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OIL PALM STEM DENSIFICATION USING AMMONIA TREATMENT: A PRELIMINARY STUDY

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KILLMANN, W. & KOH, M.P. 1988. **Oil palm stem densification using ammonia treatment: a preliminary study.** Oil palm stem material of different moisture contents was treated with aqueous ammonia solutions and subsequently compressed. The density increase in relation to initial moisture content and initial density, as well as the impact of treatment and compression on swelling/shrinkage are discussed.

Key words: Oil palm stem – ammonia treatment – densification.

Introduction

Generally, oil palms *(Elaeis guineensis)* are replaced after 25 – 30 *y*. Through the increase in plantation area in the last two decades, more than 1 million m^3 of oil palm stems are expected to be available annually after 1990 (Mohd. Hussin *et al.* 1986). In order to tap this vast resource, various uses have been tested. One of its potential uses is as sawn timber. However, the major part of the stem at the age of 25 *y* consists of tissue below 400 *kg/m* (Killmann and Lim 1985), and the recovery of suitable sawn timber is only between 8 and 30% (Ho *et al.* 1985).

Nonetheless, it is possible to improve some of the properties of oil palm stem material by ammonia treatment and subsequent densification. Stamm (1955) and Schuerch (1964) reported on the possibilities of plastifying wood through exposure to ammonia. This can be achieved by using gaseous ammonia (Davidson 1970) as well as liquid ammonia (Pentoney 1966, Bariska 1969). The impact of ammonia on the wood constituents (cellulose, hemicellulose and lignin) has not yet been fully revealed (Bariska & Strasser 1976, Parameswaran & Roffael 1984). It seems to allow a plastic deformation of the molecular system (Schuerch 1964). Thus, ammonia-treated wood can be formed or compressed to various shapes. The force required is less than that for forming after steam treatment.

It has been found that hardwoods can also be easily plasticised and formed into a number of shapes and embossed (Davidson & Baumgardt 1970). Particleboards behave similarly, provided the adhesive used is ammonia resistant (Parameswaran & Roffael 1984). With the exception of *Koompassia excelsa* (Mendoza 1977), little has been done on the plasticification of tropical wood with ammonia in any form.

In this paper, the technical feasibility of such treatment is assessed. The impact of ammonia treatment on oil palm stem material on the following parameters was investigated:

- Initial density (*g/cm*);
- Moisture content before treatment (in %);
- Soaking time (24 – 48 *h*);
- Pressure applied during densification (400 – 1000 PSI);
- Pressing time (10 – 15 *min*); and
- Targeted thickness (17 – 18 *mm*).

Previous trials (Killmann and Koh, unpublished) showed that a soaking time of at least 24 *h* in aqueous ammonia was necessary in order to improve the density during compression of the samples. Longer soaking times and a pressure above 1000 PSI did not improve the results. A pressing time of <5 *min* was too short to achieve a permanent plastification. Use of spacers below 17 *mm* (more than 15% of nominal thickness of 20 *mm*) resulted in severe cracking.

Materials and methods

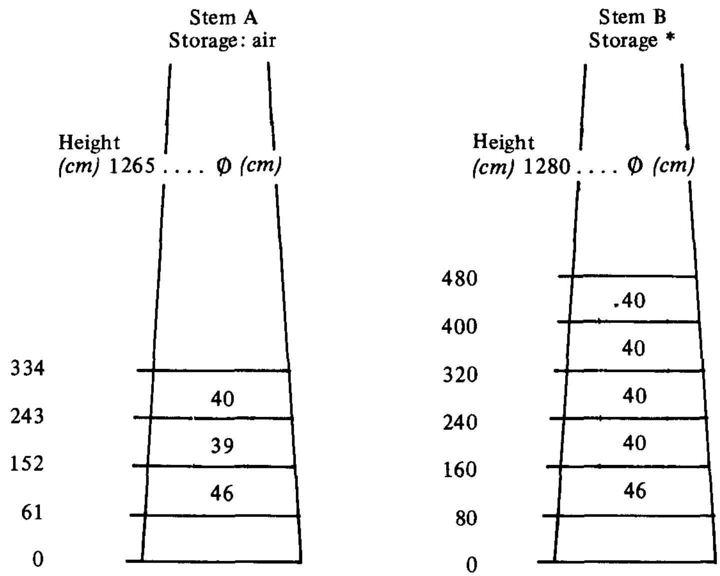
Materials

Two 35-year old oil palm stems were randomly taken from a plantation in Batang Berjuntai, in the state of Selangor, Malaysia. Each stem was cut into billets of 91 (stem A) and 80 (stem B) *cm* lengths, respectively and then transported to the Forest Research Institute Malaysia (FRIM). Some of the stem characteristics are outlined in Table 1.

Immediately after felling, test samples of dimensions 23 x 16 x 2 *cm* were cut from the periphery and within the core of each billet (Table 1) according to the cutting pattern in Figure 1.

From every billet, at least three sets of samples were recovered over the billet length and cut into half. Billets of stem A were air-stored, and those of stem B were air – or water – stored.

Table 1. Some characteristics of sample billets from oil palm stems



* 2 lower billets air-stored
3 higher billets water-stored for 2 months

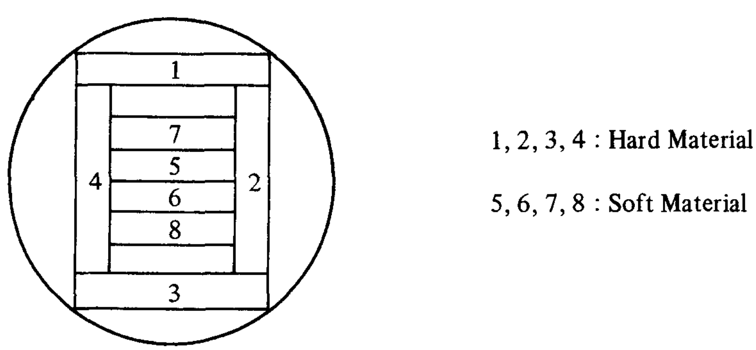


Figure 1. Cutting Pattern

Methods

Immediately after sawing, samples of top and bottom end of each board were cut and their oven dry densities as well as the moisture contents were assessed according to standards ISO 3130 and 3131. For plasticification procedure, at least four samples per billet of the same density group were placed in a beaker within a desiccator. A vacuum of 10 *mm* Hg was applied with a water jet pump for 60 *min*. Commercially available aqueous ammonia solutions of 28 and 33% concentrations were then added to the test samples separately under vacuum and left soaking under ammonia for 24 *h*. The additions were done at ambient conditions ($\sim$ 26° C). The impregnated samples were cold-pressed to thicknesses of 17, 17.5 and 18 *mm*. To attain the thickness desired, steelspacers of the respective thickness were applied. After pressing, the samples were seasoned to equilibrium moisture contents by natural air drying and under a forced heated drought at 50° *C* with clamping. Measurements of the dimensions, moisture contents, and density of the samples were made at each stage.

Results and discussion

Pressing

The application of 400 PSI (28 N/mm^2) for 10 *mm* proved sufficient to compress material with initial densities of up to 0.6 g/m^3 to the desired thickness.

Ammonia percentage

No perceivable differences between the effects of 28 and 33% of ammonia solution on the test material were observed (Figures 2 – 6).

Density

The density of palm stem increases with the amount of vascular bundles/square unit, i.e. density decreases from periphery to pith and from bottom to top of stem. With a decrease of vascular bundles/square unit the amount of parenchymatic tissue/ square unit increases (e.g. coconut palm: Killmann 1983, Oil palm: Killmann & Lim 1985). The present trials show high correlations (R = 0.86, 0.92; Table 2) in percentage of density increase to initial density. Density increases of up to 165% (Figures 2 & 3) were obtained. The lower the initial density is, the higher is the increase (Figures 2 & 3). Since the less dense material has more parenchymatous tissue, it is possible that the vascular bundles are pressed into the parenchymatous tissue and only the latter is compressed.

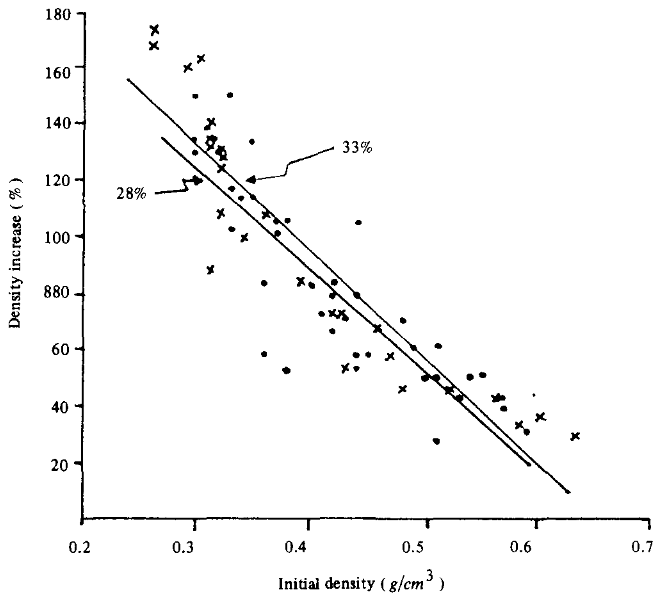


Figure 2. Density increase versus initial density of water-stored billets treated with 28% (•) and 33% (x) ammonia

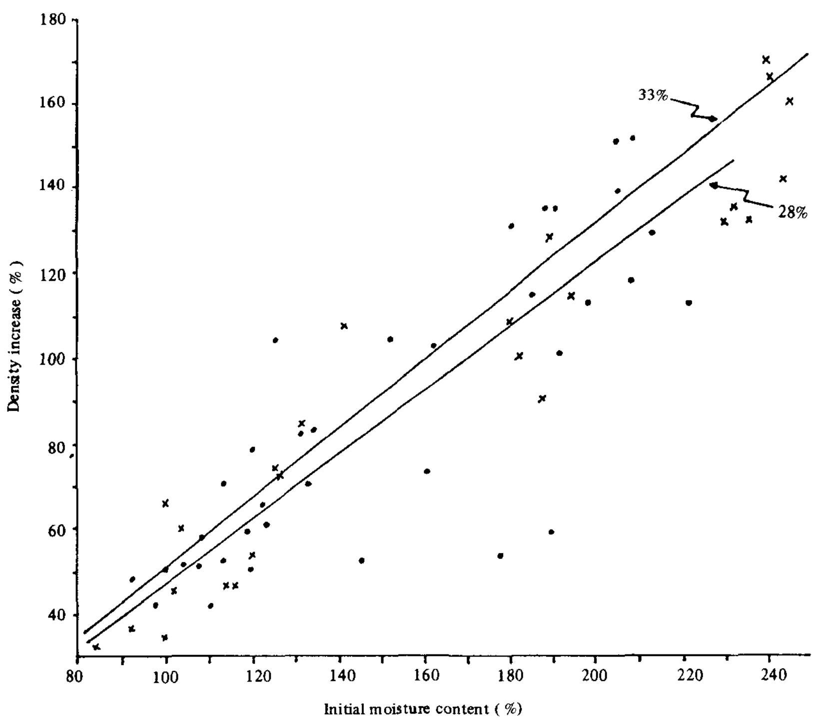


Figure 3. Density increase versus initial moisture content of water-stored billets treated with 28% (•) and 33% (x) ammonia

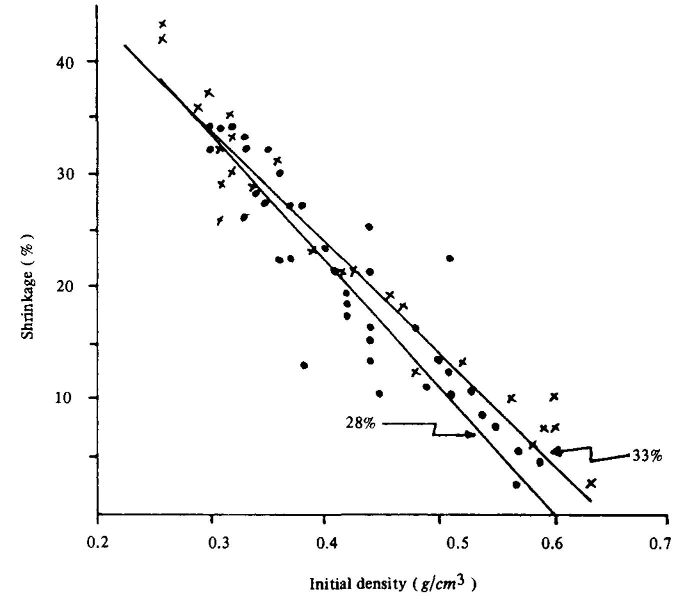


Figure 4. Shrinkage versus initial density of water-stored billets treated with 28% (o) and 33% (x) ammonia

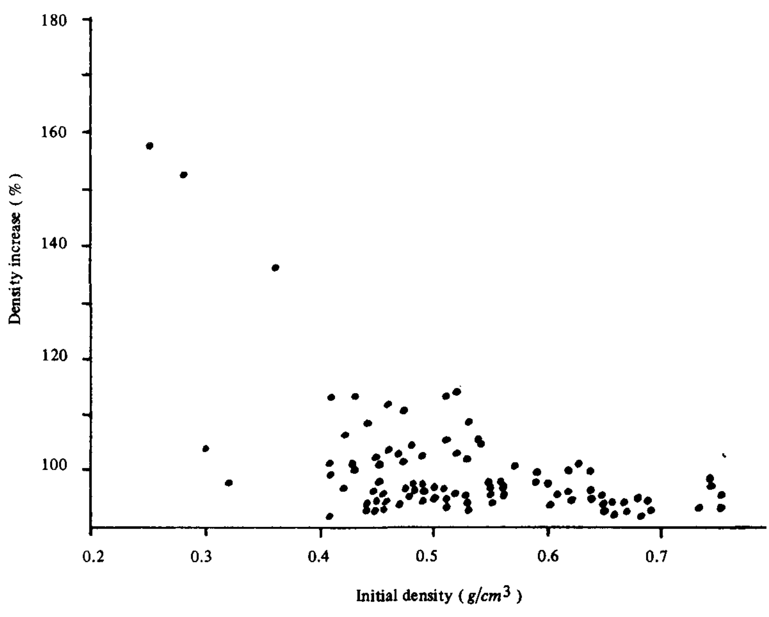


Figure 5. Density increase versus initial density of air-stored billets treated with 28% ammonia

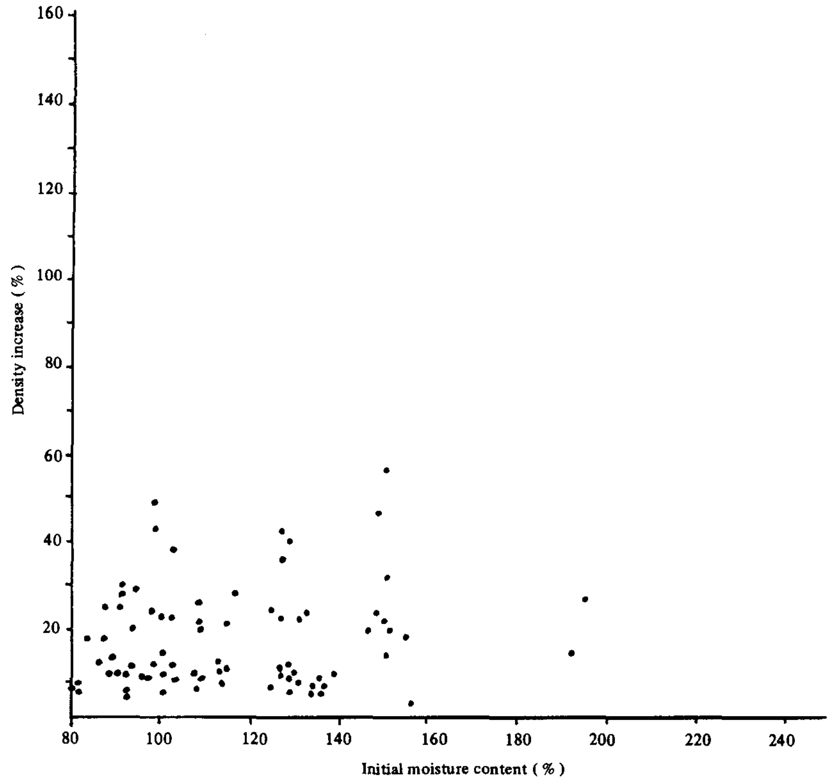


Figure 6. Density increase versus initial moisture content of air-stored billets treated with 28% ammonia

Table 2. Correlation Data of water-stored billets (Stem B)

Ammonia	Relations	R^2	R	Regression line
28	Density increase/initial density	0.74	0.86	Y = – 358 X + 233
	Radial shrinkage/initial density	0.81	0.90	Y = – 125 X + 75
	Density increase/initial moisture content	0.70	0.84	Y = 0.73 X – 25
33	Density increase/initial density	0.85	0.92	Y = – 380 X + 246
	Radial shrinkage/initial density	0.94	0.96	Y = –99.4 X + 64
	Density increase/initial moisture content	0.92	0.96	Y = 0.8 X – 29

Moisture content before treatment

The samples of tree A (Table 1) were air-stored between two and 12 weeks prior to ammonia tratement. The material was partially dried before it was treated. Just above half of them showed moisture contents below 120% (Figure 6). Initial moisture content in oil palm stem is rather high and it can reach up to 400% (Killmann & Lim 1985). It is inversely correlated to the amount of vascular bundles/square unit and thus to density (Killmann 1983, Killmann & Lim 1985).

The air-stored material proved to be less amenable to ammonia treatment (Figures 5 & 6) than the water-stored material of palm B, probably due to the low moisture content in the former (Figures 2 – 4). Subsequently, work was concentrated on the water-stored material.

Correlation coefficients of 0.84 and 0.96 for 28 and 33% ammonia, respectively, underline the importance of a high moisture content for ammonia treatment (Table 2). Substantial density increase through ammonia treatment and subsequent pressing was reached at moisture contents above 80% (Figure 3). It rises linearly with higher moisture contents. These findings verify the observations made by others (Davidson 1968, Bariska & Strasser 1976), that the presence of water in the wood enhances the performance of ammonia treatment.

Swelling/Shrinkage

Ammonia treatment of wood results in severe swelling (Stamm 1955, Bariska 1969). Immediately after leaving the press, the still wet material swelled up by 9 . . . . 14 . . . . 17%, which may partly be due to the bounce back effect reported by Bersins (1972) and Bariska and Schuerch (1977). Bariska (1969) observed that the middle lamella and cell-walls of birch did swell up to 40%. During subsequent drying, the samples shrank considerably. By measuring the radial shrinkage (perpendicular to flat side of samples), correlation coefficients of 0.90 and 0.97 (in relationship to original thickness) were obtained for 28 and 33% ammonia treatments, respectively. They underline the high correlation between density and shrinkage. Highest shrinkage values (exceeding 40%, Figure 4) were found with the most densified material, which on the other hand had the lowest density. Bersins (1973) reported the volumetric shrinkage of birch (*Betula* spp.) to reach 25% and that of aspen (*Populus* spp.) 36% after ammonia treatment.

Seasoning defects

In order to reduce seasoning defects, the material was clamped for the duration of drying. But even then, quite a number of defects occurred (Table 3). Mendoza (1977) made similar observations with trials on *K. excelsa*. Defects were less in denser material (Table 9) and were further reduced by accelerated air drying. Generally, various defects occurred together. Some defects are due to cell collapse. Bariska & Strasser (1976) pointed out that with the present techniques, a cell collapse after ammonia treatment is unavoidable. It is explained by the partial closure of the cell lumina as well as by a certain reduction of the pore volumes of the cell-walls.

Table 3. Defects occurring during seasoning (by frequency of occurrence)

Tree	Material	*Ammonia* (%)	Stem height of billets (*cm*)	No. of samples	*Twist* (%)	*Cupping* (%)	*Crack* (%)	Blue Stain (%)	Defect free (%)
A	H	28	61 – 334	20	20	10	20	65	35
B	H	28	80 – 240	36	0	6	17	6	81
B	H	28	80 – 320	52	29	27	29	21	56
B	H	28	240 – 400	25	96	84	92	60	0
B	H	33	240 – 400	11	45	9	73	0	9
A	S	28	61 – 334	10	50	50	0	0	50
B	S	28	240 – 400	16	100	50	97	38	0
B	S	28	80 – 320	40	0	0	25	25	63
B	S	33	80 – 320	16	100	50	75	6	0

H = Hard Material (periphery of stem)
S = Soft Material (pith of stem)
A & B = Palm (see Table 1)

Recommendations

As shown, with the exposure to a 28% solution of aqueous ammonia and subsequent compression, the density of oil palm stem material can be increased, and its mechanical properties thus improved. The less dense material responded to this procedure in particular. However, a further test series is required in order to assess the potential of this process for the economic use of oil palm stems. Chiefly, the following aspects have to be clarified: reduction of seasoning defects, reduction of fungal attack, and economic evaluation.

In addition, a closed system should be incorporated to reduce the use of ammonia through its recovery after test and thus reduce costs. Furthermore, trials should be carried out to reduce the treatment time and the ammonia concentration for further economy. Seasoning defects could be reduced by drying under pressure, possibly in a heated press. However, long seasoning times will increase the costs considerably. Bersins (1973), for example, reported 120 *h* for birch wood of 125 x 8 x 8 *cm*. Bariska (1969) assumes that the plasticification times can be shortened with higher initial moisture content. It is suggested that another test series with larger samples in a closed system should be carried out. Also, the retention of ammonia in the samples should be assessed.

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