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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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on the Production of Panels
from Agricultural Wastes

Vienna, Austria, 14 - 18 December 1970

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by

A.E. Chittenden
Tropical Products Institute
Ministry of Overseas Development
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In order that the very large field covered by this paper is brought into sharp focus, the first part of it has been devoted to the definition of the products and raw materials concerned. This, in itself, presents some difficulty and so that the available material is kept within reasonable bounds some omissions have had to be made.

The bibliography however is virtually complete and covers the whole field of development and research (including the literature on existing plants) on the subject over the past thirty years or so.

The text of the paper has been restricted to highlighting research and developments which were or are proving promising, especially with the needs of

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developing countries in mind. Similarly, all aspects of production and marketing problems which have arisen in the past are reviewed.

An attempt has been made to distinguish where the problems concerning the increasing use of agricultural waste materials in developing countries are technical, and where they are economic.

INTRODUCTION

The subject matter of this paper covers a very wide field, and in order to keep it within practicable bounds, it has been decided to limit the treatment given to some raw materials and products.

Firstly, the panel product plywood will not be dealt with in this report. This may not seem, on the face of it, to be a very obvious omission when dealing with agricultural waste raw materials but there has been a little work done on this with limited commercial success. There is a reference (106) to the use of corn-cobs as a plywood filler, and (if the definition of plywood is stretched a little) plywood-like consumer articles (i.e. tea-trays, table-tops, etc.) are produced commercially from the outer hard epidermis of bamboo and sugar cane in Taiwan and India respectively. These are very minor developments of very limited application and represent the limit of the use of agricultural wastes in the plywood field.

It will no doubt be noticed that in the preceding paragraph, considerable liberties have been taken in the use of the strict definitions of both raw materials and the final product. For example, the purist will object to the inclusion of such raw materials as papyrus, bamboo and reeds under the generic heading of agricultural wastes. In order that as complete a picture as possible can be given and so that a developing country shall miss no opportuniry of knowing about potential raw materials at their disposal it has been decided to interpret this term very widely, perhaps it could more correctly be termed "non-wood materials". If, as has already been suggested, the scope of this paper is to be kept within bounds some further modifications in these definitions will be required. In general, the definitions given for panel products in the FAO "Fibreboard and Hardboard" (this book is, in fact, the condensed report of the International Consultation on Insulation Board, Hardboard and Particle Board, held in Geneva in 1957) have been strictly adhered to. It is very strongly recommended that everyone who has an interest in these products should obtain this book and keep it by him as a work of reference. Raw material definitions pose rather greater difficulties. It is true to say that every raw material which has been investigated for its pulping properties by mechanical or semi-mechanical means has also, as a matter of practical fact, been investigated as a potential material for fibre-board (that is hardboard or compressed fibreboard, and insulation board or non-compressed fibreboard). To cover the whole of this field in detail is clearly an impossible task in a paper of this type. However, some raw materials which fall under this heading have been included in the bibliography but some selection has been made of those which are considered to warrant fuller treatment in the text, this selection process will be referred to again later. There is another complicating factor which has to be considered when deciding upon an orderly method of presenting material for this paper. Recent research and development work has produced a range of board-making processes and products which can be considered as intermediates between panel product types as clearly defined in the FAO publication referred to above. These are, of course, the boards made by the semi-dry and dry processes which are becoming of increasing commercial importance. They are also very relevant to this study because they can be operated with small sized particles (e.g. plywood veneer waste and sawdust) which are often found as agricultural residues. These boards are hardboard-like in appearance and in many strength characteristics, and although they probably obtain the greater part of their bonding by means of an added organic binder (as defined for particle board) there is also a probability that some of the bonding is obtained from the inherent adhesive properties of the raw material (as defined for fibreboard). In this case it has been decided that, because of the great similarity in the basic manufacturing techniques, to deal with dry and semi-dry hardboard as if they were particle boards for the purposes of this paper.

Selection has also been necessary in the bibliography and only references have been included which contribute towards the history of the subject which could prove useful in future plans for the utilization of the raw material concerned.

Selection has also had to be made of much other raw material included in this paper, but in all cases it has been kept very much in mind that this paper and this meeting are oriented towards the needs of the less-developed countries and selection has always been made with this in mind.

The search for raw materials

It is quite difficult to think of an agricultural waste material which has not at one time or another (sometimes very repeatedly) been tested for its potentialities for board making. The first commercial development for the manufacture of building board was in England in 1898, using waste-paper as the raw material. This product would probably now be classified as the pulp and paper product "chipboard" but this development did at any rate serve to get the general idea into circulation. Probably the first true hardboard can be traced back to 1909, when production was started using coarse ground-wood or newsprint pulp, but world production of wet process hardboard (mostly from timber) started after the commercial development of the thermal-plus-mechanical pulping process (Asplund) and the explosion process (Masonite). Particle board manufacture came into the field much later, experimental work on this product was being carried out in Europe and the United States before the Second World War, and the first commercial plant was installed, in Bremen Western Germany, during the war in 1941. All these developments utilized timber, at least in the first place, and it has proved rather difficult to find out who has the honour to be the first plant to produce hardboard or particle board from an agricultural waste material. It is believed that Belgium (1947) (81) was the first to produce flat particle board, but non-wood based hardboard or insulation board has never been a very commonly made product (at present bagasse is the only product of this type so used) and in the past it was often the practice to make these boards from a mixture of wood and non-wood fibre. Regretfully, therefore, honours on this point have eluded us.

Table I contains a selected list of agricultural waste materials which have been tested; it is by no means exhaustive, but does contain all those materials which have achieved commercial success. A much more complete picture will be obtained from the bibliography. One thing is immediately obvious from this table, and that is the relatively low proportion of materials tested which were eventually utilized on a commercial scale. This aspect will be discussed much more fully later. Those materials which have been (or are) successfully used commercially on a large scale are quite small in number; they are bagasse, flax and linseed residues and the European reeds, and again these will also be discussed in still more detail later on. Of the remainder in this table, papyrus achieved some limited success as a commercially used raw material for hardboard, a pilot scale plant in Israel (113) was an example, and the small but for a time at any rate very successful plant in Uganda was another. A study of the individual reports in the bibliography clearly indicates that many of the other raw materials tried are technically suitable for board production but other factors seem to have combined to prevent their commercial exploitation. Mention must be made of a good example of the possibility of using a raw material which is not easy to use by conventional processes for the production of a different panel product. The cereal straws are, in general, difficult to make into hardboard by the wet process because their pulps are so "wet" and their central hollow core results in a large part of the surface area of the straw being unavailable for the application of a glue binder. The "Stramit" board is manufactured by forcing unpulped straw into a heated extrusion tunnel where it is bonded together solely by means of heat and pressure. The board, normally about 50 mm thick and 120 cm wide, is faced on both sides with a thick kraft or cardboard liner. "Stramit" is manufactured in several countries of the world including Japan and Thailand, where rice straw is used as the raw material. So far as is known, this is the sole representative of a building board made from unpulped agricultural waste without the use of an added binder.

Industrial application problems - the raw material

Firstly, there arises the problem of the technical comparison between boards made from agricultural wastes and from wood. This is an inevitable comparison because so often the sources of both forest and agricultural waste co-exist and are economic competitors. Table II shows a comparison of particle board strength between a timber and two agricultural waste materials. The matter in this table is self-evident and serves to illustrate a fundamental point which is often forgotten when considering agricultural wastes for particle board production. The physical structure and particle size of an agricultural waste material is fixed firstly by nature and secondly by any processing it has had to extract the primary crop. On the other hand, timber can be machined or engineered into a particle size which is the optimum for board production. It is, of course, quite true that on one hand agricultural waste materials can have their physical characteristics modified by hammer-milling, refining, etc. and on the other hand that many mills utilize small sized wood waste which is not ideal for board manufacture, but in practice, it is found that this basic rule holds good. There is, however, one great advantage which some agricultural wastes have over timber and this is density. In general, wood particle board cannot be made of a density less than about 5 per cent more than the density of the original wood with acceptable strength properties. In fact, it is often difficult to achieve commercially a wood-based board of a density less than 20 per cent more than the original wood. With flax shives and bagasse, for instance, it is possible to make a board of acceptable strength below the density of that of the raw material (11). The influence of density on marketability must not be overlooked when considering the merits of these materials.

These technical differences, whilst important, can possibly be overcome during manufacture or by subsequent finishes so as to produce a marketable product and when all is said and done, this is the crucial point. There is, however, another bigger problem facing the potential use of agricultural wastes. It was said at the FAO Geneva Conference in 1957 (4) that "the greatest obstacle to increasing the utilization of many of these non-wood materials is the problem of collection and storage and the lack of suitable equipment for this purpose." This statement is, as fas as the less well developed tropical countries are concerned, as true today as it was in 1957. Further, in many cases it is this fact and not mere technical inferiority which results in so few of the materials listed in Table I achieving commercial utilization. It will be seen how this problem has been overcome (or is inapplicable) with regard to the widely used agricultural wastes in the "case histories" which appear later. The Tropical Products Institute among others has given considerable attention to this problem in developing countries over a long period, but at present it would appear that unless a material is transported to a central site in large quantities for primary processing, it stands little chance of being used as a board-making raw material on economic grounds alone. Even so, this still leaves a hard core of problem materials which are available in sufficient quantities on site but are not widely used because of technical intractability or alternative use considerations or a combination of both factors.

Coir dust (this is the portion of the coconut husk which remains as a residue after the extraction of the fibre "coir"; it represents about three-fifths by weight of the husk) is one such material which is available in large quantities throughout most of the tropics and has virtually no alternative competing uses. Almost twenty years of research effort and quite a number of laboratories (chiefly in India and the United Kingdom) have really failed to develop an economically viable board-making process to make use of it. Rice hulls, which are available from many large-scale rice production and milling projects, are another example. More recently, groundnut shells have been very thoroughly investigated (92 - 99) and still await commercial exploitation. Wild (i.e. not cultivated) materials of the agricultural residue type (papyrus, reeds, etc.) present purely a collection problem since no primary processing is involved. With the exception of the use of reeds in developed European countries, no "wild" non-wood material is at present being currently used for hardboard or particle board manufacture.

Cassava (tapioca or manioc) stems are a good potential particle board material (56, 57) but the greater part of the tropical world grows and processes the crop on small holdings, making problems of collection insuperable. There is no fore-seeable alternate use for this material and presumably its commercial utilization awaits the fruition of large-scale cassava projects which are from time to time suggested.

Another group of problems facing the utilization of agricultural wastes arises from the competition of synthetics with the primary crop. This has resulted in a levelling off at the least (in some countries an actual drop) in the production of flaxboard due to the competing effect of synthetic fibres on linen and of synthetic resins with linseed oil in paint. A similar sort of pattern would possibly be expected if the residues from the production of other vegetable fibres (e.g. jute, hemp and sisal) were made use of to a greater extent that at present. This is currently a rather vexed problem because there is considerable pressure to do just this as a palliative to the increasing synthetic replacement of the primary product. It is well known to be a matter of some economic importance to some developing countries but there seems to be no way in which this replacement trend can be hindered, nor is there any great hope that it will lessen. There will, of course, be a short term outlet for vegetable fibres in developing countries until such time as they have a heavy chemical infrastructure capable of supporting synthetic fibre plants, but the production scale (and hence the quantity of waste) is likely to be small and may well be insufficiently large to supply a board plant of an economic size.

Industrial application problems - plant and binders

There is some truth in the statement that each individual agricultural waste material needs plant specifically designed for its use. However, in practice, the amount of deviation from the basic design suitable for all materials is not very great and creates no real practical difficulties. Experience and techniques in efficiently operating plants using the different raw materials present a more difficult problem perhaps, but such expertise is available through the appropriate

United Nations agencies, and again there is little practical difficulty. It can be said, therefore, when all other problems are solved, that there would be no difficulty in obtaining plant and expertise to produce any building board, from any agricultural waste material. Similarly, the synthetic resin binder companies of the developed countries are now capable of producing a satisfactory binder for almost any conceivable raw material or condition of use. It is not proposed here to enter into the field of discussion on the advantages and disadvantages of the different types of binder available. In the particle board field, the published literature on these is very extensive and examples are given in the bibliography (3,4, 10). This brings to the fore another point which is often forgotten when considering a project for the establishment of a board plant in a developing country. Very often, the suggestion that such a plant be installed is mooted with the intent of saving foreign currency on imports of building board. This good intention is then partially negated by committing the country concerned to a considerable expenditure on synthetic resin binder which they are quite unable to manufacture economically themselves (through lack of cheap suitable raw materials).

This situation has given rise to research into the possibilities of using locally available materials as binders. It is believed that the original work on this was done in Australia (16, 17) where a particle board binder based on wattle tannin and formaldehyde was developed. This work has been expanded in South Africa (17) and this binder would be now a technically acceptable alternative to the synthetic resin binders where wattle tannin is available economically. The need for still further research was suggested by FAO's Wood Based Panel Products Committee and this was started at the Tropical Products Institute in 1969. The task of finding and developing such a product is a difficult one, but a search of the literature revealed that a great deal of work had been done in India particularly by Naryanamurti and his associates (14, 15) on the use of formulations based on cashew nut shell liquid as plywood adhesives. The problem has been taken up at this point and it is confidently hoped that a report on this will be issued in the very near future. However, this work if successful can only hope to assist those countries where supplies of a potential naturally occurring binder and adequate supplies of agricultural waste co-exist.

Mention must be made here of a whole field of activity concerning the use of agricultural wastes for the manufacture of building boards using Portland cement as the binder. Many aspects of this have been covered by the documentation of the recent UNIDO Expert Working Group Meeting (130) and still more information will be found in the section of the bibliography devoted to this subject. There has been much recent research activity in this field especially on materials other than bamboo and sisal fibre (which seem to have been the favourite materials in the past), the TPI for example has produced a paper on the use of rice-hulls for this purpose (135). The use of Portland cement as a binder presents a number of technical problems which are not within the scope of this paper but it is hoped that the next year or so will see some new developments here. There are already a few commercial plants and processes based on the use of waste timber for cement-based boards, and so there are unlikely to be any great development problems in this respect if and when a new raw material can be found or treated so that it can be used to make board.

Another problem facing the potential user of agricultural wastes is that of storage. In general, agricultural wastes are produced for only a short period of the year, and the requirements of an industrial plant using them would necessitate storing supplies for the rest of the year. They are also bulky, which further aggravates this storage problem. Bagasse presents an additional problem in that it is normally produced in a wet state (about 50 per cent water content) and contains small amounts of residual sugar. The traditional method of dealing with this is to acidify this wet bagasse to inhibit the growth of micro-organisms in baled form. Better perhaps is to dry the material before storage, for particle board manufacture it will have to be dried before processing anyway and so whilst this method represents little additional drying costs, it does mean that storage has to be under cover. There is a good deal of information in the literature on this subject, which need not be repeated here (35), but it must not be forgotten that the sugar cane season lasts the whole year in some tropical countries, for nine or ten months in many others, so that bagasse storage here is not needed. Most of the other agricultural wastes which occur in sufficient quantities for use as board-making materials are produced in a dry or nearly dry form. Here storage is a purely economic problem rather than technical, though storage costs are likely to be fairly high because of the bulky nature of these materials.

The past and the future - trends and predictions

Table III represents the best that we have been able to do in collecting together factual information on existing commercial plants using agricultural waste materials. It is largely based on information given to FAO, but has been amended and brought up to date by information from other sources. With the exception of bagasse and flax (the fluidity of the situation concerning the use of this material has already been referred to, and is possibly reflected by some inaccuracies in this table) the outlook for agricultural wastes for board production does not appear to be very promising. In fact it can be said that these two materials plus wastes from long vegetable fibre production account together for virtually the whole of the world's utilization of agricultural wastes for board production. As has been discussed above in some detail, the reasons for this state of affairs are:

(a) timber is in a great many respects a superior raw material from both technical and economic aspects;

(b) the existence of sufficiently large quantities of agricultural waste suitable for board manufacture in one place, with no competing uses, is, especially in the tropics, rare; and

(c) the availability of agricultural wastes from agro-industrial activities other than food are subject to the vagaries of substitution and so on.

There now comes the question of the future. Based on the summary of the present and past situation given above, it could be expected that any increased use of agricultural wastes for board production could derive from those obtained from food production. In effect, this means bagasse, the cereal straws and similar materials (e.g. cassava stalks, groundnut shells, etc.). It is the opinion of the author that this in fact will be the future pattern. However, it will possibly be modified by the fact that concurrently there is occurring a rapid expansion in the tropics of fast-growing timber plantations capable of yielding high-class, uniform and low-cost board-making materials, and it is felt that advantage may be taken in planning future board-making projects with this source of raw material in preference to agricultural residues, although this is clearly not possible where self-sufficiency in timber is not feasible in the foreseeable future. It is too early yet to predict the effect which the "newer" fibre board-making processes will have on the increased use of agricultural wastes. An excellent comparative review of these processes was contained in a paper given in 1968 at FAO (7b) and it is predicted that their adoption in new plants using these materials will occur to an increasing extent, but as things stand at present it is not expected that their influence will be significant in itself.

As a conclusion to this chapter and to this report, it is considered to be worthwhile to make some suggestions as to what can and ought to be done to increase the use of these agricultural wastes. The employment of small-scale operations is an obvious solution, so that the smaller, scattered quantities of these materials can be used. Unfortunately, world trends in plant size for all types of board manufacture runs against this on the grounds of size economics. FAO's conference papers (4, 6, 7a and b) on this (in the allied field of wood-based products) form yet again a ready background.

Whilst discussing the background for this meeting with UNIDO, and during the course of writing this paper, it became very obvious that progress towards the increasing use of agricultural wastes in developing countries has been very slow, even where there is not a self-sufficiency in timber. It seems that the time has come when new ideas and new approaches can be assembled, discussed and collated because it is felt that there is no single simple solution to the problem. This is precisely the purpose of this Meeting, and it is hoped and expected that our Proceedings will yield the data so badly needed to help those who are working on the different aspects of the problem.

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TABLE I

Selected Check-List of Agricultural Waste Materials Tested for Board-Making

Raw Material	Insulation Board	Hardboard	Particle Board	Other	Notes
Abaca (Manilla)			E		
Areca nut husk	E	E			
Bagasse	E,I	E,I	E,I	E - Plasterboard	
Bamboo	E	E,I	E	E - Plywood E - Woven mat E - Concrete reinforcement	Woven mat also as small-scale industry
Banana pseudostem		E			
Cashew nut shell		E	E		
Cassava stalk	E	E			
Cereal straw	E,I	E,I		E - with red mace for acoustical tile	
Coffee husk			E		
Coir - dust		E,I			
fibre + husk	E,I	E, Pilot plant			
Cotton - husk			E		
stalk			E,I		
Esparto			E		
Flax and Linseed residues	E	E	I	E - fibreboard with hemp	
Groundnut shell			E		Particle board plant designed but not yet established
Hemp	I	I	I	E - fibreboard with flax	
Jute		E,I	E,I	E - asphalted roofing material	
Kenaf			E		
Maize cob				E - plywood	
Mustard stalk		E			
Palm fronds, fruit stems (raffle)			E,I		
Papyrus	E,I	E,I			Production now ceased

continued..........

TABLE I (continued)

Raw Material	Insulation Board	Hardboard	Particle Board	Other	Notes
Peat		E	E		
Quinine stem			I		
Ramie			E		
Reeds	E,I	E,I	E		
Reeds and straw	I	I			
Rice husk			E	E - with cement for bricks and tiles	
Seaweed	E	E			
Sisal		E		E - with cement	
Sunflower husks			E		
Theel			E		
Tobacco stalk			E		
Vetiver stalk			E		
Yolyo			E		

NOTE:

"E" indicates that the material has been the subject of laboratory experimental work only.

"I" indicates that the material has been (or is being) used industrially for board manufacture.

TABLE II

Comparison of the Physical Properties of Particle Boards Made from Pine Shavings, Flax and Bagasse, for Different Densities of the Boards

Raw Material	Bending Strength kg/cm²		Tensile Strength Perpendicular to Surface kg/cm²		Swelling in thickness after 24 hrs. immersion (per cent)	
Density g/cm³	0.30	0.58	0.30	0.58	0.30	0.58
Pine	70.0	349	0.9	7.9	6.4	11.5
Flax	36.0	160	1.4	5.5	8.8	12.5
Bagasse	45.0	173	1.7	6.2	6.4	2.7

Pine shavings: Thickness 0.2 to 0.3 mm., width 0.8 mm., length 20 mm.

Glue: Urea resin "Urecoll" F Spezial: 8 per cent solid resin on completely dried material.

(From 'FAO/ECE/BOARD CONS/PAPER 4.17. p.5)

TABLE III

Industrial utilisation of agricultural wastes for fibreboard and particleboard based on FAO World Survey of Production Capacity (1968)

Country	FIBREBOARD No. operating plants 1967	1968	1969 (Estimated)	FIBREBOARD Annual Production Capacity (1,000 m.t.) 1967	1968	1969 (Estimated)	Raw Material	PARTICLEBOARD No. operating plants 1967	1968	1969 (Estimated)	PARTICLEBOARD Annual Production Capacity (1,000 m.t.) 1967	1968	1969 (Estimated)	Raw Material	Remarks
Argentina								1	1	1				Flax shives	
Belgium											250	240	230	Flax	Currently using imported material
Cuba	3	3	3	28	28	28	Bagasse (+ waste paper)	1	1	1	10	10	10	Bagasse	
Czechoslovakia											41.4	41.4	41.4	Flax	
Dominican Republic								1	1	1				Bagasse	Not operative
France											76	72	70	Flax	
Greece								2	2	2	10	5	5	Hemp Maize stalks	
Guadeloupe								1	1	1	6	9	9	Bagasse	
Guinea								1	1	1	12	12	12	Quinine stems	
Hungary											41	41	41	Flax	
India								1	1	1	10% of production for low density board			Bagasse	
Iran									1	2				1968 - cotton stalks 1969 - palm fibre	
Jamaica									1	1				Bagasse	
Malaysia								1	1	1	2	2	2	Flax	
Netherlands								2	2	2	15	15	15	Flax	
Pakistan								1	1	1				Jute sticks	
Poland											74	74	74	Flax	
Puerto Rico								1	1	1				Bagasse	Experimental plant not in operation 1968
Reunion								1	1	1	180	180	180	Bagasse	Only plant figures on 6-months basis operation during cane-grinding season
Ryuku Islands								1	1	1	16.5	16.5	16.5	Bagasse	
Taiwan	5	5	5	35	35	35	Mainly bagasse	1	1	1	20	20	20	Bagasse	
U.A.R. (Egypt)								2	2	2	20	20	20	Bagasse	
											30 t/day			Flax shives	
Venezuela								1	1	1				Bagasse	
Yugoslavia								9	9	9	40	40	40	Flax	

NOTE:

It is hoped that more recent data will be available in the Proceedings of the 3rd Session of the FAO Committee on Wood Based Panel Products, to be held in December this year (1970).

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Ministry of Overseas Development
Culham, Abingdon, Berks, England

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