This occurs due to the presence of borax contained in the resin as a component of the buffer solution which is able to maintain pH of the resin. The pH change data can be seen in Figure 2.

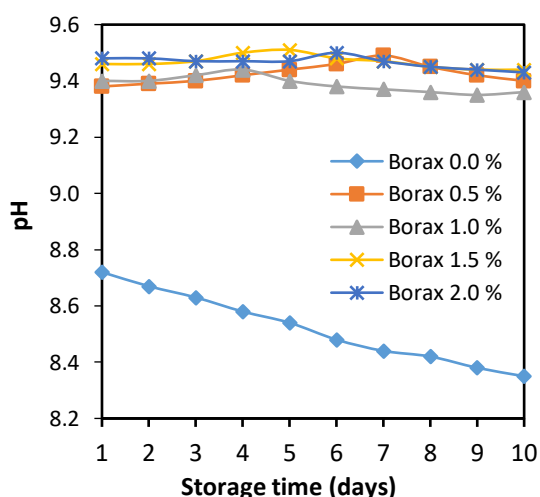


Figure 2. Changes in the pH of MF resin with borax additives

Based on the calculation of the daily viscosity change of the resin, 0% MF borax resin experienced a very significant increase in viscosity from 20 MPa to 185 MPa, while four

MF resins with borax additive did not experience a significant increase in viscosity. 0% borax MF resin easily occurs aggregation due to physico-chemical interaction between species during storage conditions because of the decrease of pH. This causes MF resin become saturated and precipitate and separate from the water solvent. Data on the change in the daily viscosity of the resin can be seen in Figure 3.

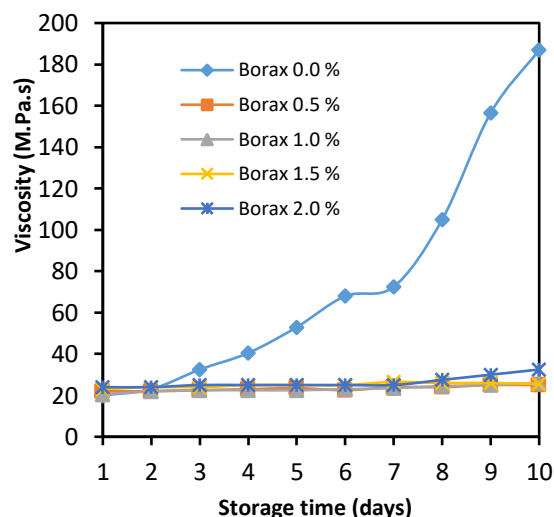


Figure 3. Changes in the viscosity of MF resin with borax additives

Based on visual daily observations of the resin (Table 1). The four MF resins with borax additives tend to have longer storage life than MF resins without borax because borax as a buffering agent will maintain pH of the resin so it does not easily decrease during the storage process and also can reduce the amount of aggregates in the resin system. Based on the results obtained, 1.5% MF borax resin has the longest storage age, 11 days. Borax 1.5% is assumed to be the optimum concentration as a buffer additive in the MF resin system.

Borax is soluble to form boric acid and salts as buffer components in aqueous-based MF resin systems. This buffer component will control the pH so it does not easily decrease during the storage process. The storage stability results of MF resin with 1.5% borax additive have the same results as MF resin with benzoguanamine additives from research (Henriques, et al., 2017), which is more than 10 days. Daily visual resin observations were carried out for 11 days.

Table 1. Characteristics of physical and chemical parameters of MF resin with borax additives

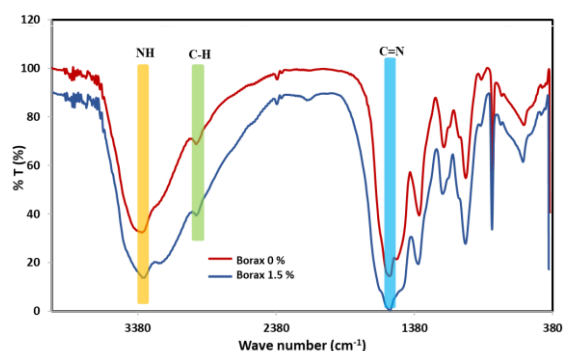
MF Resin	Parameter						
	WT (%)	SC (%)	Gel Time (s)	μ (M Pa/s)	pH	ρ (g/cm ³)	Age (day)
Standard	100-200	49-51	40-180	20-30	9 -9.8	1.21-1.22	1-3
Borax 0 %	185,28	49,51	50	20	8,72	1.2242	3
Borax 0.5 %	153.93	50,36	65	22	9,38	1.2261	5
Borax 1 %	198.86	50.02	60	20.5	9.40	1.2292	7
Borax 1.5 %	184.63	50,38	58	23	9,46	1.2338	11
Borax 2 %	179.70	50,62	61	24	9,48	1.2376	9

Table 2. Data of resin content and volatile content from the impregnation of MF resin with borax additives

No	Resin Samples	RC (%)	VC (%)
1	Gloss Standard	59-61	8-9
2	MF Resin + Borax 0 %	49,49	6,46
3	MF Resin + Borax 0.5 %	44,22	5,74
4	MF Resin + 1% Borax	46.96	7,60
5	MF Resin + Borax 1.5 %	47,19	7,31
6	MF Resin + 2% Borax	46.99	6,46

3.3. FT-IR Analysis of MF Resin

MF resin with borax 0 % and 1.5% borax resin were casted into resin films, the resin films were then analyzed for functional groups using FT-IR instruments. Figure 4 FT-IR spectra of 0% borax MF resin and 1.5% borax. Several band characteristics can be identified in the reference spectra of 0% borax and 1.5% borax MF resin.

**Figure 4.** FT-IR analysis of 0% borax MF resin and 1.5% borax MF resin

The peak at 3334 cm⁻¹ indicates the strong broad of O-H stretching vibration and medium stretching of N-H group corresponded to medium C-H stretching vibration in -OCH₂, the peak of 1555 cm⁻¹ indicates the vibration of C=N ring, 1334 cm⁻¹ indicates the CH₂ bent vibration, 1166 cm⁻¹ shows the COC strain vibration of -CH₂-O-CH₂- and -CH₂-O-CH₃. The peak of 810 cm⁻¹ shows a bent vibration of the triazine ring in the melamine structure (Henriques et al., 2017) (Chen et al., 2019).

The presence of a spectrum in the fingerprint area of the IR spectra of 1.5% borax MF resin indicated the presence of borax in the resin film. At wave number 1350 cm⁻¹, there are symmetrical and asymmetrical vibrations in the bond between BO. The wave number 1339 cm⁻¹ indicates an asymmetric strain vibration in the BO₄ tetrahedral. This shows that the fingerprint area for borax compounds ranges from wave numbers 1420-924 cm⁻¹ (Ersan et al, 2015). The chemical shift in the peak wavenumber in the spectral band of MF resin with 1.5% borax additives occurs because the borax involved in the MF resin system only provides physical interaction without chemical bonding.

3.4. Impregnation of MF Resin

Melamine-formaldehyde resin (MF) with the synthesized borax additive is then used for the impregnation of decorative paper in HPL production. The impregnation process of MF resin with borax additives was carried out manually without being able to determine the desired resin content (RC) and volatile content (VC). The value of resin content and volatile content are showed on Table 2.

Based on the results obtained, the five resin samples did not meet the standards for resin content and volatile content in the resin impregnation process for Gloss type HPL. This is due to the impregnation process being carried manually so that it is unable to set the desired RC and VC levels.

3.5. Quality Analysis of HPL Resin

High-pressure laminates from MF resin with borax additive quality were analyzed with several physical parameters based on SNI ISO 4586-7: 2017 Standards in the form of gain of weight (GOW), gain of thickness (GOT), surface rating, flexibility, and analysis of hot oil and hot water. Based on SNI ISO 4586-7: 2017 in discussing the resistance of HPL in boiling water, the percentage of mass gain or gain of weight (GOW) and the percentage of gain of thickness (GOT) has a standard of no more than 17 %.

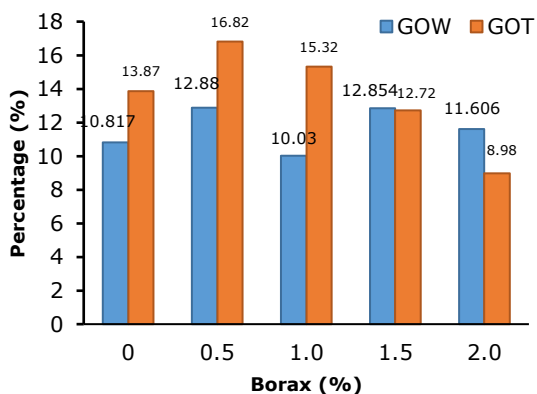


Figure 5. Analysis of GOW and GOT HPL MF resin with borax additives

The yield percentage of mass addition (GOW) and the results of the percentage addition of thickness (GOT) are showed on figure 5. Based on the results obtained, the percentage of mass gain or gain of weight (GOW) and the percentage of gain of thickness (GOT) of the five HPL samples complied with SNI ISO 4586-7: 2017 standards, which is lower than 17%.

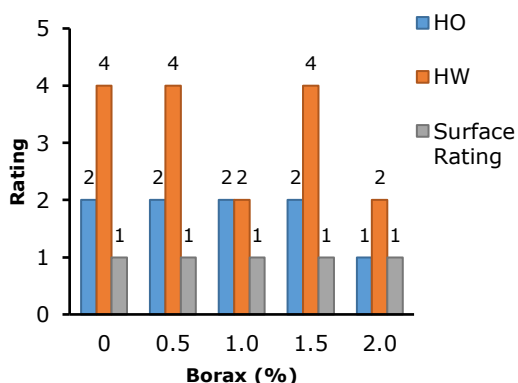


Figure 6. Analysis of hot oil, hot water, and determination of the surface rating of HPL MF resin with borax additives

The results of hot oil and hot water analysis as well as surface ratings can be seen in Figure 6. The results of hot oil and hot water analysis

from HPL MF borax 0, 0.5, 1, 1.5, and 2% respectively are 2&4, 2&4, 2&2, 2&4, and 1&2. The surface rating results of HPL MF borax 0, 0.5, 1, 1.5, and 2 % respectively were 1, 1, 1, 1, and 1. Based on the results obtained, hot water analysis of HPL resin MF with 0% borax, 0.5%, and 1.5% following SNI ISO 4586-7: 2017 standards. In the analysis of hot oil and surface rating values, the five HPL samples did not meet SNI ISO 4586-7:2017. The results of the flexibility analysis can be observed in Figure 7.

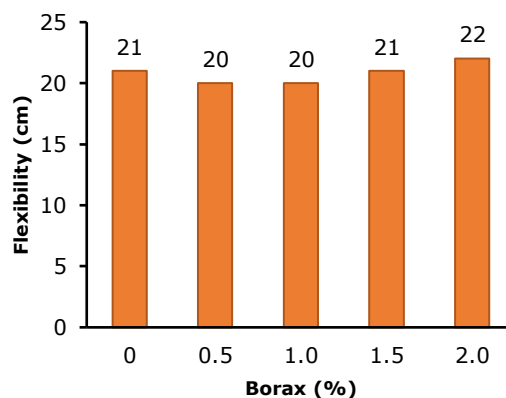


Figure 7. Analysis of HPL flexibility of MF resin with borax additives

The results of the flexibility analysis of HPL resin MF borax 0, 0.5, 1, 1.5, and 2 % respectively were 21, 20, 20, 21, and 22 cm. Based on the results obtained, the five HPL samples followed the flexibility quality standard, namely, the flexibility standard was not less than 15 cm. From the results of the HPL quality analysis, high-pressure laminates MF resin with borax additives have met several standards based on SNI ISO 4586-7: 2017 so it can be said that this HPL has similar properties and performance to commercial HPL. Compared to previous studies (Henriques et al., 2017), high-pressure laminates produced from MF resin with the addition of benzoguanamine as a comonomer additive also meet HPL quality standards. The physical and mechanical properties of the HPL are similar to those of HPL resin MF with added borax.

3.6. Analysis of HPL Gloss Level from Resin

High-pressure Laminates from MF resin with borax additive analyzed the level of gloss using a gloss meter. The results of the analysis of the gloss level of HPL resin MF with borax additives 0, 0.5, 1, 1.5, and 2% can be seen in Figure 8. The results of the analysis of the gloss level of HPL resin MF with borax

additives 0, 0.5, 1, 1.5, and 2% were 114, 112, 107, 115, and 104 respectively.

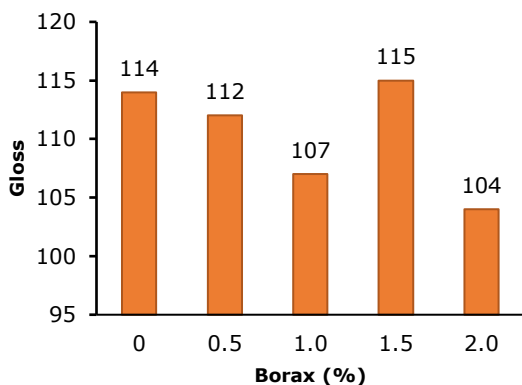


Figure 8. Analysis of the gloss level of HPL MF resin with borax additives

Based on the results obtained, the HPL of 1.5% borax MF resin has the highest gloss level of 115%. This indicates that 1,5 % borax MF resin has the best quality for gloss HPL because of longer storage age that lead to resin with clear visual. Nonetheless, these obtained data did not give a pattern of increasing the gloss level accompanied by the addition of borax due to the impregnation process was still done manually. So that the resin content (RC) and volatile content (VC) in the impregnation process of decoration paper for gloss type have not reached the expected standard. The study (Henriques et al., 2017) also conducted an analysis of the gloss level of HPL MF resin with benzoguanamine additives, the high-pressure laminates obtained had the highest gloss level of 102, which is lower than HPL resin MF with 1.5% borax additive, which is equal to 115.

4. Conclusion

The application of borax as a buffering agent successfully enhances the storage stability of melamine-formaldehyde (MF) resin holds great potential in the high-pressure laminates (HPL) industry. The storage stability of MF resin is a critical aspect in HPL production, as it can undergo unwanted polymerization reactions during storage, leading to short storage age and a decrease of overall product quality. By incorporating borax as a buffering agent stabilized the pH of the MF resin and effectively reducing the rate of undesirable physico-chemical interaction and extending the shelf life of the resin. Approaches were used in this study by varying the concentration of borax. The addition of 1,5 % borax resulting the highest storage stability and the HPL produced has the best result of

quality analysis. The utilization of borax in this manner demonstrates its promising application as a cost-effective and readily available solution to overcome the storage stability challenges faced by the HPL manufacturing industry.

Acknowledgement

The author would like to thank Mrs. Midia Fujiani as Quality Assurance Manager of PT TACO Anugrah Corporindo for providing facilities for carrying out this research.

References

- Bulian, F., & Graystone, J. A. (2009). Raw Materials for Wood Coatings (2) – Solvents, Additives and Colorants. In *Wood Coatings* (pp. 95–135). Elsevier. <https://doi.org/10.1016/B978-0-444-52840-7.00004-7>
- Chen, X., Afreen, S., Yu, X., Dong, C., & Kong, Q. (2019). Modified melamine-formaldehyde resins improve tensile strength along with antifouling and flame retardancy in impregnation of cellulose paper. *RSC Advances*, 9(63), 36788–36795. <https://doi.org/10.1039/C9RA07743J>
- Ersan, A., Kipcak, AS, Yildirim, M., Derun, EM., Tugrul, N., & Piskin, S. (2015). Determination of the Zinc Oxide and Boric Acid Optimum Molar Ratio on The Ultrasonic Synthesis of Zinc Borates. *Journal of Chemical and Molecular Engineering*. 9(12):1444-1447 <http://dx.doi.org/10.5281/zenodo.1110666>
- Dietlhem, H., Gattlen, R. (1973). US. Pat. 3,753,934-A.
- Farmakis, L., Koliadima, A., & Vamvakas, S. (2020). Stability of melamine-formaldehyde (MF) resin under different pH and ionic strength values. *Journal of Food Processing and Preservation*, 44(6). <https://doi.org/10.1111/jfpp.14471>
- Henriques, A., Almeida, M., Paiva, N., Ferra, J., Martins, J., Carvalho, L., & Magalhães, F. D. (2018). Improving hydrophobic and oleophobic performances of high-pressure laminates. *European Journal of Wood and Wood Products*, 76(6), 1685–1695. <https://doi.org/10.1007/s00107-018-1357-1>

- Henriques, A., Paiva, N., Bastos, M., Martins, J., Carvalho, L., & Magalhães, F. D. (2017). Improvement of storage stability and physicochemical properties by addition of benzoguanamine in melamine-formaldehyde resin synthesis. *Journal of Applied Polymer Science*, 134(32), 45185. <https://doi.org/10.1002/app.45185>
- HIMKI (2022). Ekspor Mebel-Kerajinan Diprediksi Rp 48 Triliun, Tertinggi Satu Dekade. <https://www.himki-indonesia.com/post/view/333-id-ekspor-mebelkerajinan-diprediksi-rp-48-triliun-tertinggi-satu-dekade>
- Hiroaki, A., Teruo, M., Hiroshi, S., Zenzaburo, S., & Tadamoto, T. (1970). US Pat. 3,515,697-A.
- Isac-García, J., Dobado, J. A., Calvo-Flores, F. G., & Martínez-García, H. (2016). Green Chemistry Experiments. *Experimental Organic Chemistry*, 417–484. <https://doi.org/10.1016/B978-0-12-803893-2.50013-9>
- Jahromi, S. (1999). The storage stability of melamine formaldehyde resin solutions: III. Storage at elevated temperatures. *Polymers*, 40.5103–5109
- Lan, P., Yang, R., Mao, H. Y., Cui, J. Q., & Brosse, N. (2019). Production of melamine formaldehyde resins used in impregnation by incorporation of ethylene glycol and caprolactam with high flexibility, storage stability, and low formaldehyde content. *BioResources*, 14(4), 9916–9927. <https://doi.org/10.15376/biores.14.4.9916-9927>
- Magina, S., Santos, M., Ferra, J., Cruz, P., Portugal, I., & Evtuguin, D. (2016). High Pressure Laminates with Antimicrobial Properties. *Materials*, 9(2), 100. <https://doi.org/10.3390/ma9020100>
- Martins, J. M., Almeida, M. L., Coelho, C. M., Ferra, J., & Carvalho, L. H. (2015). A New Methodology to Evaluate the Cure of Resin-Impregnated Paper for HPL. *The Journal of Adhesion*, 91(10–11), 792–800. <https://doi.org/10.1080/00218464.2015.1006363>
- Motavalli, M., Czaderski, C., Schumacher, A., & Gsell, D. (2010). Fibre reinforced polymer composite materials for building and construction. In *Textiles, Polymers and Composites for Buildings* (pp. 69–128). Elsevier. <https://doi.org/10.1533/9780845699994.1.69>
- Naydenov, I. (2012). European Patent Application. EP 2,402,379-A1
- Popescu, C. M. (2017). Wood as bio-based building material. *Performance of Bio-Based Building Materials*, 21–96. <https://doi.org/10.1016/B978-0-08-100982-6.00002-1>
- Pratiwi, Y. S., Prasetyowati, I., Hidayati, M. N., Antika, R. B., Oktafiani, L. D. A., Damat, D., Shoukat, N., & Ahmed, K. (2020). Review article: The effect of borax as a food additive on energy metabolism. *Annals of Tropical Medicine and Public Health*, 23(08). <https://doi.org/10.36295/ASRO.2020.23819>
- Santos, J., Pereira, J., Paiva, N., Ferra, J., Magalhães, F. D., Martins, J. M., & de Carvalho, L. H. (2021). Impact of condensation degree of melamine-formaldehyde resins on their curing behavior and on the final properties of high-pressure laminates. *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, 235(3), 484–496. <https://doi.org/10.1177/0954406220940338>
- Thompson, J. D., Mitchell, D., & Klepac, J. (2014). *Advantages and Disadvantages of Untrimmed Wood in the Supply Chain* (Issue 1).
- Ullah, S., Bustam, M. A., Nadeem, M., Naz, M. Y., Tan, W. L., & Shariff, A. M. (2014). Synthesis and thermal degradation studies of melamine formaldehyde resins. *Scientific World Journal*, 2014. <https://doi.org/10.1155/2014/940502>