IMPROVED UTILISATION OF NEEM (*AZADIRACHTA INDICA*) FOR CARVING BY THE AKAMBA CO-OPERATIVE SOCIETY

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A Consultancy work for WWF East Africa Regional Programme Office (EARPO).

March 2003

Abstract

The Akamba handicraft Co-operative Society is one of nine wood carving centres that are members of the Kenya Crafts Co-operative Union (KCCU). One of the most important and widely available species used by the carvers at this centre is ‘neem’ (*Azadirachta indica*). The tree grows extensively around Mombasa and has the advantage that it widely available and fast growing as compared to the indigenous hardwoods, which are now in short supply due to over exploitation. A valuable overseas market for neem carvings has been developed over recent years with considerable potential for growth.

There is general agreement amongst carvers 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. The two most important (and serious) problems associated with this wood are, firstly, cracking and checking of neem wood during various stages of carving and in the finished product, and secondly, the growth of mould[1] 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 a certain moisture content.

The bulk of this consultancy concerned itself with addressing these two problems. A solution to the problem for controlling the growth of mould is considered to be relatively straightforward. The use of certain fungicides has been proposed to help eradicate these moulds. However, it is proposed that their effects and interactions with stains and finishes be tested and that clear health and safety guidelines be developed on their use and application. Controlling, checks, splits, and shakes[2] will require considerably more effort, the solution to this problem will be forthcoming only after a number of controlled experiments have been completed. The justification, benefits, and mechanism for establishing these experiments are detailed herein.

It is pointed out that it is essential for the cooperative to take control of all issues affecting quality, but particularly the procurement and storage of neem wood. It should directly influence the selection of logs and stems and have complete control of the log yard. Stock control will foster quality control, and the benefits of increasing the value of stock will drive this process and directly improve the quality and value of finished products. Immediate and intermediate guidelines have been recommended to assist in minimizing the occurrence of cracks, other drying defects and controlling the growth of moulds.

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[1] US spelling, mold

[2] See Glossary

Acronyms

BDS-Busines Development Services.
EMC-Equilibrium moisture content.
FSC-Forest Stewardship Council.
KEFRI-Kenya Forestry Research Institute.
FSP-Fibre Saturation Point
KGT-Kenya Gatsby Trust.
LC-Lethal Concentration
LD-Lethal dose.
RH-Relative humidity.
UK-United Kingdom.
U.S.- United States of America.
WWF EARPO -World Wildlife, Fund for Nature, East Africa Regional Progmme Office.

1.0 INTRODUCTION

The Akamba Handicraft Society, hereinafter referred to us the Society, is based in the Kenyan coast town of Mombasa, where some 5000 wood carvers are based, of these, roughly 2800 are registered members of the Society. One of the most important and widely available species used by these carvers is known as 'neem' *(Azadirachta indica).* Neem was introduced into Kenya from the Indian subcontinent about 100 years ago where it has been planted as a multipurpose tree species. The tree can be found growing extensively around Mombasa.

The principal advantage in using this species is that it relieves the demand on other local indigenous hardwoods, (which are in short supply due to over exploitation); it is fast growing and can be readily harvested from local farms and plantations. A valuable overseas market for these 'ethically sourced' neem carvings has also been developed over recent years and it is felt that there is much room for growth. Of the 30 % of total carvings that are destined for export, most are made using neem wood. Of the balance, 30 % are sold directly to tourists from the onsite shop and 40 % are sold to local merchants.

The major constraint limiting the more widespread use of neem is the difficulty in minimising the occurrence of wood shrinkage, movement, checking and cracking. In addition, the high moisture content of finished wooden carvings encourages the growth of unsightly surface moulds. These results in poor quality lower value products and trade and orders, especially in lucrative overseas markets, are often lost. In addition, the reputation, skills, and confidence of these carvers are undermined.

In order to clarify and assist in developing a program of action focused on the establishment of quality control procedures, training of carvers in such procedures, technical investment and potential further research, the consultants were contracted by WWF EARPO (World Wildlife Fund for Nature, East Africa Regional Programme Office), reference KE0858.01. The main objective of the study was: to study and advise on how the quality of neem (*Azadirachta indica*) woodcarvings produced by the Akamba handicraft Co-operative Society (Mombasa, Kenya), could be improved. The Terms of Reference are included (Appendix 1) and the consultants' itinerary appears in Appendix 2.

2.0 Approach

The consultants were guided by a number of recent reports and publications, which provided the necessary background information on the history, structure and development of the Akamba Handicraft Co-operative Society (*KGT, 2002*), (*Muga 2002*) and *(Choge 2000)*. Four days were spent studying the flow of wood through the site, from log delivery, through various stages of carving, to finishing and conditions at point of sale in the shop and warehouse. Considerable emphasis was placed on testing assumptions with carvers and trying to understand the reasons behind certain work practices and how any recommendations to change such practices might impact on their customs and livelihoods.

In an attempt to clarify some of the complex issues surrounding the behaviour of wood as a raw material, particularly as it dries, the consultants have prepared this report to reflect the chronological utilisation of neem from standing tree to finished product as witnessed at the Akamba co-operative society.

3.0 Observations and discussions

3.1 Selection of trees and logs

The selection of trees to be cut is undertaken by log 'cutters', who cut and transport the logs to the Society. There are a total of 7 cutters of which only 4 are active. These log cutters act as middlemen between the carvers and the tree owners.

A visit to one of the felling sites at Rea Vipingo in Kilifi District, by the consultants to witness the characteristics of neem, revealed that no tree had been felled and only selected stems had been cut. It is clear that at this location (Fig. 1) neem is multi-stemmed with only a short bole or main stem. It was not clear how stems were selected or if the landowner was involved or had any input in managing this process and for unknown reasons, the cutters were unwilling to accompany the consultants to the site. It was further confirmed that these trees were approximately 40 years old. It is suggested that the wood being harvested here should be more accurately described as 'stem' or 'stem wood' (as opposed to branch or 'branch' wood) and that secondary growth from these harvested stems, be referred as 'branch' or 'branch wood'.

Fig 1. Multi-stemmed neem trees from which fresh secondary stems have been cut

The use of this stem wood for carving could have significant effects on wood quality; therefore, selection of appropriate stem wood is important.
When harvesting this stem wood, the log cutters tend to make a straight horizontal cut (Fig. 1 picture on the right) when cutting most of the trees as opposed to the flush cut (Fig. 1- picture on the left). Furthermore, no arboreal paint had been applied to any of the cut surfaces. This was observed to result in some of the stems starting to rot due to accumulation of water on the cut and unprotected wood surfaces.

3.1.2 Tree and wood Characteristics

In 'hardwoods' (angiosperms), such as neem, wood of distinctive anatomical structure is formed on branches and leaning stems, producing (as it matures), tensile forces that tend to maintain a growing branch at its particular orientation (in spite of increasing mass) or to correct disorientation. This results in production of reaction wood on the upper side of leaning stems and branches, called tension wood. Although there are various degrees of severity of reaction wood, its utilisation is generally best avoided. Reaction wood will twist, warp, and split during sawing and drying.

Presence of tension wood causes some effect on the wood quality. It has been observed that there is a continuous change in wood characteristics in the periphery of the stem from tension wood on one side through normal wood to 'opposite wood' on the other side (Nicholson *et al*. 1975). The extent and intensity of tension wood in and around the tree can vary and is apparently proportional to the intensity of the bending stress on the leaning stem at a particular time (Boyd 1977). Tension wood is also anatomically different from normal wood. It is non-lignified and mainly cellulose and has a low degree of swelling. Tension wood has markedly fewer and smaller vessels and a higher average density than that of normal wood. Tension wood also shows an abnormally high longitudinal shrinkage when it is dried and this shrinkage is probably related to a reduction in cell wall lignification, which leads to irreversible collapse.

One possible way to distinguish the presence of reaction wood, which can be easily adopted by those purchasing neem, is to determine the location of the chronological center of the stem, called the pith – indicating the first year of growth. The pith should be as central to the geometrical centre of the log as possible.

Clearly, wood selection here is critical. Only stems, which have been growing straight, should be selected for cutting and only straight sections selected for use. Stems should also be cylindrical in cross-section and as free from knots as is possible. The sapwood and heartwood should also be free from imperfections.

Figure 2 shows quite clearly how the heartwood end-grain has checked and split. This picture also shows the large volume of sapwood, and the tell-tale signs that this stem was leaning. Note the bulk of the wood material has formed on the underside of the branch, and the pith, from which the 'star' or radial shakes emanate, is not at the geometrical centre of the log. Note also the obvious presence of 'ring' shake in the underside zone, this type of shake may have been caused when the stem was felled or because of internal growth stresses. Tension wood forms in a zone on the upper side of the log, and these stresses, if serious, will be released on subsequent conversion and drying leading to further checking and distortion (twist and warp).

Fig. 2. End-grain of Neem log with eccentric pith from which radial shakes emanate.

Unfortunately, the evidence for the above scenario, however, is not definitive. Some studies indicate that a few genera exhibit tension wood without any evident orientation with respect to gravitational axis, and so tension wood may be formed with little evidence of eccentricity in the mature trunk (Panshin and de Zeeuw 1980). Therefore irregularity of cross section is not a constant indication of the presence of reaction wood. Other studies have shown that some tropical woods form tension wood in straight stems, possibly as a reaction in an attempt to obtain sufficient light in dense forest (Taylor 1968). One further publication shows a photograph of the presence of tension wood in a straight cylindrical stem, (Hoadley 1980).

It is recommended, therefore, that although the process of selection as suggested here can be adopted, it is important to record if defects associated with reaction wood are noted as occurring in otherwise cylindrical, pith centred stems. If these defects were indeed widespread, then the selection procedure would need to be reviewed.

The consultants are not aware of any recent studies having been undertaken to determine the physical, drying, or processing properties of plantation or farm grown neem.

3.2 The Log yard

3.2.1 Storage of logs

The log yard at the Society is in an open central uncovered area. Cutters deliver logs throughout the day paying Ksh. 200 as an entrance fee, as each lorry enters the gate. Each of four or five cutters maintains an approximate area in the yard where his logs are stored and sold. It can be seen from the photograph (Figure 3) that some logs are stored in a pile whilst others are scattered. Storing in a pile does offer some protection from rapid drying but this is done to save space, in addition, there is a tendency for ‘fresher’ logs to be nearer the drop off point where the vehicles discharge their load.

Drier, less desirable logs are kept further from this point, but the carvers know that they can negotiate a lower price and save on costs. An unknown, but sizeable percentage of the wood in this yard has been downgraded to firewood, which the cutters will sell at a much lower price. The carvers who know this will buy this wood at a reduced rate and again save on costs. It is Interesting to note that the cutters use the yard to their considerable advantage and it is assumed that the real cost of storage would be probably more than the Ksh. 200 paid at the entrance gate, this cost being recovered by the subsequent sale of just one or two small pieces of wood.

3.2.2 Sale of logs

Cutters sell wood directly to individual carvers who select logs or crosscut pieces of logs depending on what items need to be carved. Each carver will select a piece of wood based on the size and characteristics of the completed article and will negotiate a price with the cutter. Carving ‘blocks’ or ‘blanks’ will also be cut from larger logs using a chainsaw. Generally, only what is immediately needed is purchased, although there is some evidence to suggest that specific logs are purchased for large or specialty carvings in advance, particularly for carving larger giraffes.

The main forces driving and influencing how and when wood is purchased is price and the perceived moisture content of the wood. Carvers consistently look for wood of perceived high moisture content; this is because ‘green’ or wet fresh wood is easier to carve. As soon as a delivery arrives in the yard carvers will buy as soon as possible.

Fig. 3. Log yard at Akamba depicting piled and scattered neem logs

Logs and pieces are constantly turned and moved, either by carvers or sellers hoping to get a good buy and sale. Defects such as knots and end checks will downgrade the value of a piece. Of interest is the fact that a carver will haggle for an addition in length if end checks are in evidence. This extra inch or two will be removed and/or allowed for, but as a bonus can still be used to carve small items. Of greater significance is the observation that a piece of wood with checks and splits means that it has dried and lost moisture and therefore will be more difficult to carve.

A very rough survey was undertaken to establish the price paid for a given diameter of neem log per linear foot. To compare prices to an international standard, this price was then converted to board feet[3]. It can be seen (Figure 4) that neem wood value increases as log diameter increases. However, it appears that the value of neem wood (in Ksh. / board foot) increases slightly with log volume up to a certain limit and then drastically reduces with further increase in volume (Figure 5). This may not be conclusive due to the small sample size but may indicate that the current method used in selling of neem logs by the cutters to carvers is not a standardized as the amount paid for a given size of log size is not fixed but negotiable. A study done by Maingi on the cost of neem logs indicates that one cubic metre of neem logs costs Ksh. 1670 (Maingi, 2003). This is much lower that that charged by the Kenya Forest Department for the other wood carving species most of which are endangered i.e Ksh. 2681 for *Combretum schumanii*, Ksh. 4051 for *Brachyllaena huilensis* and Ksh. 4681 for *Olea Africana and Dalbergia melanoxylon* (Forest Department, 2002).

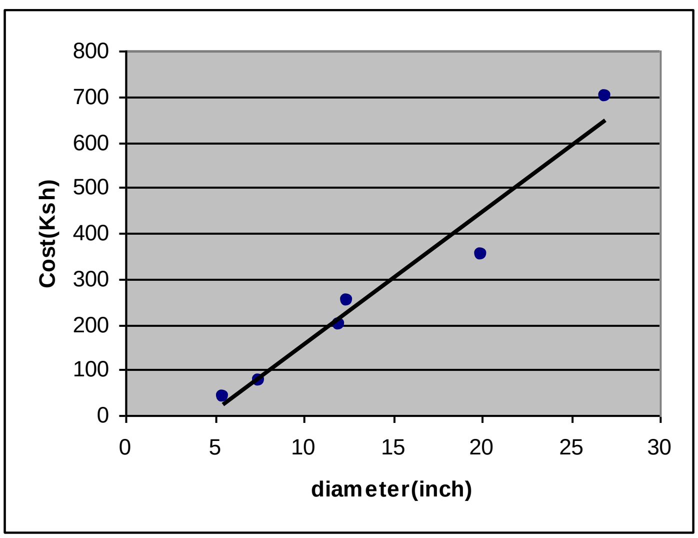

Fig. 4. Value of neem wood as a function of log diameter

[3] Board foot = a piece of wood 12 inches wide x 1 foot in length x 1 inch thick. (144 cubic inches).

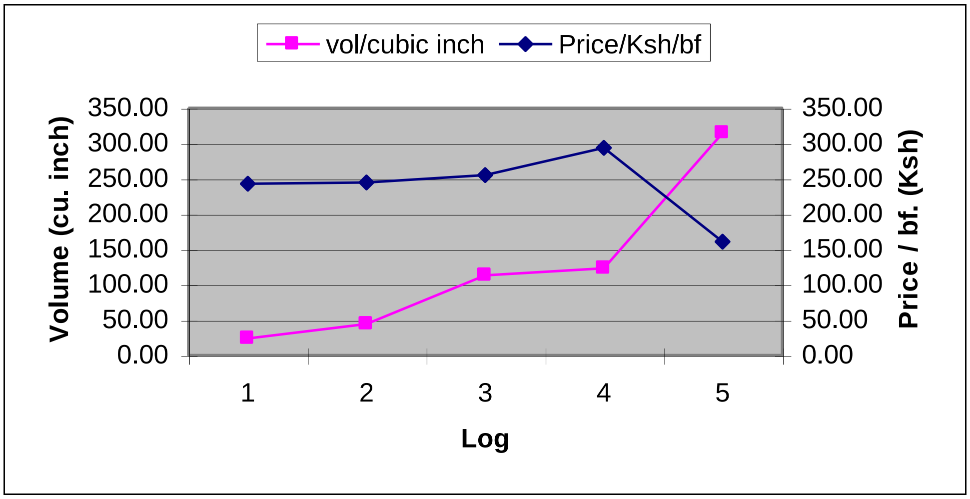

Fig. 5. Effect of log diameter on price per board feet of neem wood.

3.3 Can end sealing of the logs be practical?

It is very difficult to determine when a log or piece will be sold, how its value depreciates over time as it dries, when it may be sold as firewood, or when firewood may be sold as providing material for carving. The rate of moisture loss is unknown and the economic loss of checked and cracked wood is also very difficult to determine. Because of this, it is clearly impractical to suggest under the present circumstances, that the end-grain of logs be sealed against moisture loss as a means to minimise checking and splitting that this causes. A very brief discussion with a number of carvers revealed that if the end-grain of logs could not be seen (because of the application of a sealant) then they could not trust that the log was free of checks and splits. They would probably ask for the painted end to be sawn off to reveal and confirm that no defects were being hidden. With a decision to purchase based on this visual inspection it is quite possible that the log would have to be repainted if not purchased.

The constant movement of logs by hand around the yard also precludes end-grain sealing. The mess created would be impossible to control and faith in the ability of advisors and management to make decisions of benefit would be seriously undermined.

The use of end sealants may only be practical once the co-operative can retain full control of the log yard. The main advantages of establishing the practice of end-sealing logs will be to minimise checking and restricting moisture loss - thus meeting the needs of carvers who prefer carving green wood with high moisture content. There are a number of end sealants in the market that could be used. A short research note[4] clearly shows that there is a great deal of variation in the effectiveness of various waxes and paints that could be used to seal the end-grain of logs (Table 1). Clearly, paraffin wax is the most effective,

[44] USDA Techline, Durability, Protecting Wood from Humidity. Forest Products Laboratory. Issued 05/98 (III-9)

Table 1: Moisture-excluding effectiveness (MEE) of wood finishes (three coats after 14 days at 90% humidity).

Finish	MEE
Paraffin wax	95
Two-component epoxy/polyamide gloss paint	87
Aluminium-pigmented polyurethane gloss varnish	84
Soya-tung satin enamel	80
Pigmented flat shellac	73
Two-component polyurethane wood sealer	63
Orange or white shellac	46
Phenolic/tung floor sealer	35
Paste wax	1
Linseed oil	0

but its availability and price in Mombasa is unknown. It would be best to look for by-products from industries using similar wax and paint products. These are more likely to be cheap and readily available. Testing the effectiveness of these local products should be straightforward, as determining moisture loss over time (detailed later in this report) will be the parameter to measure. It is also essential, however, to also evaluate all health and safety issues when using such products. It will also be necessary to establish the economics of end sealing of the logs.

3.4. The Carving Process

After a log or carving blank has been purchased at the log yard, there is a sense of urgency expressed by the carvers to realise their investment as quickly as possible. This need is reinforced by the fact that the wood carves best when fresh and before it has the chance to loose moisture. The principal carving tool is the adze, and most carvers have a range of sizes, the largest swung with both hands like a felling axe, the smallest, a delicate instrument used to chip the final flakes from a carving before sanding.

3.4.1 Large carvings

For many of the bigger carvings, however, wood removal is clearly a multi-staged process. For large giraffes (see Figure 6) work needs to commence outside the workshop, sometimes in full sun, but with sufficient clearance to wield a heavy adze. Large carvings like these are worked intermittently; new surface layers of wood are exposed and subject to drying. These new surfaces dry very quickly and consequently the heartwood will check and crack, but this may not be a problem if these surfaces are subsequently removed during the next stage of carving. This multi-staged process can be seen as valuable drying time, however, what is not known is the extent of moisture movement from the core of the wood to the surface. It is this moisture at the core of the finished

Fig. 6. Large giraffes being carved in the sun outside the carving shed.

carving that will eventually need to be removed in a controlled manner if drying, with minimum degrade, is to be successful.

For some of the large products, there would be much to be gained from leaving a ‘buffer’ of end-grain (head and feet for example) until the rest of the carving was completed. This would help control moisture loss, as well as provide some much needed additional support to the limbs of delicate carvings, which are often broken, and need repairing. Design would also clearly help, tall thin carvings have much less end-grain surface area as a percentage of total surface area than do fat sleeping hippopotamuses, which often check and crack. As neem is often stained before final polishing, the sapwood is often not so clearly distinguished from the heartwood. This could be used to advantage so that the sapwood constitutes a large surface area. In the case of sleeping hippopotamuses, the carving could be attempted with the wood selected so that grain orientation allows the sapwood to form the belly.

3.4.2 Carving of Face marks

The carving of facemasks reveals additional information regarding the characteristics of neem wood. These carvings are thin, most are less than ½ of an inch thick (12 mm) and they range in size from that of an adult’s hand to an adult’s torso. Very few of these carvings show any signs of splitting, cracking, or checking. This would seem to indicate that neem wood willingly yields its moisture through lateral surfaces with minimum degrade. In addition, of the many masks inspected, very few of the larger examples showed any signs of distortion (warp and twist), which might be expected if the wood had any tension wood (from leaning stems) included. Furthermore, neem wood has mildly interlocked grain, this can be seen as alternating bands of wood on radially cut surfaces and this may also cause thin products to twist and warp. Facemasks show little evidence of drying subject to these defects. Of benefit would be to determine the drying profile of these facemasks, from wood selection to finished product, and then determine moisture loss at point of sale.

The significance of how these facemasks behave during drying and on display highlights the need to understand the magnitude of the role that tension wood plays in wood selection. This is why controlled experiments need to be undertaken to determine at what point eccentric pith becomes unacceptable (as an indicator of the presence of tension wood), furthermore it needs to be determined to what extent tension wood contributes to the development of checks and cracks and separately to distortion during drying.

3.4.3 Final stage of carving

The final stage of carving is the removal of tool marks from the carving; this is done almost exclusively by using sandpaper[5] of various grit sizes. Final finishing for most carvings involves the use of 'wet and dry' sandpaper[6], which is used with water to achieve a polished finish (Fig 7). This soaking with water will probably be of benefit to the woodcarving as it may retard the development of checks and cracks. It is expected that the water will not penetrate deeply into the wood but it will take the moisture content of the surface of the wood above fibre saturation point, below which point these defects occur. Research should be carried out to determine and confirm that this practice is beneficial, it is felt that it is at this stage that a fungicidal solution could be incorporated to check the growth of mould.

3.4.4 Staining and Polishing of carved products

Various colours of stains are used either in combination with water or methylated spirit to give the carvings the final look. The carvers use shoe polish (Kiwi brand) of different colours to polish the carved items. The se materials for finishing are obtained mainly from the co-operative shop at wholesale prices. The finishing of woodcarvings is mainly done by women (Figure 8). The women charge a negotiable price. It would be interesting to establish if the stains and /polish act as a buffer to moisture loss.

[5] Sand is no longer used, usually garnet, carborandum or aluminium oxide.
[6] Silicon carbide is used for 'wet and dry' sandpaper where the paper used is waterproofed.

Fig. 7. Wet sanding of a carving

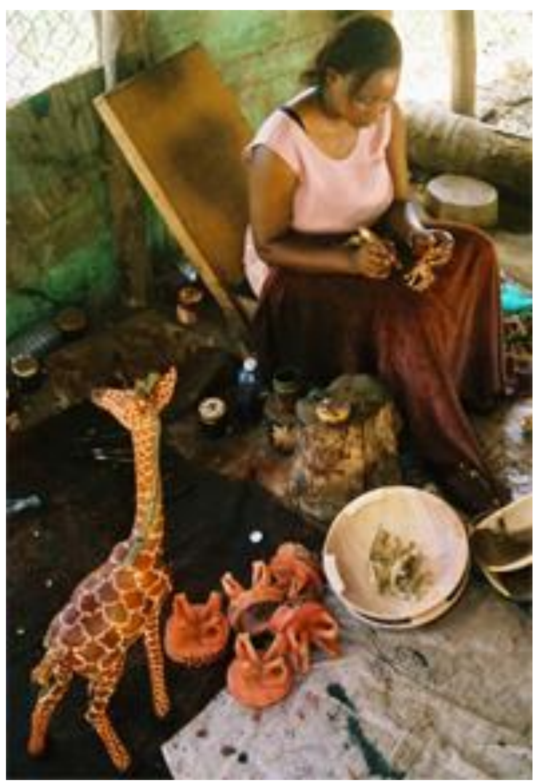

Fig 8. Finishing of woodcarvings.

3.5 Artificial drying of wood carvings

The Society currently has two types of kiln, which have been used to dry wood. These two methods of drying of wood and carvings artificially were assessed. Little evidence exists that any benefits have been or could be gained from their continued use. Both methods were considered unsuitable and their use should be discontinued. Neither has any mechanism to control humidity and both can only supply a source of heat; this means they are really ovens rather than kilns. As there is no shortage of a source of heat (solar and/or the burning of waste wood) it is humidity that needs to be controlled. So that wood can be correctly dried, both heat and humidity need to be controlled. Over the drying period, temperature and humidity are adjusted to control the optimum-drying rate (gradient), which is a compromise between time (speed of drying) and the minimum acceptable levels of degrade. Left on its own to dry, a piece of wood will dry to a final moisture content determined by ambient temperature and humidity. This moisture content is referred to as EMC (equilibrium moisture content). In Mombasa, based on average meteorological records (Table 2) for a twelve-month period (morning and afternoon) the EMC of wood would be about 19 % (80 % Relative Humidity [RH] at 26 ^{0}C)[7]. Although this is below fibre saturation point (FSP[8]), the carving will still degrade further if moved to an environment where heating or air-conditioning, (common in many temperate countries), results in an EMC about 12% (65 % RH and 30 ^{0}C).

It is important to note that virtually all the published literature on the conversion and drying of solid wood relates to sawn timber. Very little (if any) work has been undertaken on the controlled drying of thick carving blocks or finished carvings. The skills needed to master these techniques will need to be developed by the Society and based on a series of objective controlled experiments. It should also be realised that there is often as much variation within a tree species (i.e. between neem carving blocks) as there is between tree species. The former variation can, however, be minimised through correct selection of the

Table 2. Meteorological data for Mombasa.

Parameter	Units	Month												Total
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Average Wind Speed	Mph	11	12	10	10	11	11	11	10	9	8	9	10	10
	Km/h	18	20	16	16	18	18	18	16	14	12	14	16	16
Average Temperature	°F	82	82	83	82	79	77	76	76	77	79	81	82	79
	°C	27	27	28	27	26	25	24	24	25	26	27	27	26
Average morning Relative Humidity	%	93	91	92	93	93	93	94	94	93	94	94	94	93
Average afternoon Relative Humidity	%	61	59	60	66	70	67	67	66	65	66	67	66	65

[7] Note 26 ^{0} C based on 24hours. Average day temperature is about 28 ^{0} C.
[8] Fibre saturation point (FSP) is the point at which the cell wall yields its water is referred. For most species this point is at about 28 % moisture content.

raw material.

3.5.1 Prototype kiln

It is necessary to modify the current system of drying neem and carved products artificially by putting in place mechanisms for controlling humidity, air circulation and temperature. A series of kiln schedules will need to be developed for various size classes of products (reflecting different thickness of wood). These can be developed using a relatively inexpensive prototype kiln. This kiln will be inexpensive to run, and most importantly, control samples of wood can be used rather than actual products. It is suggested that a simple solar kiln should be built using locally available materials, however, systems to control vents and humidity will need to be imported. The consultants will finalise these details when results from initial tests to determine green moisture contents of neem wood have been undertaken

4.0 Way forward for Control of the Quality of raw materials and further research.

The most significant way to improving raw material quality is for the co-operative to have full control of the log yard. With stock control comes control of quality, and it is only then that the benefits of using end-grain sealants can be tested. Before this is attempted however, it is important for the co-operative to purchase logs directly from the cutters. There are many ways in which this can be accomplished and basic guidelines can be used from the way in which other species are currently being purchased in a similar manner (Mahogany, Blackwood etc). In this way, size and quality can be stipulated and controlled, reaction wood, ovality, sweep and taper in logs can be controlled and logs with these defects and characteristics not purchased. This process of selection will add value to the wood, thus creating the incentive to store logs in a manner, which is cost effective, practical and continues to add value.

It would not be correct, at this stage, to suggest that all logs or pieces be protected with an end-grain sealant. Neither would it be correct, to say that all logs should be stored under cover. The green moisture content of neem is not known, but it is expected to be considerably higher in the sapwood than in the heartwood. It was observed that the sapwood is included in many carvings as it is easy to carve and thus favoured. As it also does not tend to check or split, the sapwood appears to act as a ‘buffer’, controlling the loss of moisture from the heartwood. This is probably why the end-grain of heartwood of neem logs and pieces check and split. This principle can be used as guide to help understand how a given log or piece of wood might behave through the many stages of carving as it is exposed (or new surface layers of wood are exposed) to the drying forces of the surrounding air.

To assist the cooperative in determining the optimum conditions for storing logs and blocks of wood, a series of controlled experiments will need to be undertaken. The samples used in such experiments should represent the range of wood qualities and values. The conditions will reflect how moisture is lost in various locations representing the various stages of processing (and their ambient conditions) and recording degrades[9].

4.1 Procedures for drying of Neem and control of moulds.

4.1.1 Drying

When wood dries, moisture moves from the centre of a piece to the surface where it is evaporated by the surrounding air. The difference in the moisture content between the center of a piece and the surface provides the 'drying gradient'. If the differences are large then the drying gradient is steep, if the differences are not great, then the drying gradient is shallow. Generally, it is a steep drying gradient that causes wood to check, split, warp and twist. These faults are referred to generically as 'drying degrade'. Generally wood losses moisture 100 times faster through the end-grain of a piece than through lateral surfaces (Kollman *et al.* 1975).

It can be seen, therefore, that the drying gradient at the end of a log progressing through to the interior will be steep. A further complication is the fact that wood only physically responds to moisture loss when the cell wall begins to loose water, so drying degrade only occurs below this point. The cell wall will only begin to dry when the water inside the cell has dried i.e. after reaching the fibre saturation point. The fibre saturation point is not completely uniform between different wood species because of the variations in their chemical organization but generally falls between 25 and 30 % (Panshin and de Zeeuw 1980). For many practical purposes, the FSP is assumed to be 30 %. For neem, therefore, it is not considered important to determine this property exactly. The water inside the cell is referred to as 'free water'; the water in the cell wall is referred to as 'bound water'. So, the end grain of logs will check and split when the surface of the wood at point of contact with the air falls below FSP and the drying gradient is steep. It is the steepness of the drying gradient that determines when degrade occurs and its severity.

The correct way to dry neem wood carvings cannot be determined unless the carvers and the society management are ready and willing to accept that the solution to controlling all quality issues must rest with themselves. Only then can financial and technical assistance from other agencies have their intended benefits. It needs to be determined when neem carvings should be dried. Carvers will want to complete as much of the carving as is possible whilst the wood is wet and soft. However, it is unlikely that carving can be fully completed before being dried because the carvings will shrink and distort to a degree, which has not as yet, been determined. It is important to understand, that here again, it is controlled experiments that will help determine this optimum balance between at what stage in the carving process a carving should be dried, and when it can be finished with minimum degrade. In fact, it is quite likely that finishing (sanding) will be much easier when the wood is dry, resulting in the use of less sandpaper. Staining should also result in a more uniform finish, and lustre (following the application of wax and polish), should also be much improved.

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[9] Checks, splits, warp, twist etc.

In order to develop procedures for drying neem products, it is suggested that the following tests be undertaken.

1. Test, evaluate and if necessary, modify the prototype kiln before using it for large scale drying of carvings.
2. Purchase basic equipment to accurately determine the moisture content of neem at various stages of processing in order to help monitor drying. This basic equipment to include:

(a) Desiccating gravity oven to determine moisture content of a range of samples exposed to varying drying conditions.

(a) Electronic portable rechargeable laboratory scales to weigh samples and thus determine moisture content and rate of drying.

(b) Electronic Calipers for measuring samples.
(c) Small band saw for preparing control samples.
(d) Hygrometers.
(e) Thermometers
(f) Tongs
(g) Anemometer
(h) Wind vane

3. Employ a laboratory technician (physics/ chemistry options) who could be in charge of these equipment and responsible for carrying out the test under the supervision of the quality control officer. The technician to be trained by KEFRI at Akamba, using the purchased equipment, on moisture measurement and wood cutting procedures.
4. Provide secure and controlled area; probably in the current export room, to install this equipment.
5. Determine the green moisture content of neem (sapwood and heartwood), how these vary with increasing diameter of logs. The moisture gradient from pith to bark will also need to be determined. In tandem with these measurements, controlled experiments could also be undertaken to determine how various end-grain sealants control moisture loss and checking. These will need to be done in direct sun and shade. A simple but secure experimental area will need to be established close to the administrative offices. An area 12 feet by 12 feet should be adequate.

Objectives for the proposed research

The primary purpose of the basic research for the Co-operative to undertake is to determine the steepness of drying gradients under various conditions.

The following objectives are proposed:

1. To determine the average green moisture content of freshly cut wood from pith to the heartwood/sapwood boundary for different diameter classes. The moisture content of sapwood can also be determined.
2. To establish the extent, if any, of moisture content variability from pith to bark of various different log diameters.

3. To establish how much water needs to be removed to dry neem to 10-12% moisture content.
4. To establish controls to determine moisture loss under the following conditions: shade, direct sunlight, end coated with various sealants, (these sealants should be low cost, cheap, readily available – paints, paraffin wax etc). [Here, whole samples, which must be fresh green wood and protected from moisture loss, will provide the initial weight. Samples can then be weighed periodically and moisture loss calculated over time.].
5. To determine the drying profiles of various products from wood selection to finished product, and then determine moisture loss at point of sale. [To determine moisture loss of the finished products, a small secure area in the tourist shop and/or warehouse with wire netting; 2-3 feet of vertical shelf space will be required].
6. To undertake tests using the experimental kiln with controls to determine optimum drying rates before degrade occurs. [In this way a kiln schedule can be designed and the decision taken as to what type of kiln will work best for the many different sized carvings and products].

KEFRI is familiar and experienced to provide training that samples are correctly sourced, prepared and measured. For moisture content determination, samples are weighed green, dried in a desiccating oven at 103 ^{0} C and weighed until no further weight loss is recorded. These samples are referred to as 'oven-dried'.

The moisture content of wood is measured as the ratio of the weight of water in a given piece of wood to the weight of the wood when it is completely dry. The moisture content is therefore based on oven dry weight, which is why for many species it can exceed 100%. It is obtained using the following formula:

Moisture content (%)= ([green weight – oven dry weight] /oven dry weight)] x100-- (1)

Once this technique is supervised and learnt then nearly all of the other experiments will be straightforward to conduct.

It is important that this work be seen to be experimental. Recommendations to change working practices must be based on methods that have proven to work and yield benefits. It is important to remember that it is these same skills and knowledge in determining moisture content and ambient conditions that need to be learnt to operate a kiln successfully. These are therefore, essential and practical skills that the cooperative needs to master if it is to control stock and quality.

4.1.2 Control of moulds

As research on the drying of neem wood and carvings is going on to establish the best way to dry neem with minimal cracks and to achieve a low enough moisture content to protect the wood from the moulds, it is suggested that suitable fungicides be applied to control the moulds. Some of the chemicals that could be used in this regard include: boric acid, Borax (disodium octaborate), ethylene glycol, and mixtures of some of these (Carnell 2003). Boric acid can be mixed with disodium octaborate in a ratio of 46:64 to make a borate wood preservative (Hale personal. com). There are two types of borate products that are commercially available for treating wood: Sodium octaborate for making solutions in water (Tim-Bor ®) and a 40 % solution of sodium octaborate in ethylene glycol (Bora-Care ®). Bora-Care (from the Nisus Corporation) and Tim-Bor (from U.S. Borax) have been used extensively by pest control companies dealing with control and prevention of infestations in wood. Whether these are readily available in Kenya and how much they would cost locally is yet to be established. If not available, their importation can be arranged through various chemical companies. However, their equivalents and more concentrated solutions can be easily prepared from borax, boric acid and ethylene glycol at much lower costs. Boric acid and ethylene glycol are cheap and readily available in Kenya, 1 kg of each costing about Ksh.600.

Bora-Care which comes in liquid form, is much more expensive than Tim-Bor (Table 3). The additional cost may be worthwhile if one is treating dry wood, because Bora-Care includes a glycol solution that promotes diffusion of the borate into wood. When treating wet neem wood (over 20 % moisture content) Tim-Bor that is sold as pure DC powder, could work fine. It is typically mixed with water at 1-2 lb./gal. (0.01 kg/ litre) to achieve a 10 to 20 % solution (Nisus Corporation 2003).

All the suggested fungicides can be sprayed on to wood though dipping provides the most reliable coverage. Tim-Bor and Boric acid could be applied during the wet sanding stage and Bora-Care and ethylene glycol could be used to treat carvings, which are dry sanded. However, should a suitable drying schedule be developed where products are dried before final sanding and finishing, then the chosen fungicide could be applied immediately prior to kilning.

Before the carvers put these chemicals into use, it would be necessary to establish the identity of the fungi growing on neem to see if it is one of those that is vulnerable to borates, it would also be necessary to experiment and establish the best method and stage of application of the fungicides. Though the manufacturers of these chemicals claim that they may not have any effects on the varnishes it would be necessary to test their effects and interactions on the various stains and finishes (used by the carvers) which will be applied subsequent to treatment with these chemicals.

Table 3: Cost comparison Table for Tim-Bor and Bora-Care (Nisus Corporation 2003).

Chemical	How sold?	Approx. Cost ($ US)	Approx. Cost ($ US)	Cost (US $) /kg 20 % DOT[10]
Bora-Care	Liquid concentrate	60-70065/gal.	13.2-14.2/ L	5.5-7.04
Tim-Bor	Powder	2-3/lb.	4.4-6.6 / kg	0.88-1.32

[10] According to Bora-Care directions, one gallon (4.55 litres) of 20 % solution will treat 400 bd. ft. of wood at 13.3 kg/ m^3

Health and safety issues

Borates including boric acid have been used since the days of ancient Greeks for cleaning, preserving food and other daily activities. Boron has long been recognized as an effective and very safe pesticide in wood (Nisus Corporation 1993). Boric acid (LD_{50}[11]=2660 mg/kg) and Boron No. 10 (LD_{50}= 3500 mg/kg) are not significantly different in toxicity than common salt (LD_{50}=3,000 mg/kg) and are less toxic than aspirin (LD_{50}=1000 mg/kg). It appears that as compared to these common household items, Boric acid and Boron No.10 are not particularly dangerous, and if used properly will not cause poisoning. Similarly Tim-Bor and Bora-Care are less toxic than asprin. Tim-Bor has low acute oral toxicity (LD_{50}=2,550 mg/kg), low dermal toxicity (LD_{50} =2,000 mg/kg), low acute inhalation toxicity (LC_{50}=2.0 mg/kg), is non-irritant to the skin and may only cause mild eye irritation effects (U.S. Borax 1997). Bora-Care has an oral lethal dose of 5,000 mg/kg, acute dermal LD_{50} greater than 2,000 gm/kg, acute inhalation LC_{50} greater than 5,000 mg/kg of body weight. These chemicals may only be harmful or fatal if subjected to intentional misuse by deliberately concentrating and inhaling them.

The material data sheets out lining the procedures for the safe use of these chemicals can be easily obtained from the manufacturer or through the Internet. However, simple and easy to understand health and safety guidelines on the use and application of these chemicals need to be developed for the carvers. It would also be necessary to identify and train some wood carvers or Society personnel on the safe use and application of these chemicals so that the use of these chemicals is restricted to one point and only those trained and authorized to handle them. There will also be need for a chemical store for dry indoor storage of these chemicals. Discussions will also need to be held with the local authority on how best and where to damp the chemical wastes to avoid pollution of water bodies. No special disposal treatment is required for Tim-Bor, Boric acid and Borax and small quantities of these chemicals can usually be disposed of at landfill sites. However, guidelines for disposal of Bora-Care and ethylene glycol and large quantities of the other chemicals may need to be sought from relevant government authority.

4.3 Funding of the research

The consultants recommend that the cost of establishing this research on wood drying and quality issues be funded externally for the first year, this will include the cost of equipment as detailed, the salary of a competent technician, and the cost of training, experimental design and support from KEFRI. During this period every effort must be made to ensure that research on improving and implementing quality control procedures be accepted by the Society as being an essential ongoing component of its production activities. It is estimated that US$ 10,000-15,000 will be required.

4.5 Role of the Society

Responsibility for completing this first year of work should be assumed by the Co-operative Society with assistance from KEFRI. Beyond this first year, ongoing quality

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[11] LD_{50}-A dose that would cause the deaths of 50 % of a specific animal population [mg of dose per body weight (kg)]

control costs will be funded by the Society and that this work culture be assumed by them and incorporated into an ongoing and comprehensive programme of quality control.

It is essential that the Society assumes responsibility for controlling product quality. This needs to be done at the outset. The Society, as being the best way to find solutions to problems and planning for improvements, should assume all preliminary research. As in any private enterprise, it is this ownership and control of problems that leads to innovative thinking and ultimately competitive advantage. It is also very important that this process be viewed as an investment and that simple mechanisms be instigated to measure benefits, perhaps here again KGT can advise on how this can be accomplished.

The Society needs to begin discussing these issues at the earliest opportunity, and in tandem with ongoing research. Planning is essential here and may well need to be dovetailed into the logistics of introducing the Forest Stewardship Council (FSC) certification scheme.

5.0 Conclusions

It can be concluded that the net result of these changes will mean that by definition of 'stock control', some of the decisions currently made by individual carvers on wood selection will need to be controlled by the Society. The implications of this process of attempting to control storage conditions means (logically) that eventually the Society might grade logs or blocks according to product. For example, only (say grade 'A') logs should or must be used by carvers to make giraffes destined for export over 24 inches tall. This will inevitably mean that carvers will need to pay a premium for wood that has been graded as being of a premium grade. This is an extra cost that the carver will need to externalise, and likewise, the Society will also need to look at how these costs can be passed on to consumers. Clearly, the successful promotion of 'quality' as a key factor influencing the decision to purchase a carving must be investigated. Again, how this need dovetails with the aims of promoting an ethically sourced product, in terms of marketing, will need to be investigated.

6. 0 Recommendations

6.1 Immediate

It is recognised that there is a pressing need to establish simple mechanisms, which can assist the Society in improving the quality of its finished products, especially for important export markets. Clear procedures for drying neem products cannot be specified until most of the experimental work has been completed, however, there are a number of practices, which can be used to assist in minimising the occurrence of cracks and other drying defects. The following guidelines should be seen as short term and limited to the most valuable and important export orders.

1. There is need for a clearer understanding of how neem wood is sourced in order to develop appropriate guidelines on tree and stem selection for log cutters. The Society should ask cutters to select stems, which have grown straight, are cylindrical and free from knots and other growth defects. The best of these pieces should be earmarked for export orders and specific products.

2. Carving should start as soon as possible and the work finished as soon as is practical, but finishing (sanding) should be left until these rough carvings have had as long as possible to dry. Sanding should be easier when the wood has dried and any cracks or checks can be filled at this stage.

3. The carvings should be air-dried under cover (shade). At the first sign of checking or cracking the carvings should be immediately (but intermittently) covered with a damp cloth, (or one large cloth covering many carvings). Alternatively, they can be sprayed with a fine mist of water and/or borax solution. The damp cloth should be prepared using the same borax solution.

4. Carvers should not attempt to export large carvings at this stage, as it is these that are more likely to develop defects after export. Also, large bodied animals should be redesigned following the guidelines and observations made in the main text. If this is not possible, then larger carvings could have their exposed end-grain areas sealed with paraffin wax (during this air-drying stage). This wax can be easily removed before final sanding and finishing. Alternatively, (or in addition to end-grain sealing), more end-grain wood can be left on the carving to act as a buffer against moisture loss. Although this will crack and check, it can later be removed.

5. It should be recognised, that there is no guarantee that the finished products will not crack and check when exported. However, because the carvings have been dried for as long as possible before shipment, and because any cracks have been filled after this period of drying, it is possible that the reoccurrence of further defects will have been minimised.

6. At the earliest opportunity, the Society needs to have full control of the log yard; it is only then when the benefits of using end sealants can be tested. Meanwhile, the co-operative should purchase logs directly from the cutters and ensure that the logs being admitted into the yard are obtained from stems, which have been growing straight. It is important to record defects associated with reaction wood in these otherwise cylindrical and pith centred stems. The extent of these defects to be assessed and if need be the selection procedure be reviewed. It is important that discussions begin on how these changes can be implemented as soon as possible.

6.2 Intermediate

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

7. To assist the co-operative in determining optimum conditions for storing logs and blocks of wood, a series of controlled experiments have been recommended**.** These include determination of moisture content and its variation from pith to sapwood for various diameter classes; as well as determining moisture loss under different conditions and at the point of sale. In addition, the need to determine the drying profiles of various products and to undertake tests using the experimental kiln will help the cooperative understand how to dry, store, display, and export different sizes and designs of products.

8. There will also be need for a set aside area where quality control equipment can be securely installed and used for the proposed experiments and quality control.

9. To implement the suggested use of fungicides for control of moulds, on an experimental basis, it would first be necessary to establish the identity of the fungi growing on neem, determine the best method and stage of application of the fungicides, test the effects and interactions on the various stains and finishes which are often applied subsequent to treatment and to develop simple and clear health and safety guidelines on how these fungicides should be stored, used and disposed of**.**

10. More natural light should be allowed into the tourist's- show room by using translucent sheets, or other method to allow for filtered light. It is essential that the quality control room be well lit; current assessment of carved items is almost impossible. A makuti roof should replace the tin roof at the wholesale show room as it makes the room to be so hot and this could accelerate checking and cracking of the items.

11. Confirmation should be sought from the appropriate national arboreal/forestry agency, that in order to maintain the health of neem trees and prevent infection, neem stems should be cut as flush to the main stem as possible, and that these cut surfaces should be protected with a suitable arboreal paint (tree paint).

Acknowledgements

The completion of this study document would not have been possible without the help of many people. We would like to thank all who gave of their time, expertise, and patience, particularly the Akamba woodcarvers and craftsman.

In return, we hope our efforts in this report will help assist the Akamba Cooperative and all who strive to use wood more wisely.

The authors are particularly indebted to the kind and knowledgeable assistance provided by the following individuals.

Dr. Susanne Schmitt	WWF (UK)
Mr. David Maingi	WWF (EARPRO)
Mr. Kithala Mwema	Manager, Akamba Handicrafts Society
Mr. Urbanus Musau	Export Manager, Akamba Handicrafts Society
Ms. Mary Onyango	BDS Manager, Kenya Gatsby Trust
Mr. Obiero Thomas Were	Business Advisor, Kenya Gatsby Trust
Dr. M. Hale-	University College North Wales (UNCW), Bangor, UK

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