A STUDY ON IMPROVED UTILISATION OF NEEM (AZADIRACHTA INDICA *A.* JUSS) FOR CARVING BY THE AKAMBA CO-OPERATIVE SOCIETY

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1.0 Introduction

Wood carving industry is a major informal industry in Kenya that provides a livelihood for many families from the drought prone Eastern province. Traditionally, woodcarvers have used specific tree species in their work. These include Muhugu (*Brachylaena huillensis* O. Hoffm), Mpingo (*Dalbergia melanoxylon* Gull. & Perr.), Olive (*Olea europea L.*), Mgurure (*Combretum Schumanni* Engl.) and Mutanga (*Spirostachys africana* Sond.). The demand for these slow growing indigenous tree species has tremendously increased due to the growth of the industry resulting in severe over exploitation and short supply of these species. In abid to save these species, WWF and its partners have been promoting the use of faster growing tree species, termed 'good woods'.

Neem (*Azadirachta indica* A.Juss) is one of the most important and widely available 'good wood' species used by the carvers at Akamba handicraft Co-operative Society at the Kenyan Coast. The tree regenerates naturally and grows extensively around Mombasa and has the advantage that it is widely available and fast growing as compared to the over exploited indigenous hardwoods. A number of farmers at the Kenyan coast have also been sensitized and are now tending the natural regenerants of neem trees. A valuable overseas market for neem carvings has also been developed over recent years with considerable potential for growth.

Carvers at Akamba Co-operative Society (hereinafter referred to as the Society) generally agree that neem is an acceptable wood suitable for carving, and the ability to produce quality products in terms of design and finish is much in evidence. However, there are two important (and serious) problems associated with this wood. Firstly, neem wood has been observed to crack and check during various stages of carving and in the finished product, and secondly, its sapwood is susceptible to the growth of mould and these have been observed on finished products. Both these problems are moisture related, in the first, generally associated with too rapid drying, and in the second, with insufficient drying to below certain moisture content.

A solution to the problem for controlling the growth of mould is relatively straightforward as fungicides can be used to eradicate them. However, the effectiveness and optimal concentration of selected fungicides and their effects on and interactions with stains and finishes needed to be established. Clear health and safety guidelines also needed to be developed on the use, application and disposal of the fungicides. Controlling checks, split, and shakes would require considerably more effort; the solution to this problem would be forthcoming only after a number of controlled experiments have been completed (Burclaff and Muga, 2003).

In order to meet the demands of research and quality control for improved utilization of neem, Burclaff and Muga (2003) recommended that, the Society needed to develop the abilities to measure, record, and analyse the behaviour of neem under various conditions. The ability to use simple measuring equipment and follow basic experimental procedures would enable the Society to find solutions and continually improve the quality of their products. Skills and knowledge in determining moisture content and ambient conditions were to be learnt in order to operate a drying kiln successfully. These are therefore, essential and practical skills that the Society needed to master if it were to control stock and quality.

This study was therefore designed to attempt to solve these two problems and to equip the Society with knowledge and skills in the necessary experimental procedures required for improving the quality of neem woodcarvings. The specific objectives of the study were as outlined below.

Objectives

1. To determine the average green moisture content and density (basic specific gravity) of neem and their variation from pith to sapwood for 4 diameter classes.
2. To establish how much water needs to be removed to dry neem to 10-12% moisture content.
3. To assess the extent of (a) drying degrade and (b) moisture loss over time of neem logs under different conditions.
4. To assess the economics of end sealing of the logs.
5. To establish the identity of the mould fungi growing on neem carvings.
6. To determine the most effective fungicide, best method and stage of their application on the wood or carvings.
7. To test the effects of the proposed fungicides on and their interactions with various stains and finishes used on wood carvings.
8. To liaise with Solar World (EA) limited in designing, fabrication and testing of an experimental kiln for drying of the woodcarvings.
9. To undertake tests using the experimental kiln with controls to determine optimum drying rates before degrade occurs and establish a kiln drying schedule that will work best for the many different sized carvings and products.
10. To write simple guidelines for carvers to follow while purchasing neem logs, storing logs, applying fungicides and drying carvings.
11. To liaise with Kenya Gatsby Trust (KGT) inorder to provide the missing information required for the finalization of the draft production manual.
12. To train 3 employees of the Society in experimental procedures of the whole process including Neem tree selection, log yard storage and treatment and wood drying operations.

The findings are reported under five main sections: Determination of green moisture content and Density (basic specific gravity) of neem, Identification of the type of mould fungi growing on neem woodcarvings at the Society and their control, Economics of end sealing of neem logs with paraffin wax, Experimental solar dryer and general discussions, conclusions and recommendations.

2.0 Determination of green moisture Content and Basic specific gravity of neem

2.1 Introduction

Specific gravity and moisture content are very important physical properties of wood. Specific gravity is the single most important physical property. Most of the mechanical and physical properties of wood are correlated to specific gravity. The strength, stiffness and heat transmission of wood all increase with specific gravity. The shrinkage and swelling behaviour of wood is also affected by its specific gravity.

Green moisture content of wood is the moisture content of wood at the time of harvesting while basic specific gravity is the mass of dry wood substance per cubic metre or the ratio of the density of green wood to the density of water at 4 ^{0}C (1 g/cm^3). It is a standard procedure to determine both the two properties based on the oven dry weight of wood as shown in equations 2-1 and 2-2. Specific gravity of wood remains fairly constant above the fibre saturation point (about 25-30 % moisture content for most species) but below this point, it increases as the moisture content decreases, this is because the oven dry weight remains the same while the volume of wood decreases during drying (Bowyer *et al*. 2003) The green moisture content and specific gravity of wood varies considerably among kinds of trees, between heartwood and sapwood in the same tree, and even between logs cut from different heights in the same tree. The two properties have been used in a number of studies to identify and group species of similar drying characteristics. They have also been used as estimators of drying time. It was therefore essential to establish these properties in order to understand the drying and related characteristics of neem.

Objectives

1. To establish the basic density and moisture content of neem and establish their variation from sapwood to the pith.
2. To estimate the rate of moisture loss from neem under different storage conditions.
3. To estimate the amount of moisture that the kiln would be required to evaporate in order to dry the carvings to 12 % moisture content.
4. To train 3 personnel at the Society on experimental procedures for determination of the basic physical properties of wood (moisture content and density).

2.2 Materials and methods

2.2. 1. Materials

Wood samples

Wood samples used in the study were obtained from three freshly cut neem trees at KARI regional Research Centre at Mtwapa. The samples represented four diameter classes: D_1 (8- 11 inches), D_2 (12-16 inches), D_3 (17 –23 inches) and D_4 (24 inches and above). For each diameter class, discs of about 6 inches (15 cm) were obtained. The samples were transported to the Society immediately after they were cut. Samples for moisture content and density were prepared the same day and their initial weights recorded.

2.2.2 Methods

Procedure for determination of Moisture content

1. Samples were obtained from bark to bark (Figure 2-1).
2. The samples were labeled using permanent markers to indicate position of sampling i.e. sapwood, heartwood or pith.
3. Each sample was weighed and the initial weight recorded in a data sheet provided (Appendix 1) before being put in an oven to dry at 103^0 C.
4. The samples were weighed again after 24 hours and the weight recorded in the data sheet.
5. The weighing of samples was thereafter continued at an interval of 3 hours until a constant weight was obtained.
6. The final weight, which is the oven dry weight, was recorded.
7. Moisture content was obtained using the following formula:

   Moisture content (%) = [(Initial weight- Oven dry weight) x 100]/ Oven dry weight. --*Eq. 2-1*.

Procedure for determination of the basic specific gravity of neem

1. The same samples for moisture content were used.
2. The green samples were dipped in water over night until they were fully submerged into the water. The volume of the samples was determined using the displacement method.
3. Each sample was weighed and the initial weight recorded in a data sheet provided (Appendix1) before being put in the oven to dry at 103^0 C.
4. The oven dry weights of the samples were obtained as outlined above and recorded.
5. The basic specific gravity was obtained using the following formula:

Basic specific gravity = Oven dry weight/green volume (g/cm^3)---------------------*Eq. 2-2.*

Sw_1	Sw_2	Hw_1	Hw_2	Hw_3	Pith	Hw_4	Hw_5	Hw_6	Sw_3	Sw_4

Key : Sw-Sapwood Hw- heartwood

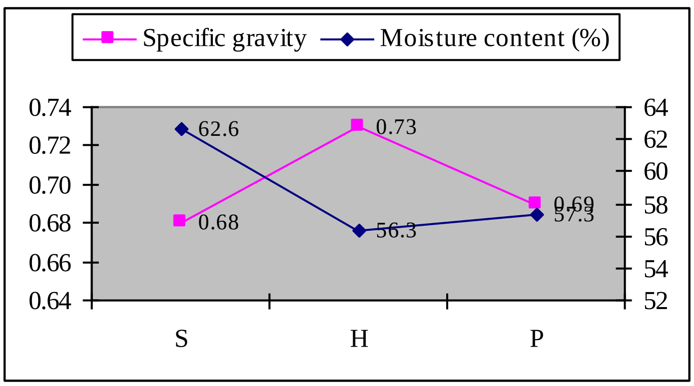
Fig. 2-1. Sampling of wood specimen for moisture and specific gravity tests.

2.3. Results and discussions

2.3.1 Basic specific gravity

The results are recoded in Table 2-1 and illustrated in Figures 2-2 and 2-3. The mean basic specific gravity of neem was found to be 0.71. This specific gravity value is equivalent to a density of 710 kg/m^3. Though the calculations were based on the oven dry weight of the samples, it is in the same range of that recorded for the same species in India based on green weights (600-800 kg/m^3, Prospect database). However, it is lower than those for all the traditional woodcarving species: *Dalbergia melanoxylon* (1.23), *Brachylaena huillensis* (1.15), *Olea africana* (0.99) *Spirostachys africana* (1.04) and *combretum schumanii* (0.93) (Muga *et al*, 1998). The results of this study indicate that neem growing at the Kenyan coast as that grown in India has a medium density. This confirms its suitability for carving as woods that are selected for this purpose are normally of low to medium density (0.45-0.8) because they are softer and easier to work with hand tools (Hopewell, 1998).

The basic specific gravity of neem had a general tendency to increase from sapwood and reach the peak at the heartwood and then reduce to about the same level at the pith (Figure 2-2). The higher density in the heartwood as compared to that in the sapwood could be due to higher concentrations of extractives in the former (Bowyer et al, 2003).



Key: S-sapwood, H-heartwood and P- pith.

Fig. 2- 2. Variation of density and moisture content of green neem logs with position of sampling

The smaller diameter (8-16 inches) neem logs seem to a slightly higher mean specific gravity (0.72) than the larger (17-24 inches) ones (0.69), Figure 2-3. However, the results indicate that there is not a great deal of variation between diameter classes, thus suggesting the material being used for carving is fairly homogenous material.

2.3.2 Green Moisture content

The results of this study indicate that the green moisture content of neem varied slightly with position of sampling. There was a general tendency for the moisture content of the wood to decrease from the sapwood to the pith except for the largest diameter class where there was a reversal in the order (pith > heartwood> sapwood). This is due to the wood density. It is a generally established fact that the green moisture content of wood decreases with increase in basic specific gravity (Simpson, 1993). It could also be due to the fact that as wood changes from sapwood to heartwood, the amount of moisture in the cells may decrease as a result of deposition of extractives (Bowyer et al. 2003). These extractives tend to take the place of water molecules associated with cellulose and hemicellulose.

Sapwood conducts water and minerals between roots and leaves and therefore generally contains more water than heartwood, and this together with its high starch and nutrient content makes it more vulnerable to attack by wood bio-deteriorating agents. The differences in moisture content between sapwood and heartwood are generally smaller in hardwoods than in softwoods. For example, in USA moisture content in the range of 46 to 95 % for heart wood and 44 to 137 % for sapwood in the case of hardwoods and 33 to 98 % for heartwood and 110 to 249 % for sapwood in the case of softwood have been reported (USFPL 1987 cited in Bowyer et al 2003).

The green moisture content and density of wood are important factors in developing and modifying necessary drying schedules for drying a particular wood species. Drying of wood is essentially a process of evaporating water from the wood. A drying kiln would therefore be expected to provide the latent heat of evaporation to change the liquid moisture in the wood to moisture vapour. This heat is normally about 50 % of the total heat requirement (about 4.5 MJ /kg of moisture), (Australian Timber seasoning manual, and 1997). Some heat would also be required to raise the temperature of kiln air, and any incoming exchange air, to operating temperature and is estimated to be between 2 to 2.5 MJ / kg of moisture. From the results of this study, it is possible to estimate the mass in kg of moisture to be evaporated per m^3 of neem if the wood were to be dried to 12 % moisture content. This can be estimated by the following formula:

M= basic density x (MC prior to drying –dried MC) ----------------------*Eq. 2-3.*

(Where, M= the mass in kg of water to be evaporated per m^3, MC =Moisture content)

Substituting the values obtained in the study, the mass of water to be evaporated from neem, M, = 707x (0.598-0.12) =338 kg/m^3.

To dry 1 m^3 of green neem samples would therefore require about 1521 MJ (4.5 x 338) of heat. To dry green rough carvings of about 30 % moisture content would require 572.9 MJ.

Table 2-1. Basic specific gravity and green moisture content of neem.

Diameter class	No. of logs	Position of sampling	Basic Specific gravity			Moisture content		
			Mean	s.d	C.V (%)	Mean (%)	s.d	C.V (%)
1	3	S	0.70	0.02	3.0	62.0	2.6	4.3
		H	0.73	0.02	2.5	54.0	1.2	2.2
		P	0.71	0.02	2.1	53.5	1.6	2.9
		Mean	0.71	0.02	3.5	57.1	4.5	7.9
2	4	S	0.68	0.03	4.0	65.1	6.1	9.3
		H	0.74	0.04	5.0	53.0	4.7	8.8
		P	0.73	0.02	2.7	51.7	2.8	5.3
		Mean	0.72	0.04	5.8	56.2	7.7	13.7
3	2	S	0.65	0.03	4.1	66.0	4.3	6.5
		H	0.72	0.02	2.8	58.9	2.9	5.0
		P	0.67	0.04	5.7	58.2	3.7	6.3
		Mean	0.69	0.04	5.6	61.0	4.8	7.8
4	1	S	0.69	0.03	4.4	57.3	3.5	6.1
		H	0.71	0.06	8.3	59.4	9.1	15.4
		P	0.63	-	-	65.7	-	-
		Mean	0.69	0.05	7.4	59.2	7.2	12.1
Overall mean			0.71	0.04	6.4	59.8	5.9	9.9

Key: S-sapwood, H- heartwood and P-Pith, CV – coefficient of variation, s.d-standard deviation.

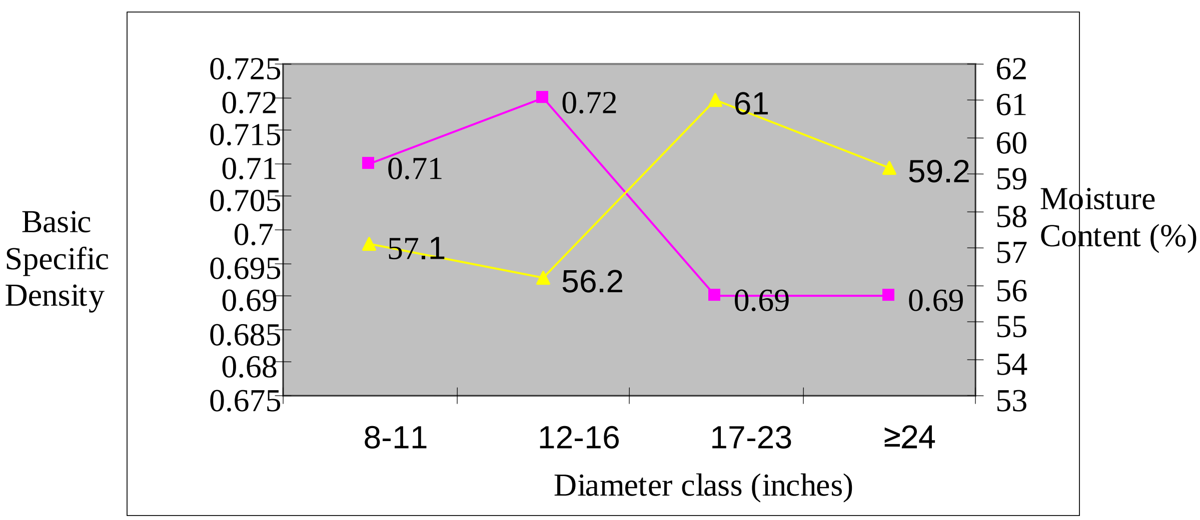


Fig. 2- 3. Variation of density and moisture content of green neem logs with diameter

The amount of moisture lost by neem wood under different storage conditions

Estimation of moisture loss in semi- round blocks of neem wood samples

Green neem samples (semi- round blocks, Figure 2-4) were put to dry under 4 different conditions thus: Shade without end sealing, shade with end sealant applied, sun without end sealant and sun with end sealant applied. The amount of moisture loss was estimated by determining the original moisture contents of the samples and then estimating their moisture contents on a daily basis by taking their weighs using an electronic balance Detailed procedure on how the estimates were made is recorded in Appendix 1.

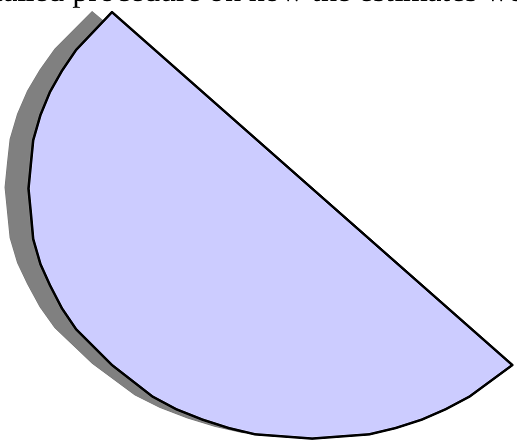


Fig. 2-4. An example of semi round neem block used in the experiment.

The results for experiments on moisture loss from neem under different storage conditions are as shown in Table 2-2 below. Un sealed wood samples put in direct sunlight had lost the highest amount of moisture (27.4 %) of the initial moisture content after 35 days. The end sealed samples put under a shade had lost the least amount of moisture (16.7 %) after 35 days. This was only slightly lower than that (17.5 %) for those samples that had been end sealed and put in the sun. This shows that end sealing of the neem logs can effectively help in retaining considerable amount of water in the wood for long periods. Cracks and checks were observed in the samples placed in the sun and not end sealed, within the same day and the numbers increased with duration of exposure. It was also observed that samples that had been end sealed developed moulds within a week. However, minimal checks and cracks were observed on end sealed samples.

Table 2-2. Estimated moisture loss in neem samples

No. of days	Moisture content (%)			
	Under shade and not end sealed	**Under shade and end sealed**	**In the sun and not end sealed**	**In the sun and end sealed**
0	56.4	60.8	56.5	60.8
7	44.5	57.9	47.6	55.6
14	41.2	54.5	42.9	52.6
35	30.7	44.1	29.1	43.3
Total moisture loss at 35 days	25.7	16.7	27.4	17.5

Below (Fig. 2-5.) is a graphical representation of the above results with extrapolation

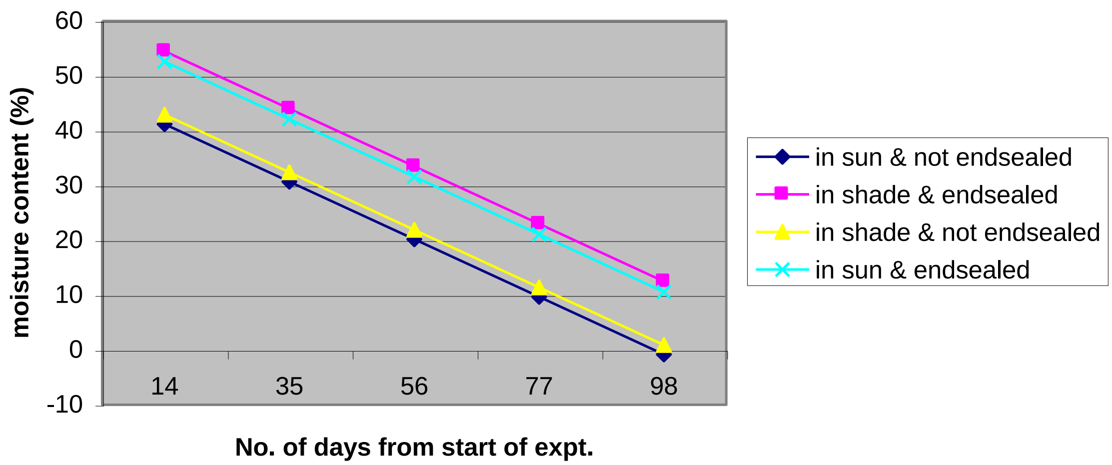


Figure 2-5. Extrapolated graphs showing loss of moisture in neem with time.

It appears from the gragh that it would theoretically take about 77 days for the moisture content of neem to reduce from about 60 % to 10 % for samples put in the sun and in the shade without end sealant and 98 days for the end sealed ones that were either in the shade or in the sun to reach the same level of moisture content. However, practically this may not be the case to due to environmental factors and the fact that the moisture loss may not fully assume a linear model. An analysis of the actual (oven dry) moisture content of the samples put in the shade and not end sealed, after 3 months (120 days) indicates that the samples had attained a moisture content ranging from about 14 -18 % and with a mean of 16.7 %.

<u>Estimation of moisture loss in round blocks of neem wood samples</u>

To establish the effect of different conditions of storage/drying on moisture loss of round neem blocks, samples 43 cm in diameter and each 30 cm long were obtained from a butt log and subjected to the following conditions: Shade without end sealing, shade with end sealant applied, sun without end sealant, sun with end sealant applied and solar kiln. The sampling was done as shown in Figure 2-6, below. The actual moisture content of the wood after 4 months under the above conditions was established using the oven dry method. The specimens for the moisture content tests were obtained from sapwood and heartwood. The results are recorded in Table 2-3.

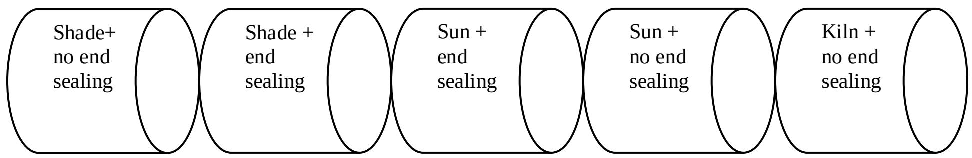


Figure 2-6. Sampling of round logs used in tests.

Table 2-3. Actual moisture content of the neem samples after 4 months of drying under different conditions.

Drying conditions	Position of sampling	Moisture content (%)	Mean moisture content (%)
Shade + no end sealing	HW SW	35.3 33.2	34.3
Shade + end sealing	HW SW	56.3 50.2	53.2
Sunshine + no end sealing	HW SW	30.4 19.4	24.9
Sunshine + end sealing	HW SW	60.1 43.9	52.0
Kiln + no end sealing	HW SW	22.7 14.1	18.4

Key: HW- Heart wood; SW- Sapwood.

From Table 2-3, it is apparent that neem samples put in the kiln had the least amount of moisture after 4 months, followed by those that had been kept in the sunshine without any end sealing and finally those in the shade without any end sealing; the samples that had their ends sealed with paraffin wax did not lose a significant amount of water. It is also evident that, the sapwood had lower moisture content as compared to the heartwood, in all cases. There was a more or less uniform moisture content in the samples kept under shade as compared to those kept in the sunshine irrespective of whether they were end sealed or not. The apparently significantly higher loss in moisture in the sapwood of samples that had been kept in the sun irrespective of end sealing could be due to the peeling off of the bark due to the harsh environmental conditions, as shown in Figure 2-7. With the bark peeled off, there was probably an increase in the loss of moisture through the exposed wood rays.

It appears that to achieve a substantial loss in moisture in neem wood put in the shade, a minimum of about 35 days would be required for neem logs that have been bisected into two and their ends left un sealed and about 60 days for the same type of neem logs with paraffin wax applied at the ends. A minimum of about 120 days would be required for round neem logs put in the shade but without any end sealant applied. It appears that it would be beneficial to split the logs at the pith, end seal the same and put these to dry under shade for about 2 months before they are carved. End sealing of selected round logs may only be advantageous if such logs are to be specifically kept a side by the Society for an impending export market order. The end sealing in this case would help in retaining the moisture in the wood and also minimize cracking and checking of these logs.

Fig. 2-7. Endsealed neem log put in the sun has bark peeling off.

Fig. 2-8. Endsealed neem log put in shade has bark intact.

3.0 Identification and control of moulds growing on neem woodcarvings at Akamba

Moulds are fungi that are characterised by cottony or downy growth, varying in colour from white through shades of yellow, brown-red, purple-blue, and green to black. Mild temperatures favour the development of moulds, an abundant supply of moisture and still air (poor ventilation) (Panshin and de Zeeuw, 1980). Wood and wood products when stored in such conditions may be contaminated and usually becomes stained; the colour of the stain depends on the type of fungi. Such conditions may be prevalent when wood is not properly piled for air seasoning, when green wood or wood products is shipped, in highly humid buildings and may even occur in dry kilns when wood or wood products are subjected to high humidity and low temperatures for a long period of time.

Moist wood surfaces support the growth of many different fungi that cause staining on it. Some of these fungi are Penicillium, Aspergillus, Fusarium and Rhizopus species.

Moulds apparently do not affect the strength properties of wood as they do not usually deteriorate the cell walls of wood but grow either on the surface or within the cell lumina of ray parenchyma (Bowyer *et al*. 2003). However, they have the potential of contaminating food when wood is utilised for food containers. Moulds are generally confined to sapwood surfaces only, due to the presence of sugar-starch in sapwood. They are particularly troublesome in freshly felled logs and recently sawn timber whose surface is relatively wet and sugar-starch content is high. Heartwood is immune to mould infestation except when wood items containing both heartwood and sapwood are steamed or soaked in hot water, and then moulds may develop also in heartwood. This is as a result of soluble materials from sapwood leaching out and subsequently penetrating the heartwood, thus making it susceptible.

The surest way of controlling fungal infestation on wood is proper drying and storage in a dry atmosphere. In air seasoning of wood, moulds can be controlled by sufficient air circulation. Keeping moisture levels in wood below 20 % is usually successful (Bowyer *et al.* 2003, Panshin and de Zeeuw, 1980). However, there may exist areas within a given item in which moisture content could be considerably in excess of the critical moisture content. This amount of moisture could be sufficient enough to allow spore germination or contact spread of hyphae. It is therefore necessary to supplement the above measures by chemical treatment of wood. Chemicals such as sodium penta-chlorophenate or ethyl mercury phosphate have been used for such treatments through dipping and spraying treatments (Panshin and de Zeeuw, 1980). However, these chemicals are no longer used, as they are not environmentally friendly. Boric acid, borax and ethylene glycol, which are more environmentally friendly (due to their lower toxicity), have been recommended for trial for control of fungal infestation and growth on neem woodcarvings (Burclaff and Muga, 2003). However, borax is not available locally in Kenya.

Boron has been shown to be toxic to *Merulius lachrymans* (the dry rot fungus) and to *Coniophorea cerebella* (the celler fungus) (Carr 1959; Findlay 1959 cited in Thornton 1964).

Before adopting the actual use of these chemicals by wood carvers to prevent mould infestation, it was necessary to evaluate their effectiveness and any possible drawbacks. It was also necessary to know the identity of the fungi in order to project how potentially severe the infestation may be and to assist in getting the most effective method of control.

Objectives

1. To identify the type of mould fungi growing on Neem wood
2. To test the efficacy of boric acid and ethylene glycol in controlling the moulds.
3. To establish the effect of dipping time on the amount of chemical absorbed by neem wood and the control of fungal growth on the wood.
4. To evaluate the effect of treatment of wood with these fungicides on the finishing of the woodcarvings.
5. To compile information on the health and safety issues of the fungicides.

3.1 Materials and Methods

3.1.1 Materials

Wood samples

Two woodcarvings with moulds were obtained from the woodcarving show room at the Society in Mombasa and transported to KEFRI pathology laboratory in Muguga for isolation and culturing. A freshly cut neem sapwood sample was also obtained after one month and used to prepare wood blocks for the tests.

Chemicals

Ethylene glycol

1. Boric acid
2. 95 % ethyl alcohol
3. Malt extract
4. Agar technical

Other materials

1. Petri-dishes
2. Auto clave
3. Oven dryer

3.1.2. Methods

Isolation and culturing of moulds

3.1.2.1 Isolation of microorganisms

The woodcarvings with moulds were surface sterilized using 95 % ethyl alcohol and then washed thoroughly in several changes of sterile distilled water and plated on malt extract using a sterile scalpel and forceps. The plates were then incubated at 18-22 ^{0} C and observed for growth of any fungus. After 20 days the fungus growing around the wood sample were isolated, purified and maintained on agar technical for further studies.

3.1.2.2. Identification of isolates

Cultural and morphological characteristics of isolates were studied and their identity confirmed. The cultures were sub cultured and stored for further investigations.

3.2 Determination of the effect of dipping time on the amount of fungicide absorbed by wood.

In order to know the amount of time required to dip neem sapwood in the fungicidal solutions, a small experiment was carried out to establish the amount of each fungicide that would be absorbed by the wood at varying duration of dipping. Initial weights of wood approximately 7.5 x 5.0 x 5.0 cm were obtained. Samples were dipped in 40 % boric acid and 40 % Ethylene glycol solutions and water (control) for varying times (5 min, 20 min, 1 hour, 2 hours and 3 hours) and the final weight obtained. Three samples were used for each treatment.

Chemical control of mould growth

(a) Evaluation of various fungicides using sterile wood blocks

Two fungicides viz. boric acid and ethylene glycol that are cheap and available locally were tested at 40 % concentration against mould fungi. Wood blocks from freshly sawn Neem sapwood, that had been sterilized in an autoclave (at a pressure of 20 lb/in^2 for 30 seconds), were dipped in fungicidal solution for 2 different dipping times 5, and 20 minutes and excess solution drained completely before placing inside the Petri dishes for inoculation. Some wood blocks were dipped in distilled water to serve as control. Wood blocks (2.0 x 1.0 x 1.0 mm) were used for tests.

The test blocks were inoculated with a disc from actively growing cultures of mould fungi. For each fungicidal treatment there were 3 replicate wood blocks. The Petri dishes were incubated at $28 \pm 2\ ^0$ C for 2 weeks.

The fungal growth on the blocks was visually assessed using the rating index in Table 3-1.

Table 3-1. Rating index for assessing the fungal growth (after Plackett, 1982).

Rating	Growth
0	No growth
1	Trace growth
2	Light growth
3	Medium growth
4	Heavy growth

3.2.1 Results

Identity of the fungi

Two types of fungi mycelia grew from the piece of neem specimen into the culturing media. Identification under a microscope revealed the two fungi to be Rhizopus spp and fusarium spp.

3.2.1.1 Rhizopus

Rhizopus is a cosmopolitan filamentous fungus found in soil, decaying fruit and vegetables, animal faeces, and old bread. While Rhizopus spp. are common contaminants, they are also occasional causes of serious (and often fatal) infections in humans. Some species are also plant pathogens. The genus Rhizopus contains several species.

3.2.1.2 Fusarium

This is also contaminant found mainly in soils.

3.3 Tests on the effectiveness of boric acid and ethylene glycol in controlling moulds on neem wood carvings.

Results of initial tests indicate that neem sapwood treated with 40 % ethylene glycol developed moulds after 2 days of being inoculated with fungi. Observations on the wood blocks treated with 40 % boric acid and inoculated with the fungi showed no trace of fungal growth.

The apparently higher effectiveness of the boric acid as compared to ethylene glycol could be due to the fact that neem seems to be absorbing more boric acid than ethylene glycol for either dry or green samples as shown in Table 3-2. From the table, it is evident that neem absorbs more boric acid for any duration of dipping than ethylene glycol and water and for either green or dry wood. The amount of water absorbed by green neem wood is significantly higher than that of ethylene glycol when samples are treated for 60 and 120 minutes. The amount of ethylene glycol absorbed is only significantly higher than that of water absorbed by dry neem samples treated for 5 min.

Table 3-2. Effect of dipping time on the amount of fungicide absorbed by wood.

Treatment	Increase in weight (%) after various duration of treatment									
	Green Samples (> 50 % MC)					Air dry samples (18 % MC)				
	5 min	20 min	60 min	120 min	180 min	5 min	20 min	60 min	120 min	180 min
Boric acid	1.1	1.0	2.3	3.8	4.8	1.4	2.5	3.9	4.4	5.9
Ethylene glycol	0.6	0.4	0.6	1.0	1.7	1.5	1.8	2.2	3.0	3.3
Water	0.6	0.7	1.6	2.2	2.4	0.8	1.2	2.3	2.8	3.6

Results of further tests, with varying concentrations and duration of soaking in the boric acid are as recorded in Table 3-3.

Table 3-3. Effect of duration of soaking and concentration of boric acid on mould control.

Boric acid concentration (%)	Duration of soaking in boric acid (seconds)	Observation after one week	Rating of fungal Infestation
40	30	No growth	0
40	60	No growth	0
40	120	No growth	0
40	1200	No growth	0
20	30	No growth	0
20	60	No growth	0
20	120	No growth	0
20	720	No growth	0
20	1200	No growth	0
10	1200	Trace growth	1
10	720	Light growth	2
5	1200	Heavy growth	4
5	720	Heavy growth	4
3	1200	Heavy growth	4
3	720	Heavy growth	4

It is apparent from the table and the initial trials that the optimum concentration of boric acid should be 20 % and above and this should be applied for at least 30 seconds. This concentration is in the range (18-25 %) recommended by (Harrow 1955 Cited in Vinden 2001)

Treatment with boric acid should be done on carvings that have any trace of sapwood. A person who has been properly trained on handling of the chemical can apply the boric acid. The procedure for the preparation of the acid solution is outlined in Appendix 2. The Material safety data sheet (MSDS) and safety guidelines on the use of boric acid are also outlined in Appendix 2. The boric acid is to be applied immediately after wet sanding of the carvings by completely immersing a carving into a 20 % solution of the acid. It is expected that there will be a minimal increase in the amount of water in the neem wood during this operation. An experiment designed to estimate the potential increase in the weight of wood carving due to this procedure, indicated that during normal wet sanding the increase in weight is approximately in the range of 1.8 to 4.1 % with a mean of 2.6 % (Table 3-4). This is similar to the amount of boric acid solution absorbed by neem after 20 minutes of soaking (2.5 %, Table 3-2).

Table 3-4. Increase in weight of neem samples during wet sanding

Sample No.	Dry Weight (g)	Wet Weight	Weight of Water	Amount of water absorbed (%)
A	384.55	391.50	6.95	1.8
B	517.50	527.10	9.95	1.9
C	79.25	82.50	3.25	4.1
Mean				2.6

1.1 3.4 Evaluation of the effect of treatment of wood with these fungicides on the finishing of the woodcarvings.

Wood samples that had been treated with either boric acid or ethylene glycol were subjected to the routine finishing operations at Akamba co-operative and observed for a period of one month for any possible effects of the chemicals on the finish.

An assessment of neem wood samples treated with these chemicals showed no observable effect of the fungicides on the finishing of the woodcarvings. However, treatment of neem wood with boric acid was noted to leave white crystals/residues on the surface of the wood. It would therefore be necessary to wipe the surface of a treated carving with a wet cloth or a sand paper once it has dried but before it is stained or varnished.

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4.0 Economics of end sealing of neem logs with paraffin wax.

End sealing is an operation that is performed on logs or sawn timber that are to be air dried for a long period of time with an aim of controlling moisture loss from the wood and hence reducing chances of end splitting. Burclaff and Muga (2003) recommended that the economics of end sealing of neem logs or blocks be established before it could be considered for adoption at the Society. This information was vital in order to assess how much more a carver would be expected to pay for the raw material if the logs were to be end sealed. It was for this purpose that this study was designed.

4.1 Method

A known amount of paraffin wax was put in a cooking pot (sufuria) and heated using a known quantity of charcoal. After melting, samples whose dimensions had been established were each dipped into the hot solution of the wax for 30 seconds, Figure 4-1. The process of dipping samples continued until the paraffin wax was all used up. The remaining amount of the wax in the pot was carefully removed and weighed and this weight subtracted from the initial weight of the wax, to obtain the actual quantity of the wax that was used for end sealing. Nine neem samples were used in the study and their details are recorded in Table 4-1.

Fig. 4-1. Neem log being endsealed using paraffin wax.

Table 4-1. Data for the economics of end sealing of neem wood**.**

Sample code	**Length of sample (cm)**	**Sample diameter**	**Surface area sealed (cm^2)**	**Estimated price of sample at the yard (Ksh.)**	**Price of all the rough Carvings obtainable from sample**	**Type of carving Obtainable**	**No. of each carving**
$D_{2.2}$	15.0	30.0	1414.3	40	160	5'' Elephants	1
$D_{2.2}$	15.0	27.94	1226.8	30	160	5 '' Elephants	1
T_1	32.5	15.4	369.2	40	150	Thin men	2
T_3	42.75	16.35	420.0	80	120	Thin men	2
$D_{2.3}$	27. 5	32.0	1609.2	150	300	8 '' giraffe	2
$D_{2.3}$	27.5	36.84	2132.8	150	400	10 '' Elephants	2
$D_{2.1}$	17.5	29.0	1321.6	150	350	5 '' Elephants	2
$D_{1.1}$	12.5	20.5	660.4	150	300	4 '' Elephants	6
T_3	62.5	17.6	486.8	80	300	Thin men	4
Total			9644.4	870	2240		22
Mean			**1071.6**	**96.7**	**248.9**		**2.4**

Calculations

Volume of wood = S X L (where S = Surface area of one end of wood to be sealed and L = length of sample) --- (1).
S= P D^2 /4 (where D= diameter and P = 22/7) -- (2)
Total Surface area of wood to be end sealed for any length of sample = 2 x S--------- (3)
From (eq. 1), surface area to be end sealed = (Volume/ L) ----------------------------- -(4)
The total surface area of 1 m^3 of neem logs, which are each 1 m long to be end sealed would be = 2 m^2

Assumptions

1. Supervisor will be required and earns a maximum of Ksh. 10, 000 a month (about Ksh. 330 per day which is Ksh. 41.25 an hour).
2. A carver makes an average of two rough carvings a day of a total value of Ksh. 320 and this is done in 8 hours.
3. Other costs to include the cost of paraffin (about 50 ml required for lighting a cooking stove) and matchbox.

The costs incurred in end sealing the above samples are recorded in Table 4-2 below.

Table 3-2. Costs incurred in end sealing of the neem samples

Cost item	Quantity used	Unit Cost (Ksh)	Total cost (Ksh)	Total cost per cm^2 of surface area sealed (Ksh)	Total cost per m^2 of surface area sealed (Ksh)	Total cost per m^3 of logs treated (1 m long of same diameter) (Ksh.)
Opportunity cost for the carver in end sealing	27 min	0.66	18	0.00187	18.7	18.7
Supervision	45 min	0.69	31.1	0.00324	32.4	32.4
Charcoal	1.26 kg	15.00	18.9	0.00196	19.6	19.6
Paraffin wax	1.27 (kg)	550	698.5	0.07243	724.3	724.3
Other costs[i]			5	0.00052	5.2	5.2
Total			771.5	0.08002	800.2	800.2

From the results, the cost for end sealing of neem logs would be about 8 cents (Ksh. 0.08) per cm^2 of the surface area of the sample or log sealed. The cost of end sealing of the samples used in the study is about 86.5 % of the estimated price of the samples at the log yard. However, as these samples were fairly short, it is expected that the price of end sealing longer samples with the same surface area would constitute a small proportion of the price of these logs at the log yard. Using Maingi's (2003) estimate of the cost of neem logs at the farm or forest of Ksh. 1261.5 /m^3 and at the log yard of Ksh. 8362.2 /m^3, the cost of end sealing 1 m^3 of these logs (about 44.5 logs with a mean diameter of 16.9 cm and length of 1 m), for example, would be 63.4 % the estimated price of the logs at the forest or farm and about 9.6 % of the estimated price at the log yard.

As a carver can get profits ranging from 12.7 % (for carvings sold at the whole sale shop) to 108.7 % (for carvings sold at the retail shop without the assistance of a tour guide) (Maingi, 2003), the end sealing costs could probably be easily absorbed by the carver.

Implications of end sealing

Observations from some of the end sealed samples indicated that after about 5-7 days, they developed moulds. End sealing seem to be economical only for logs that the carvers may want to keep in their sheds in green condition for long periods and without developing checks and cracks or for logs that may be kept in the yard for long periods. When a central logging system is put in place by the Society, it would be necessary to spray the ends of such logs with 20 % boric acid before being sealed with paraffin wax.

5.0 **Experimental Solar Kiln**.

Air-drying of neem woodcarvings is a haphazard method of allowing moisture to escape from the wood. One is at the mercy of the elements of the environment and excessive damage can be caused to the wood through the variance of the conditions it is exposed to. The artificial methods previously used at Akamba dry neem have also proved unfruitful and ineffective. Burclaff and Muga (2003) proposed that it is necessary to modify the current system of artificially drying neem and carved products at Akamba by putting in place mechanisms for controlling humidity, air circulation and temperature. The construction of a simple solar drying kiln was proposed. A series of kiln schedules were also to be developed for various size classes of products (reflecting different thickness of wood).

A solar dryer captures a part of the sun's heat and uses it to dry wood. By this method, wood can be reduced to lower moisture content than by air drying alone and such wood is suitable for high-quality uses as in furniture. A solar kiln can bring wood down to about 8 percent moisture content in time; the time being determined by initial moisture content of the wood, time of the year (intensity of the sun), and wood species being dried.

The manner in which a solar dryer works is as follows: the sun's rays pass through a glass and a portion of the available heat is absorbed on a black metal heat collector. The metal in turn heats the air space within. When the fans are in operation, the heated air is circulated through the wood picking up moisture. When the fans are not operating, some drying still takes place as air moves slowly through the dryer by convection. When moisture-laden green wood is being dried, vents may be left full open; as lumber becomes drier, vents may be gradually closed. The purpose of venting is to keep the relative humidity of the air in the dryer as low as possible while maintaining a high dry-bulb temperature.

Design and Construction of the experimental kiln

The design adopted in the construction of the kiln was a modified semi green house one. The experimental solar kiln is as shown in Figure 5-1. The body is made of a metal frame and supported by timber studs. The wall is made of mild steel. Fibreglass is put in between the two sheets of steel to provide insulation thus minimizing heat losses. Only the roof is glazed with glass and all the other surfaces are opaque and insulated. Apart from the glass collector, additional hot air is ducted into the kiln, by the help of a fan, from a solar heat generator at the side of the kiln. This type of design reduces conduction heat losses substantially, and is therefore expected to result in higher temperatures and faster drying of the wood. It is also possible to achieve low final moisture contents with this kind of design. A solar panel has also been fitted to store power for charging the battery that runs the fan.

The kiln is located at the log yard and the area is securely fenced off. Due to possibilities of flooding at the Akamba Co-operative grounds, the base of the kiln had to be raised about 2 feet above the ground level.

Fig. 5-1. Experimental solar kiln

Loading is done manually using two doors on the western side of the kiln. The doors are wide enough to allow for entrance of loaders and large carvings. A few sliding shelves (made of wood and wire mesh) are available for putting the carvings.

Two vents have been put on the wall on the northern side, to help in controlling humidity. These vents can only be closed and opened manually. Varying the relative humidity in the dryer can control the drying rate in the dryer. When high humidity is required the vents are to be kept fully closed. This is to be supplemented by occasional introduction of fine mist of water from a bucket fitted with a tap, a pipe and a wick at the tip of the pipe. The hot air from the generator can also be kept away from the kiln, when necessary, by switching off the fan that is fitted to blow the hot air into the kiln. Further regulation of temperature is achieved by using a sheeting material to cover the glass roof.

For a species like neem, which is prone to checking and cracking, the vents will need to be kept nearly fully closed for the first several days in order to keep humidity high and to keep drying from proceeding too rapidly.

Testing of the kiln

After the construction of the kiln was completed, a series of tests were carried out. The initial tests involved assessing the temperature and humidity range within the kiln and how these could be regulated. The results of the tests indicated that the heating capacity of the kiln was sufficient though this was expected to vary with the intensity of the sun rays among other factors as mentioned earlier. The test also indicated that there was need to provide a stronger air circulation in the kiln, two powerful fans (power rating of 65 W) were therefore installed in the kiln to complement the one that had been installed to duct in the hot air from the hot air generator. As the power generated by the solar panel could not be sufficient to meet all the power requirements of the kiln due the additional fans installed, it was necessary to tap additional power from the mains.

Temperature and humidity variation in the kiln during this initial test were determined using a psychrometer and are recorded in the tables below.

Table 5-1. Temperature and humidity in the experimental solar kiln with roof uncovered.

Parameter				Introduced humidity		Mean
Humidity %	87	75	70	78	84	77.3
Dry Bulb ◦C	37	42.2	46	40	39.2	41.7
Wet bulb ◦C	20	28.4	30	25	24	26.1

Table 5-2. Temperature and humidity in the experimental solar kiln with roof ccovered.

Parameter/Time	At start	10.30 am	11.00 am	11.30 am	12.00 noon	12.30 pm	2.00 pm	3.30 p.m.	Mean
Humidity %	88	82	82.5	80	79.2	79	76.3	81	81.7
Dry bulb (^{0}C)	28	31.1	33.1	34.5	35.1	35.4	35.5	34	33.0
Wet bulb(^{0}C)	12.5	16.5	17.5	19.0	19.8	20.1	20.6	19	17.8

When the collector was left open, the temperature ranged from 37-46 ^{0}C with a mean of 41.7 ^{0}C while the relative humidity was in the range of 75-87 % with a mean of 77.3 %. When some water was introduced into the kiln from the bucket through the wick, the humidity increased and the temperature was reduced. With the collector covered, the range in temperature was 28-35.4 ^{0}C with a mean of 33-36.5 ^{0}C and the range in the relative humidity was 76.3 to 88 % with a mean of 81.7 %. It is therefore apparent that when the roof of the kiln is covered, it is possible to increase the relative humidity and reduce the temperature in the kiln and also its variation by covering the collector with a sheet.

Trials with the Kiln

A preliminary trial (before the additional fans were installed) was carried out by putting neem carvings of different sizes in the experimental kiln for 3 days to establish the extent of moisture loss (weight loss) as drying progressed. The temperature and relative humidity were measured using a psychrometer. With a daily mean kiln temperature range of 33-36.5 ^{0}C and a mean humidity range of 46-53.5 % for the three days (Table 5-5), it was possible to remove moisture in wood carvings of different sizes in the range of 1.1 – 3.5 % within a period of three days, Table 5-4.

A further trial was done after the two additional fans had been fitted and all the possible leaks in the kiln sealed off. The moisture loss is shown in Table 5-5. A higher moisture loss was experienced as compared to that in the first trial. A weight loss varying from 8.9 -21.7 % was realized after 4 days. With roof of the kiln partially covered, it was possible to get a mean relative humidity of 64.8 %; dry bulb temperature of 36.8 ^{0}C and wet bulb temperature of 28.9 ^{0}C. 8 rough carved neem wood samples dried under these conditions were able to loss moisture from about 40 % moisture content to 10-13 % moisture contents within a period of two weeks.

Table 5-4. Weight loss in woodcarvings during drying in the solar kiln.

Carving type	Size (Thickness in inches)	Weight of sample (g) Original	2nd day	3rd day	Moisture loss (%)
Giraffe 8"	3	76.6	76.1	75.7	1.2
Girraffe 12"	4	362.6	360.8	358.7	1.1
Girraffe 24"	6	1832.0	1822.1	1810 .0	1.2
Elephant 4"	2	449.9	441.8	434.1	3.5
Elephant 8"	6	1621.5	1595.5	1570.5	3.2

Table 5-5. Variation in humidity and temperature in the kiln with time for each of the 3 days.

Day/time		10.00 am	12.00 noon	2.00 pm	4.00 pm	Mean
6/9/2003	Temperature ^{0}C	31	35	35	31	33.0
	Humidity (%)	63	50	49	52	53.5
7/9/2003	Temperature ^{0}C	31	38	40	36	26.3
	Humidity (%)	63	50	49	52	53.5
8/9/2003	Temperature ^{0}C	31	37	38	34	34.0
	Humidity (%)	62	38	38	46	46.0

The kiln-drying schedule

Based on the results of the above trials it was possible to develop a general and simplified drying schedule for small neem carvings. The schedule should be able to assist in drying neem carvings up to 4 inches thickness with minimal degrade. The schedule is a basis upon which further schedules will be developed as experience is gained on the drying of carvings.

Table 5-8. Solar Kiln Drying schedule for neem woodcarvings

Step	Moisture content (%)	Dry bulb temperature ^{0}C	Relative humidity (%)	Vents	Fans	Collector
1	Above 50	35-37	80-83	Closed	On day time only	1/3-way open
2	50-40	35-37	70-76	Closed	On day time only	1/3-way open
3	40-35	35-37	65-67	Closed	On day time only	1/3-way open
4	35-28	35-37	65-67	Closed	On day time only	1/3- way open
5	28-25	40-45	50-55	Open in AM and closed in PM	On in AM and off in PM	½ -3/4 way open
6	25-20	49-54	40-48	Open in AM and closed in PM	On in AM and off in PM	Fully open
7	20-15	55-58	< 40	Open in AM and closed in PM	On in AM and off in PM	Fully open
8	15 -12	60-65	< 40	Open in AM and closed in PM	On in AM and off in PM	Fully open

Testing of the drying schedule

To test the effectiveness of the above drying schedule, a product range comprising of 19 neem wood samples, 3 replicates of each were used, giving a total of 57 samples. The 57 samples dried were able to achieve moisture content in the range of 10 -12 % within a period of 29-33 days. Based on these results, the duration of time required to dry each product type was estimated and is recorded in Table 5-6. The details of the ambient conditions and conditions in the kiln are as shown in Appendix 4. Some difficulties were experienced in attaining temperatures lower than the ambient conditions and also humidity lower than 40 %. From the tests, it was also evident that samples removed from the kiln were gaining some moisture while in the store. It would therefore be necessary to carryout all the subsequent treatments including finishing within two days from the time the samples are removed from the kiln.

Table 5-9. Estimated duration of drying a range of neem wood carving products at Akamba Co-operative Society using an experimental solar kiln.

Specimen code	Thickness (inches)	Height (Inches)	Width (inches)	Length (inches)	Estimated duration of drying in the kin (Days)
G1	6	24		10	30-35
B4	6	8	6		25-30
B10	4	6	4		25-30
R1	6	10		13	30-35
H1	3		4	9	25-30
G4	3	12		3	25-30
OB4	0.25		10	18	25-30
G7	4	14		4	27-33
M1	3	24		6	30-35
B1	6	8	6		30-35
B7	4	6	4		25-30
OB1	0.25		9	16	30-35
P1				12	25-30
P4				12	25-30
E1	6	9		14	30-35
E4	4	6		11	30-35
H4	4		6	12	30-35
R4	4	4		8	30-35
OB7	0.25		7	12	25-30
H7	2	2	3	6	30-35
R7	5	6		12	30-35

Key- E: Elephant, P- Serving spoons, M-Masai, OB-Oval Bowl, G-giraffes, H-Hippo, R-Rhino and B-Book end

6.0 General discussions and implications of the results in the utilization of neem wood at Akamba.

The results of this work will be useful in the in preparation of quality assurance guidelines that are expected to significantly minimize the occurrence of checks, splits and presence of moulds in finished carvings made from neem wood. However, the Society will need, to fully understand how the experimental kiln operates in order to optimize on its use and to be able to effectively operate a production kiln.

The four main quality issues that are bound to be affected by the results of this study are: procurement of suitable wood for carving, storage of green harvested logs, prevention of mould and drying of finished carvings. A number of things have been learnt and achieved by the study on these areas and an attempt has been made, hereunder, to point out the main issues under each. A flow chart giving a summary of the findings is shown in Figure 6-1.

1. Procurement of suitable wood for carving

In wood utilization, the user is mainly concerned primarily with the variability that may be encountered in the properties of the product, regardless of it source. It would therefore be important to know roughly what kind of variability in green wood density and green moisture content of neem, one would expect. To estimate the range of green wood densities and moisture contents that one might normally encounter in neem wood, the mean CV in each property is multiplied by the average obtained for each property (Table 2-1) and then by 1.96 (to include 95 % of a normally distributed population). This gives a range of 0.09 (6.4/100 x 0.71 x 1.96) for density (specific gravity). The range of density to be expected in neem therefore is approximately 0.71± 0.09 = 0.61 to 0.80. Similarly, the range in, moisture content of neem would be 59.8 ± (9.9/100 x 59.8x 1.96) = 59.8 ±11.6 = 48.2 to 71.4 %. The variability does not seem too much, and this is good as it shows that the material being used is fairly homogenous. However, significant variations in these properties may be expected due to site and age factors. The other factors that may significantly affect the quality of neem wood for carving are the presence and size of knots; log straightness, presence and proportion of heartwood, presence of juvenile and reaction (tension) wood. It would therefore be essential to have some kind of log grading based on these factors. A simple guideline has been proposed (Appendix 3) to grade the logs and some details that need to be incorporated in the log clerk's record book have also been suggested. It is essential that the best logs be used for the highest value carvings.

2. Storage of green harvested logs

A central purchasing system as recommended by Burclaff and Muga (2003) needs to be put in place now. The logs procured from the forest to be kept under a shade at a designated place in Akamba. A well-ventilated shed/storage area needs to be constructed to provide shade for log storage. It should have sufficient area to manouvre logs and pieces. The Society has already identified a place next to the administration offices, which seem sufficient for this purpose. The management should endeavour to construct this shed using 'makuti' roofing as soon as possible to ensure that the logs are not exposed to harsh environmental conditions that promote cracking and checking. The log clerk at the Society will need to be trained on how to decide which pieces to be end-sealed, how they are going to be date marked or stacked according to rough date. A study needs to be carried out by the 'company' or KGT in consultation with Mr. Maingi to roughly estimate what the stock holding investment costs are likely to be.

For a start, it is suggested that green neem logs for making the small carved items, be bisected at the pith. The small carvings can then be carved out of these and the rough carvings put in the shed to dry. Alternatively, if the supply of the logs is abundant the bisected logs should have their ends sealed with paraffin wax and put in the shed to dry for a minimum of about 60 days before carving starts. For special overseas orders, prime logs should be set a side whenever they are received at the log yard. These to be sprayed with or dipped in boric acid, end sealed with paraffin wax and kept in the shed, with occasional spraying with a weak boric acid. End sealing will ensure that these logs retain moisture and if any is to be lost, it is done uniformly without the creation of any steep moisture gradient hence minimizing the incidences of cracking and checking during the storage.

3. Prevention of moulds

The results of this study indicate that moulds from two genera of fungi, namely, Fusarium and Rhizopus infest the sapwood wood of neem carvings at Akamba. The sapwood is the most susceptible to fungal attack because it is the living part of the tree (rich in nutrients and starch – ideal food for other organisms). Tests using boric acid show that this chemical is effective in controlling the growth of these moulds. A minimum duration of 30 seconds for soaking of carvings in a 20% solution of boric acid appears sufficient. All carving samples with any trace of sapwood should be treated with this solution of boric acid to prevent the growth of moulds. Carvings made from 100 % heartwood may not have to be subjected to boric acid treatment.

Carvings that have been dried, filed and wet sanded should be dipped (totally immersed) for 30 seconds in a 20 % boric acid solution in a trough or a basin. Mist spraying of the acid has proved a little ineffective, as boric acid appears not to be completely miscible with water. It will therefore be necessary for the person applying the acid to stir the solution in the trough or basin with a rod just before the carvings are immersed into it. This person, as outlined in Appendix 2, must put on protective clothing. To enhance the solubility of boric acid it could be mixed with ethylene glycol, for every gram of boric acid 3 ml of ethylene glycol should be added. This will enhance mist spraying of the fungicidal solution and will make it possible to treat all logs as they enter the yard.

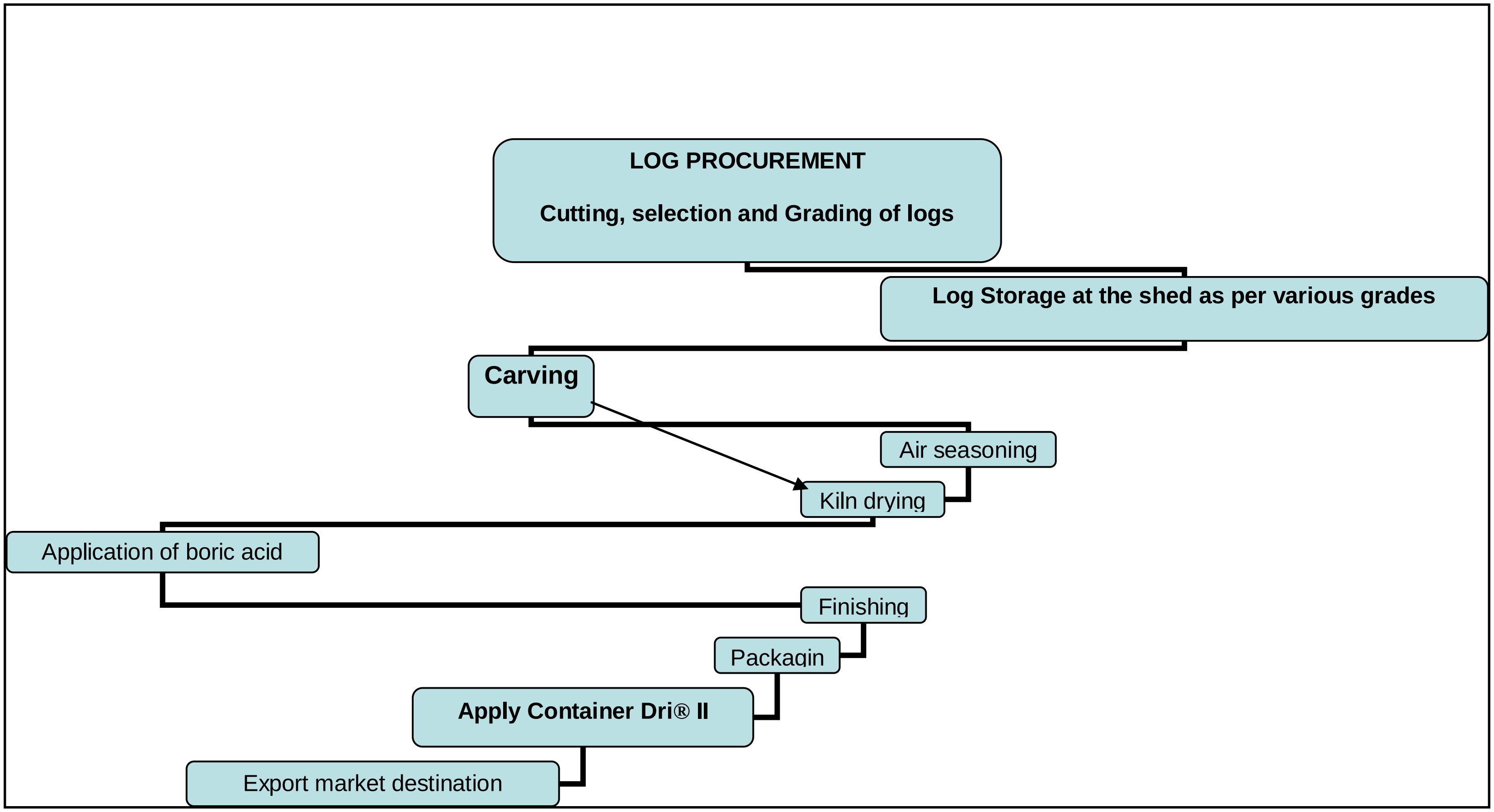
As boric acid is likely to leach out from the wood during use, it would be advisable to apply about 4 coats of the finish on items that are to be used as food containers e.g. Bowls, spoons etc to ensure that these items are food safe. The effectiveness of the many layers of the finish and or any other identified methods in controlling the leaching out of the boric acid from the wood should be tested. The amount of boron in the leachate for each treatment will need to be established and this compared with the European Union requirements for such products. The use of Benzalkonium chloride in the place of boric acid has been suggested by Vinden (2004, pers com) as this does not leach out. However, this chemical is not locally available in Kenya and has to be imported and the price is about 15 times higher than boric acid and about 8 times the price of borax. Its effectiveness will also need to be tested. Whether its use on functional products is acceptable as per the European Union standards is yet to be established.

4. Drying of finished carvings.

The basic skills to measure and record humidity, temperature, and moisture loss have been established and mastered by Akamba technicians. The technicians at Akamba can do this with minimal supervision. This was essential for Akamba to learn how to dry wood using the kiln. Learning how to use the kiln has also been achieved though it is still continuous as it is very much 'suck it and see' process. The study has achieved its objective as 'low risk' easy to dry carvings can now be dried successfully using a drying schedule developed during the study. This early success can now be used to demonstrate to the carvers and customers that things are on the right track However, drying degrade will need to be monitored quite closely and necessary adjustments made on the schedule from time to time, to bring these to a very minimum, as the technician gains experience on the use of the kiln.

As two of the three technician trainees did not finish the training, as the Society fired one (the log clerk) and the other one (Export Manager) was too busy with the Society's assignments, it is necessary to train more personnel at Akamba on the use of the kiln and how to do the essential measurements and records. The new log clerk, a new nominee and the technical team should be trained on the whole operation. The technician who is already trained with some backstopping from KEFRI can do this. This will be important in ensuring that the operation of the kiln is not halted due to the absence of the trained technician

FLOW DIAGRAM SHOWING THE CHAIN IN THE PRODUCTION OF WOOD CARVING FOR EXPORT MARKET



7. Conclusions and Recommendations

1.2 Conclusions

1. The Akamba Co-operative Society has mastered the ability to measure, record, and analyse the behaviour of neem under various conditions. Its capacity to use simple measuring equipment and follow basic experimental procedures has also been enhanced. Skills and knowledge in determining moisture content and ambient conditions have been learnt and can be applied in operating a drying kiln with minimal supervision.
2. The identity of moulds that affect neem wood has been established up to genus level. The two genera identified to be growing on neem wood obtained from Akamba Co-operative society are: Fusarium and Rhizopus.
3. Trials on the control of moulds indicate that a solution of 20 % boric acid applied for a minimum of 30 seconds would be effective.
4. Simple safety guidelines on the storage and application of boric acid have been developed.
5. Studies on end sealing of neem samples with paraffin wax indicate that such a treatment is cost effective and useful in reducing the rate of moisture loss from neem wood and thus minimises the amount of cracks and checks that result from a high moisture gradient between sapwood (outer wood) and heartwood (inner wood). The green moisture content and basic specific gravity (density) of neem have been determined. The green moisture content of neem is about 60 % while the basic specific gravity is 0.71.
6. To dry green neem from green condition to 12 % moisture content it is necessary to evaporate about 338 kg/m^3 of moisture.
7. An experimental solar kiln has been designed, fabricated and tested and found to be effective in drying neem wood carvings (up to 6 inches thickness) to10 % moisture content within about 30 days with minimal degrade.
8. A drying schedule has been developed, tested and found to be effective in drying neem woodcarvings with minimal degrade.
9. A range of woodcarvings have been tested using the drying schedule developed and the duration of time required to dry various product types and sizes to 12 % moisture content have been estimated.
10. The results of the study have been discussed with KGT and incorporated in the production manual.

1.3 Recommendations

1. As the issue of the ‘safeness’ of boric acid when applied to functional products is yet to be resolved, it is recommended that the leachate obtained from functional products made from neem that have been subjected to various finishing treatments be tested for the concentration of Boron to see if they would comply with the European Union Standards.
2. As it has been observed that wood samples that are end sealed with paraffin wax, develop moulds within a week due to high moisture content, it is recommended that all logs that are to be end sealed with paraffin wax be sprayed with a fine mist of boric acid before such a treatment is done.

3. To ensure that the woodcarvings reach the export market destination without any incidence of moulds while in transit, it is necessary to try the use of chemicals such as silica gel, moisture muncher or Container Dri® II[1] in controlling the growth of moulds. However, the effectiveness of these chemicals and the additional costs to be incurred by the carvers on their use need to be established.
4. As it has been observed that once the wood carvings leave the kiln they start regaining moisture almost immediately, it is recommended that the operation of treating the dried carvings against moulds and finishing be done within two days from the day they are removed from the kiln. To make this achievable, it is necessary to have most of the fine details on the rough carvings in place at the time the carvings are put in the kiln, this will reduce the amount of time for finishing of the products as it is harder to carve the wood when dry than when green.
5. The Society needs to continue monitoring the drying of neem woodcarvings products and recording of various defects as the drying progresses in order to gain experience in operating the kiln and to be able to modify the drying schedule as necessary with time or upon introduction of a different species.
6. The management at Akamba should endeavour to construct a log storage shed using ‘makuti’ roofing as soon as possible to ensure that the logs are not exposed to harsh environmental conditions that promote cracking and checking. The log clerk at the Society will need to be trained on how to decide which pieces to be end-sealed, how they are going to be date marked or stacked according to rough date. A study needs to be carried out by the ‘company’ or KGT in consultation with Mr. Maingi to roughly estimate what the stock holding investment costs are likely to be.
7. Once the shed is in place, the Society will need to apply the acquired skills to experiment on drying of logs at the shed. Initially, Neem logs for making the small-carved items to be bisected at the pith have their ends sealed with paraffin wax and then put in the shed to dry for a minimum of about 60 days before carving starts. The Society will monitor the drying process at the shed and make adjustments on the duration of drying as necessary. For special overseas orders, a deliberate decision should be made to set aside prime logs whenever they are received at the log yard. These to be sprayed with or dipped in boric acid, end sealed with paraffin wax and kept in the yard, with occasional spraying with a weak boric acid.
8. In liaison with KGT and KEFRI, the carvers should develop appropriate carving designs. These designs should ensure that a thin layer of wood, that will facilitate faster drying and fewer defects, is used.
9. There is need for the carvers to try carving techniques that will integrate log utilization, especially when carving large carvings. Lots of wood that go to waste during the carving of the large carvings could be used to carve smaller items if better cutting techniques were applied. Some trials on these techniques could be carried out by carvers in liaison with KEFRI.

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[1] Container Dri® II eliminates mold, corrosion, mildew, peeling labels, and other harmful effects of moisture related damage during shipping and storage without generating liquid water.

10. A production kiln 30 to 40 m^2 should be constructed based on the results of the experimental kiln. This will ensure that a sizeable number of carvings for the export market are dried in a batch.
11. The technician who has been trained with some backstopping from KEFRI should train more personnel at the Society on the use of the kiln and measurement of ambient and kiln conditions.

7.0 Acknowledgements

I would wish to thank all the persons who contributed in one way or the other for the success and completion of this work.

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Mrs. Rose Otieno	Manager, Akamba Handicrafts Society
Mr. Urbanus Musau	Export Manager, Akamba Handicrafts Society
Mr. Obiero Thomas Were	Business Advisor, Kenya Gatsby Trust
Mrs. Consta Kandie	Business Advisor, Kenya Gatsby Trust
Mr. Charles Rioba	Solar World E.A. Ltd.
Mr. Joseph Githiomi	Centre Director, KEFRI
Mr. George Muthike	Research Officer KEFRI
Mrs. Nellie Oduor	Research Officer KEFRI
Mr. Machua	Research Officer KEFRI
Mr. Linus Mwangi	Senior Research Officer KEFRI
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Mr. Lukas Gibera	KEFRI Technologist
Mr. Gicheru	KEFRI Technologist
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Mr. Maritim	KARI, Mtwapa
Mr. Jeff Hann	University of Melbourne, Australia
Prof. Peter Vinden	University of Melbourne, Australia

Akamba handicrafts technical team

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APPENDICES

Appendix 1: Data collection sheets

Form 1: Moisture content calculation from oven dry weight

Project Ref: ---

Date: ------------------------------

Specimen code		Weight (g)							Moisture content (%)
	Initial weight (g)	Intermediate						Oven dry	

Form 2: Wood basic specific gravity data sheet

Project:---

Date: ---------------------------------

Data Recorded by: --

Specimen code	Green weight (g)	Vol. Of water in cylinder (cm^3) C	Vol. Of water + wood (cm^3) D	Vol. Of wood C-D (cm^3) E	Oven dry weight (g) F	Basic Specific gravity of wood (F/E)*100

Form 3: Daily Record of Temperature and relative humidity at Akamba Handicraft Society, Mombasa.

Month: --Year--

Day	Time	Temp. ^oC		Relative humidity	Remarks
		Min.	Max.		
	AM				
	PM				
	AM				
	PM				
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1.0 Procedure for measuring moisture content loss rates.

1. Obtain small samples of 25 mm thickness from each control sample.
2. Weigh the control samples.
3. Weigh the 25 mm sections (sawn earlier from the control samples) and place them in the oven at 103 ^{0} C for 18 –24 hours, reweigh them and obtain the oven dry weight (O.D).
4. Calculate the moisture content (MC) of the sections with the formula below.

$$\% \text{ MC}= [\{\text{Wet weight}/ (\text{O.D})\}-1] \times 100$$

5. Average the MCs of both sections taken from each control sample.
6. Estimate the oven dry weight of each large control sample using the formula below:

$$\text{Estimated O.D weight} = \{(\text{wet weight})/ (100 + \% \text{ MC}_{25\text{ mm}})\} \times 100$$

7. Record the estimated oven –dry weight of the control samples and return them to the kiln.
8. Re-weigh the sample boards daily and calculate the current moisture content.

$$\text{Current } \% \text{ MC} = \{(\text{Current weight} / \text{estimated O.D weight}) -1\} \times 100.$$

9. When the estimated moisture content reaches 20 %, a more accurate estimate of moisture content can be obtained by cutting a new 25 mm section. Follow steps 2-8. Be sure to use the new wet weights and the new oven –dry weight of the section in finding the current MC of the control sample (step 8).

Appendix 2: Information on the safety of boric acid and guidelines on its use

Information on safety of Boric acid
BORIC ACID MSDS

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1. Product Identification
Synonyms: ortho-Boric acid; boracic acid; Borofax, boric acid (H_3BO_3)
CAS No.: 10043-35-3
Molecular Weight: 61.83
Chemical Formula: H_3BO_3
Product Codes:
J.T. Baker: 0084, 0091, 0092, 4035, 5168, 5599, 9820
Mallinckrodt: 1326, 1394, 2536, 2549, 2552, 7779, 7794

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2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
Boric Acid	10043-35-3	100%	Yes

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3. Hazards Identification
Emergency Overview

WARNING! HARMFUL IF SWALLOWED OR INHALED. CAUSES IRRITATION TO SKIN, EYES AND RESPIRATORY TRACT. AFFECTS CENTRAL NERVOUS SYSTEM, LIVER AND KIDNEYS.

SAF-T-DATA(tm) Ratings (Provided here for your convenience)

Health Rating: 2 - Moderate (Life)
Flammability Rating: 0 - None
Reactivity Rating: 1 - Slight
Contact Rating: 2 - Moderate (Life)
Lab Protective Equip: GOGGLES; LAB COAT; VENT HOOD; PROPER GLOVES
Storage Color Code: Green (General Storage)

Potential Health Effects

Inhalation:

Causes irritation to the mucous membranes of the respiratory tract. May be absorbed from the mucous membranes, and depending on the amount of exposure could result in the development of nausea, vomiting, diarrhea, drowsiness, rash, headache, fall in body temperature, low blood pressure, renal injury, cyanosis, coma, and death.

Ingestion:

Symptoms parallel absorption via inhalation. Adult fatal dose reported at 5 to > 30 grams.

Skin Contact:

Causes skin irritation. Not significantly absorbed through the intact skin. Readily absorbed through damaged or burned skin. Symptoms of skin absorption parallel inhalation and ingestion.

Eye Contact:

Causes irritation, redness, and pain.

Chronic Exposure:

Prolonged absorption causes weight loss, vomiting, diarrhea, skin rash, convulsions and anemia. Liver and particularly the kidneys may be susceptible. Studies of dogs and rats have shown that infertility and damage to testes can result from acute or chronic ingestion of boric acid. Evidence of toxic effects on the human reproductive system is inadequate.

Aggravation of Pre-existing Conditions:

Persons with pre-existing skin disorders or eye problems, or impaired liver, kidney or respiratory function may be more susceptible to the effects of the substance.

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4. First Aid Measures

Inhalation:

Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician.

Ingestion:

Induce vomiting immediately as directed by medical personnel. Never give anything by mouth to an unconscious person.

Skin Contact:

Remove any contaminated clothing. Wash skin with soap or mild detergent and water for at least 15 minutes. Get medical attention if irritation develops or persists. Wash clothing before re-use.

Eye Contact:

Immediately flush eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Get medical attention immediately.

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5. Fire Fighting Measures

Fire:

Not considered to be a fire hazard.

Explosion:

A mixture of potassium and boric acid may explode on impact.

Fire Extinguishing Media:

Use any means suitable for extinguishing surrounding fire.

Special Information:

In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full face piece operated in the pressure demand or other positive pressure mode.

6. Accidental Release Measures

Ventilate area of leak or spill. Wear appropriate personal protective equipment as specified in Section 8. Spills: Pick up and place in a suitable container for reclamation or disposal, using a method that does not generate dust.

7. Handling and Storage

Store in closed containers in a cool, dry area. Carbon steel or aluminum containers are suitable for storage. Stainless steel is needed for moist conditions. Use good housekeeping practices to prevent accumulation of dust and follow sound cleaning techniques that will keep airborne particulates at a low level. Wash hands after handling this material. Avoid contact especially when skin is cut or abraded. Containers of this material may be hazardous when empty since they retain product residues (dust, solids); observe all warnings and precautions listed for the product.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:

- OSHA Permissible Exposure Limit (PEL):

15 mg/m3 total dust, 5 mg/m3 respirable fraction for nuisance dusts.

- ACGIH Threshold Limit Value (TLV):

10 mg/m3 total dust containing no asbestos and < 1% crystalline silica for Particulates Not Otherwise Classified (PNOC).

Ventilation System:

A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document, *Industrial Ventilation, a Manual of Recommended Practices*, most recent edition, for details.

Personal Respirators (NIOSH Approved):

If the exposure limit is exceeded and engineering controls are not feasible, a half face piece particulate respirator (NIOSH type N95 or better filters) may be worn for up to ten times the exposure limit or the maximum use concentration specified by the appropriate regulatory agency or respirator supplier, whichever is lowest.. A full-face piece particulate respirator (NIOSH type N100 filters) may be worn up to 50 times the exposure limit, or the maximum use concentration specified by the appropriate regulatory agency, or respirator supplier, whichever is lowest. If oil particles (e.g. lubricants, cutting fluids, glycerine, etc.) are present, use a NIOSH type R or P filter. For emergencies or instances where the exposure levels are not known, use a full-face piece positive-pressure, air-supplied respirator. WARNING: Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.

Skin Protection:

Gloves and lab coat, apron or coveralls.
Eye Protection:
Use chemical safety goggles. Maintain eye wash fountain and quick-drench facilities in work area.

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9. Physical and Chemical Properties
Appearance:
White powder or granules.
Odor:
Odorless.
Solubility:
1g/18mL in cold water.
Density:
1.43
pH:
5.1 Aqueous solution: (0.1M)
% Volatiles by volume @ 21C (70F):
0
Boiling Point:
Decomposes.
Melting Point:
169C (336F)
Vapor Density (Air=1):
No information found.
Vapor Pressure (mm Hg):
2.6 @ 20C (68F)
Evaporation Rate (BuAc=1):
No information found.

---

10. Stability and Reactivity
Stability:
Stable under ordinary conditions of use and storage. If moisture is present, boric acid can be corrosive to iron.
Hazardous Decomposition Products:
Loses chemically combined water upon heating, forming metaboric acid (HBO_2) at 212-221F, then pyroboric acid ($H_2B_4O_7$) at 285-320F, and Boric anhydride at higher temperatures.
Hazardous Polymerization:
Will not occur.
Incompatibilities:
Potassium, acetic anhydride, alkalis, carbonates, and hydroxides.
Conditions to Avoid:
No information found.

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11. Toxicological Information

Toxicological Data:
Oral rat LD50: 2660 mg/kg; oral woman LDLo: 200 mg/kg; investigated as a mutagen, tumorigen, reproductive effector.

Reproductive Toxicity:
See Chronic Health Hazards.

--------\Cancer Lists\--

Ingredient	---NTP Carcinogen--- Known	Anticipated	IARC Category
Boric Acid (10043-35-3)	No	No	None

12. Ecological Information

Environmental Fate:
No information found.

Environmental Toxicity:
The EC50/48-hour values for daphnia are over 100 mg/l. This material may be toxic to aquatic life.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be managed in an appropriate and approved waste disposal facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

Preparation and application of Boric Acid solution

1. Boric acid is harmful if swallowed or inhaled. It may cause irritation to skin, eyes and respiratory tract. Therefore put on a dustcoat, gloves and goggles provided.
2. Measure 2500 ml of distilled water using a measuring cylinder and pour into a container designated for this work.
3. Pour all boric acid (500 g) from a new 500 g packet into the distilled water in (2) to make a 20 % solution of boric acid.
4. Stir the mixture until the powder mixes with water. Boric acid has a low solubility in water and will not dissolve quickly, so keep on stirring.
5. Completely immerse dried, filed and sanded woodcarving (s) into the boric acid solution for about 30 seconds.
6. After using this solution for treatment of carvings pour the same in a labeled plastic container with a lid.
7. Wash hands after handling this material. Avoid contact especially when skin is cut or abraded.
8. Containers of this material may be hazardous when empty since they retain product residues (dust, solids). Observe all warnings and precautions listed for the Product.

Appendix 3: Log selection guidelines for the cutters and log clerk

Log cutters

The logs to be grouped in two main categories: Those from the main stem and those from the branches then categorized in terms of straightness.

From the main stem

1. Straight logs from the main stem, without any branches (knots) and free from rot, to be regarded as prime logs and categorized grade A.
2. Straight logs from the main stem, with one or two branches and free from rot, from the main stem to be categorized as good logs and put in grade B.
3. Straight logs from the man stem, with 3 or more branches (knots) and free from rot, to be regarded as fairly good logs and put in grade C.
4. Crooked logs from the main stem, with or without knots and put in grade D.
5. Crooked logs full of knots and rot to be rejected and used for firewood.

From the branches

1. Straight, knotless logs, with heartwood and pith at the centre Grade BA
2. Straight, knotless or with a few knots, without heartwood and pith at the centre Grade BB.
3. Any other logs to be put in grade BC.

Log Clerk

The following details need to be incorporated in the log clerk's record book or sheets.

Inventory of logs entering the log yard

Date	Log diameter	Label	Grade	Source

Guidelines for Storage of logs

1. All logs that are to be stored to be put in a shed that has been cleared off any grass.
2. Always store each grade of logs in a particular and marked place.
3. Logs that are to stay in the shed for more than a week should be sprayed with boric acid and the ends sealed with paraffin wax.
4. Be checking the logs for growth of moulds on a regular basis

Appendix 4

Table A-5. Kiln and environmental conditions during the drying of the 57 woodcarvings

Date	Time	Humidity in the Kiln (%)	Humidity of the environment (%)	Environmental temperature ^{0} C	Dry bulb Temp in kiln ^{0} C	Wet bulb Temp in kiln ^{0} C
18-12-03	9:00 AM	69.8	40		33.3	26.7
	12 Noon	67.8	32		37.9	31.3
	3:00 PM	58.4	42		37.4	30
19-12-03	9:00 AM	69.7	34		34.1	28.7
	12 Noon	59.6	36		40.1	31.1
	9:00 AM	58.9	38.7		40.4	31.2
20-12-03	12 Noon	71.7	52		30.4	25.6
	3:00 PM	65.9	32		39.4	31.4
21-12-03	12 Noon	58.7	38		39.9	31.4
	9:00 AM	71.4	38		31.5	28
	12 Noon	60.2	32		38.1	30.1
22-12-03	9:00 AM	70.1	36		33.2	30.1
	12 Noon	70.5	72		35	25.4
	3:00 PM	61	50		38.2	29.4
23-12-03	9:00 AM	71.5	46		28	30.6
	12 Noon	69.3	38		33.3	34.9
	3:00 PM	72.6	58.1		33.5	37.7
24-12-03	9:00 AM	66	36	31.6	33.5	27.5

	12 Noon	69	32	32.6	38.1	30.7
	3:00 PM	58.4	38	35.3	38.3	29.2
25-12-03	9:00 AM	71.7	38	29.4	32.6	26.2
	12 Noon	62.6	26	34.9	39.2	30.6
	3:00 PM	56.4	39.4	36	41.7	31.4
26-12-03	9:00 AM	65.5	38	30.2	32.8	26.8
	12 Noon	50.5	24	38	40.6	31.2
	3:00 PM	57.6	39.4	36	41.7	31.4
27-12-03	9:00 AM	61.5	42	30.4	31.4	24.7
	12 Noon	53.4	28	36.2	39.2	29.6
	3:00 PM	57	44	35.2	36	30.4
28-12-03	9:00 AM	66	46	29.4	31.1	35.3
	12 Noon	52.8	32	36.4	39.9	29.8
	3:00 PM	54.1	38	35.8	41	28
29-12-03	9:00 AM	67	38	30	31	25.4
	12 Noon	77	28	30.7	37	29
	3:00 PM	58	40	34	38	30
30-12-03	9:00 AM	67	38	30	31	25.4
	12 Noon	77	28	30.7	37	29
	3:00 PM	60	36	38	38	30
31-12-04	9:00 AM	61.5	42	30.4	31.4	24.7
	12 Noon	53.4	28	36.2	39.2	29.6
	3:00 PM	57	44	35.2	36	30.4
1/1/2004	9:00 AM	60	42	29.5	31	25.2
	12 Noon	52	36	38.8	40.2	30.7
	3:00 PM	54	38	36.9	38.4	31.2
	9:00 AM	61	38	31.6	33	26.6

2/1/2004	12 Noon	54	30	35.6	40.2	29.7
	3:00 PM	56	36	34	38	32
3/1/2004	9:00 AM	62	44	31	33	26.9
	12 Noon	55	36	42	43	31
	3:00 PM	57	35	40	42	30
4/1/2004	9:00 AM	60	38	31.6	33	26.6
	12 Noon	53	30	35.6	42	31
	3:00 PM	52	36	34	40	30.5
5/1/2004	9:00 AM	62	48	30.1	31	26
	12 Noon	51	32	32	43	32
	3:00 PM	52	36	31	41	30.9
6/1/2004	9:00 AM	52	48	30.1	31	26
	12 Noon	44	32	32	44	32.7
	3:00 PM	50	40	33	43	32.4
7/1/2004	9:00 AM	53	46	30	32	26.7
	12 Noon	46	32	33	45	33
	3:00 PM	50	38	32	44	32.8
8/1/2004	9:00 AM	52	70	28.5	30	24.9
	12 Noon	76	84	30	32	26
	3:00 PM	49	87	31	31	25.7
9/1/2004	9:00 AM	50	60	28	31	26.4
	12 Noon	44	54	32	39	30
	3:00 PM	48	57	31	37	29.7
10/1/2004	9:00 AM	52	57	32	43	32.6
	12 Noon	46	34	34	45	34
	3:00 PM	50	38	38	44	33.7
11/1/2004	9:00 AM	52	48	32.1	44	31.7

	12 Noon	45	36	33	47	36
	3:00 PM	46	38	34	48	37.7
12/1/2004	9:00 AM	50	48	31	42	31.7
	12 Noon	45	38	33	50	38
	3:00 PM	46	40	34	48	37.4
	9:00 AM	48	48	32	41	32
13-1-04	12 Noon	44	38	34	49	38
	3:00 PM	46	39	34	48	37.1
14-01-04	9:00 AM	42	58	28	35	28
	12 Noon	40	68	32	42	31.7
	3:00 PM	40	68	30	40	30
15-01-04	9:00 AM	50	48	28	38	29.7
	12 Noon	40	58	32	45	33
	3:00 PM	38	66	30	43	32.4
16-01-04	9:00 AM	50	52	28	32	26.6
	12 Noon	44	88	30	36	28
	3:00 PM	46	76	32	40	30
17-01-04	9:00 AM	50	60	27.8	32	26.4
	12 Noon	46	58	31	38	28.6
	3:00 PM	48	60	32	40	30