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Moulded Product**Field of the invention**

The invention relates to mouldable products. More particularly, this invention relates to moulded products manufactured from plant fibers.

Background of the invention

In this specification, where a document, act or item of knowledge is referred to or discussed, this reference or discussion is not an admission that the document, act or item of knowledge or any combination thereof was at the priority date, publicly available, known to the public, part of common general knowledge, or known to be relevant to an attempt to solve any problem with which this specification is concerned.

Whilst the following discussion concerns products such as containers, protective packaging and shock absorbing packaging it is to be understood that the same principles apply to any products manufactured according to the present invention from plant matter including table tops, cups, take-away food containers, partitions, packing materials, golf tees and all products comprising either a flat piece or a container. A product according to the invention may be of any convenient shape and may optionally include partitions or protrusions.

Many currently used products are made from plastics and petroleum based derivatives or natural wood. Plastics materials do not degrade and cannot be disposed of effectively. Such materials may be collected and often recycled. However, recycling does not completely solve the environmental problems posed by many plastics because the breakdown of these compounds releases harmful gases into the atmosphere. Plastics products which are not recycled may lead to land and water pollution causing irreparable damage to the environment. Wood-based products, such as paper boxes and paper pulp packaging, lead to deforestation. Whilst disposal of paper products may not have a direct harmful effect on the environment, deforestation resulting from the need for wood chips for paper products causes ozone layer depletion which is equally harmful to the environment. Reforestation takes at least 15 years and the harmful ecological impact during the recovery period may not be remedied, even over an extended period of time. Further, some paper products, such as paper cups, have a coating that is non-biodegradable which can cause further ecological harm.



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These adverse environmental and ecological effects caused by the disposal of voluminous waste give rise to a need for a substitute material to produce these products, preferably a material that is derived from a biodegradable and/or readily renewable resource.

While biodegradable materials are available, the previously known materials may not be useable as a substitute for some plastics products.

There are known processes which form products by binding together loose materials. For example, chipboard or particle board uses a compression method and adhesives. However it is not convenient to produce shaped articles from chipboard.

There is a process that uses a biodegradable material such as plant fibers to form products by thermo-foaming. In this process, steam is used to cook the raw materials, mainly starch, so that the starch can expand and bind with the next molecule of starch. As the starch is heated in the presence of moisture, it expands and creates a multitude of small air pockets in the product. This product mainly consists of starch therefore the product degrades or disintegrates very quickly when it contacts a liquid such as water. As a result, the product cannot be coated with a water-proofing material since it starts to degrade once it contacts the liquid.

This prior art thermo-foaming process relies on foam formation of the material to shape the material into receptacles. Such shaped products are soft and "cushion-like" and so will not be durable and strong enough to withstand hard knocks. As a result, the products which can be made via this process are limited. Another issue with this process is the cost of production. The methodology used is very costly and the limited uses does not provide the volume of production to make the production line cost effective.

We are aware of a series of prior US Patents in the names of Andersen and Hodson and assigned to E. Khashoggi Industries, LLC including US Patents 5,662,731; 5,783,126; 5,868,824 and 6,030,673 (the Khashoggi patents). These US Patents all refer to manufacturing moulded articles. However, the Khashoggi patents all teach the addition of at least 10 wt % of starch and quote a typical range as being 10-80 wt %. For example, Khashoggi US patent number 5,783,126 teaches a preferred starch content of 30 to 70% which gives rise to a problem due to the relatively high cost of starch-based binder and the excess time and energy necessary to remove the solvent. Khashoggi therefore teaches the addition of inorganic fillers or aggregates. The Khashoggi patents also teach the addition

of inorganic fillers in relatively high concentrations and quote a typical level of inorganic aggregate as being greater than 20 wt %.

The present applicants have found that the high levels of added starch and inorganic aggregate as taught by the Khashoggi patents lead to high costs and a tendency to form a multitude of small voids within the moulded product. The formation of the voids also tends to impart a "cushion-like" structure which has low structural strength. The applicants have now found that contrary to teachings of the Khashoggi patents, moulded products having significant structural integrity can be satisfactorily produced with low starch concentrations or even the absence of added starch and without the addition of inorganic aggregates.

Summary of the invention

According to one aspect of the invention, there is provided a moulded product formed from a moulding mixture including:

- (i) 40 to 60 wt% plant fibre pieces optionally combined with 0 to 10 wt% added starch; and
- (ii) 10 to 55 wt % water and 3 to 10 wt % one or more water-soluble binding agents or adhesives

According to a further aspect of the invention, there is provided a moulded product formed from a moulding mixture including:

- (i) 40 to 60 wt% plant fibre pieces optionally combined with 0 to 2 wt% added starch; and
- (ii) 10 to 55 wt % water and 3 to 10 wt % one or more water-soluble binding agents or adhesives

According to a further aspect of the invention, there is provided a moulded product formed from a moulding mixture including:

- (i) 40 to 60 wt% plant fibre pieces optionally combined with 2 to 10 wt% added starch; and
- (ii) 10 to 55 wt % water and 3 to 10 wt % one or more water-soluble binding agents or adhesives

According to a further aspect of the invention there is provided a moulded product formed from a moulding mixture including:

- (i) 40 to 60 wt% plant fibre pieces combined with 2 to 10 wt% starch; and
- (ii) 25 to 55 wt% water and 2 to 10 wt% one or more water-soluble and biodegradable binding agents or adhesives.

According to a further aspect of the invention, there is provided a moulded product formed by a process comprising the following steps:

- (a) preparing a moulding mixture by:
 - (i) taking 40 to 60 wt% plant fibre pieces and optionally combining 0 to 10 wt% added starch with the plant fibre pieces; and
 - (ii) adding thereto 10 to 55 wt % water and 3 to 10 wt % one or more water-soluble binding agents or adhesives;
- (b) pouring the mixture into a mould, the mould being at a temperature of at least 60°C;
- (c) subjecting the mixture in the mould to a temperature in the range of 15 to 60 °C and a pressure in the range from 1000 to 7000 PSI for a period of time such that a portion of the water in the mixture is converted to steam which causes the mixture to fill the mould while remaining in a mouldable state;
- (d) reducing the pressure so that steam continues to form within the mould without causing an explosion whilst maintaining the mixture in a mouldable state;
- (e) increasing the temperature and pressure to a temperature in the range from 100 to 200°C and a pressure in the range of 500 to 1500 PSI;
- (f) removing the steam or allowing the steam to escape until the moulded product is substantially dry;
- (g) removing the substantially dried and moulded product from the mould.

According to a further aspect of the invention, there is provided a moulded product formed by a process comprising the following steps:

- (a) preparing a moulding mixture by:

- (i) taking 40 to 60 wt% plant fibre pieces and optionally combining 0 to 2 wt% added starch with the plant fibre pieces; and
 - (ii) adding thereto 10 to 55 wt % water and 3 to 10 wt % one or more water-soluble binding agents or adhesives;
- (b) pouring the mixture into a mould, the mould being at a temperature of at least 60°C;
- (c) subjecting the mixture in the mould to a temperature in the range of 15 to 60 °C and a pressure in the range from 1000 to 7000 PSI for a period of time such that a portion of the water in the mixture is converted to steam which *causes the mixture to fill the mould while remaining in a mouldable state*;
- (d) reducing the pressure so that steam continues to form within the mould without causing an explosion whilst maintaining the mixture in a mouldable state;
- (e) increasing the temperature and pressure to a temperature in the range from 100 to 200°C and a pressure in the range of 500 to 1500 PSI;
- (f) removing the steam or allowing the steam to escape until the moulded product is substantially dry;
- (g) removing the substantially dried and moulded product from the mould.

According to a further aspect of the invention, there is provided a moulded product formed by a process comprising the following steps:

- (a) preparing a moulding mixture by:
 - (i) taking 40 to 60 wt% plant fibre pieces and optionally combining 2 to 10 wt% added starch with the plant fibre pieces; and
 - (ii) adding thereto 25 to 55 wt% water and 2 to 10 wt% one or more water-soluble binding agents or adhesives;
- (b) pouring the mixture into a mould the mould being at a temperature of from 70 to 100°C;
- (c) subjecting the mixture in the mould to a temperature in the range of 15 to 60°C and a pressure in the range from 1000 to 7000 PSI for a period of time

such that a portion of the water in the mixture is converted to steam which causes the mixture to fill the mould while remaining in a mouldable state;

- (d) reducing the pressure so that steam continues to form within the mould without causing an explosion whilst maintaining the mixture in a mouldable state;
- (e) increasing the temperature and pressure to a temperature in the range from 100 to 200°C and a pressure in the range of 500 to 1500 PSI;
- (f) removing the steam or allowing the steam to escape until the moulded product is substantially dry;
- (g) removing the substantially dried and moulded product from the mould.

According to a further aspect of the invention, there is provided a moulded product formed by a process comprising the following steps:

- (a) preparing a moulding mixture by:
 - (i) taking 40 to 60 wt% plant fibre pieces and optionally combining 2 to 10 wt% added starch with the plant fibre pieces; and
 - (ii) adding thereto 10 to 55 wt % water and 3 to 10 wt % one or more water-soluble binding agents or adhesives;
- (b) pouring the mixture into a mould, the mould being at a temperature of at least 60°C;
- (c) subjecting the mixture in the mould to a temperature in the range of 15 to 60 °C and a pressure in the range from 1000 to 7000 PSI for a period of time such that a portion of the water in the mixture is converted to steam which causes the mixture to fill the mould while remaining in a mouldable state;
- (d) reducing the pressure so that steam continues to form within the mould without causing an explosion whilst maintaining the mixture in a mouldable state;
- (e) increasing the temperature and pressure to a temperature in the range from 100 to 200°C and a pressure in the range of 500 to 1500 PSI;

- (f) removing the steam or allowing the steam to escape until the moulded product is substantially dry;
- (g) removing the substantially dried and moulded product from the mould.

In a preferred embodiment, the product is formed by a process which further comprises the steps of:

- (h) at least partially coating the moulded product with one or more binding agents or adhesives; and
- (i) heating the coated moulded product to substantially dry and cure the coating.

The invention involves employing the action of the steam to force the mixture to be distributed throughout the mould. Any excess solids material will thus be forced out of the mould by the action of the steam. Once the action of the steam has spread the mixture throughout the mould, the steam is removed or escapes through the gap or a valve.

Without this steam action, the solids in the mixture would not spread throughout the mould and would end up being compressed at the bottom of the mould in which case the mixture would no longer be in a readily mouldable state.

Preferably the process comprises a further step of trimming the edges of the product prior to coating the product in step (h). Typically, such trimming is conducted using a die-cut machine. Other methods for trimming may also be used within the scope of the invention including polishing and/or sanding down the edges of the product.

Since the main component of the mixture is plant fibers which are bonded together by an adhesive which hardens as it cures, the cured product will not disintegrate immediately upon contact with liquid. Depending on the density of the product (and thus the porosity of the product), the product will take a minimum of ten minutes before it starts disintegrating and could last as long as one hour. The density of the product is dependent on the pressure applied during formation of the product. Therefore, the product is liquid-resistant enough to withstand treatment with water-resistance agents or decorative materials.

The cured product can be further treated with a water resistance material or decorative materials. If decorations such as colorings are added then the coloring paint/ink should be oil-based and not water-based since it provides a better finish and will adhere to the

surface. Preferably, water-based colorings are not used because the cured product is hard after curing and will not absorb the paint. The water-resistant coating may be any appropriate material such as wax, paint or a water soluble latex base. Typically the coating is non-toxic. For environmental reasons, preferably the coating is a biodegradable material such as a water soluble wax. Alternatively, the coating is a non-biodegradable material such as a wax which is soluble in non-aqueous solvent, a polymeric material such as a vinyl – or polyurethane – based polymer or a conductive paint such as Statichan™. Preferably the coating is Neoprene™ which has FDA approval in addition to being environmentally friendly. The coating process can be by way of brushing, spraying or dipping or any other convenient method. Preferably, the coating is applied by spraying. The product may be partially or entirely coated depending on the intended use of the product.

The period of time for which pressure in the range of from 1000 to 7000 PSI is applied in step (c) is preferably in the range of from 3 to 10 seconds. Preferably, in step (c) the mixture in the mould is subjected to a temperature of about 29 °C.

Preferably, the pressure in step (d) is reduced to a pressure in the range of from 500 to 1500 PSI before pressure is increased in step (e). Most preferably the pressure in step (d) is reduced to atmospheric and then increased in step (e) to a pressure in the range of from 500 to 1500 PSI more preferably about 1000 PSI.

Preferably, the temperature in step (e) is increased to about 140°C.

Step (f) typically occurs for a period of time in the range of from 10 seconds to 30 minutes or longer till the product is dry at a temperature in the range of from 100°C to 250°C.

The plant fibers can come from any source. For example, suitable plant fibres may be chosen from the group comprising rice stalks, wheat stalks, sugar cane, corn leaves, banana leaves, corn cobs, roots, grass, flowers, recycled paper or combinations thereof.

The size of the fibers affects the texture of the final product. The requirements of the final product will dictate the size of the fibers required. For example, a table top will need to be strong and is flat so this will allow larger longer pieces of fiber to be used than those used in a smaller or curved item such as a cup. Preferably, the plant fiber pieces used in the composition and process are in the range from 0.1mm to 5 mm. More preferably, the

length should be between 1 mm to 2 mm. However it is possible to use plant fibers which have been ground smaller than 1 mm, eg. powdered.

The binding agents or adhesives which are used to bind the fibres are water soluble and preferably are environmental friendly. It is preferred that non-biodegradable plastics or synthetic polymers are not used so that the process provides a biodegradable product although it is to be appreciated that biodegradability of the binding agents or adhesives is not essential where the end product does not need to be biodegradable. Preferably, water based biodegradable adhesives are used so that the end product is biodegradable. Preferably, latex-based adhesives, such as Neoprene, are used in accordance with the invention.

Preferably, any added starch used in accordance with the present invention is selected from the group comprising tapioca flour, ground sweet potatoes or any other root powder, corn starch, flour and combinations thereof. While corn starch and flour are suitable for use as added starch in accordance with the present invention the results are not as good as when other starch sources are used. There is no need to modify the added starch prior to processing.

The fiber and flour or other added starch are mixed together initially in step (a)(i) to produce an even mixture. Further, if the liquid ingredients contact the flour before it is evenly mixed in, the flour will form lumps and this will create holes in the product as the starch is removed during the process. Once all the ingredients are combined in step (a)(ii), the mixture is stored in a sealed container until required for step (b) to prevent the mixture from drying out. The mixture is preferably stored at room temperature prior to use to prevent hardening. The mixture may be stored at a temperature in the range from the freezing point of the mixture to about 25°C. Preferably, the mixture is stored at a temperature in the range from 15 to 25°C. Further, at higher temperatures there is a possibility that mould will form because of the combination of water and an organic mixture. Preferably, step (a) occurs at a temperature at or below 25°C.

The water used can be of any quality. The water quality chosen will depend on the intended use for the product. For example, non-potable water such as sea water may be used as well as normal utility water. However, products intended for food contact must be made from drinking quality water. The water is converted to steam during the process. This aids in spreading the mixture evenly in the mould. The mixture does not foam

because the pressure prevents the mixture from expanding, and the action of the steam is directed towards spreading the mixture throughout the mould. Once the spreading is complete, the steam is removed to allow the product to dry.

The amount of pressure applied to the mould will affect the density of the final product. The denser the product, the harder it is. Therefore, if a more flexible product is desired then a lower pressure should be used. When the pressure is applied to the mould, any excess material will be squeezed out of the mould. Preferably, the pressure is at about 4000 PSI.

The strength of the product will depend on four factors:

(1) the fibre pieces.

The finer the pieces, the higher the density and hence the greater the strength of the product.

(2) the type of adhesive including the crystallization rates and viscosity of the adhesive. Different types and grades of adhesive contribute differently to the strength of the products. Different crystallization rates and viscosities of different adhesives result in different products. Crystallization determines the rate of initial strength development. The faster the rate of crystallization, the faster the rate of strength development. Viscosity influences the inherent strength of the adhesive film, the solution viscosity, and solids content. The higher the polymer viscosity, or the higher the molecular weight, the higher the film strength, the higher the adhesive viscosity, or the lower the solids at a given adhesive viscosity.

(3) the structural design of the mould.

The product design may enhance the strength of the overall product. For example, a box with ribs will be stronger than one without.

(4) the type of fibre. For example, sugar cane fibre provides a moulded product that is inherently resilient but not brittle. Conversely, rice husks tend to provide a product that is hard, but comparatively brittle.

Products produced by the process of the invention can be recycled with very minimal loss of original material and with no harmful by-products. In other words, a product can be recycled to produce an almost identical product.

When disposed of, products produced by the process of the invention will breakdown and disintegrate to form substances which are not detrimental to the environment. This is because all of the materials used are non-toxic and are mostly natural and edible. If the products are collected after disposal and left to decompose, the resultant manure can be used as a fertilizer because of the fact that the main component of the product is plant fibers.

Further, the plant fibers may be obtained from the unwanted parts of crops such as rice-stalks, sugar cane pulps or any other fibers that are not directly consumed. This helps to dispose of such waste from harvesting sites, factories etc. which would otherwise be disposed of by burning and thus causing air pollution. The use of such raw material helps to reduce this air pollution.

Further, during the process of the invention, bacteria are killed due to the high temperatures being applied.

The present invention relates to biodegradable as well as non-biodegradable materials. Since the manufacture of products from biodegradable materials requires that steam be able to escape from the mould, the use of biodegradable materials to produce large objects, such as table tops, has not been viable due to the extended drying time required for such large objects. As a result, investigations were made into developing a mould appropriate for such large products.

It will be readily apparent to those skilled in the relevant technology that many of the moulds of the prior art can be used to produce the product of the present invention. The product of the present invention may also be produced by a novel mould comprising one or more valves in the top and/or bottom ends of the top and/or bottom parts of the mould to enable steam to be removed wherein the openable valves are closed when the mixture is placed into the mould and then the valves open when the steam needs to be removed.

The mould consists of at least two parts - a top and a bottom part and is typically made of metal. However, it is possible to use moulds which come in three or more parts provided that there is still a top and a bottom part. In use, the mould is preferably compressed vertically, that is, in a downward and upward manner so that the top part is compressed against the bottom part. Typically, there is a gap of 1 mm between the top and bottom mould parts through which the steam and excess mixture can escape.

The surface of the mould is preferably smooth, that is the surface is not rough or feels like sand paper. If desired a pattern may be engraved into the mould. Any protrusions in the mould must not interfere with the removal of the product from the mould. The shape and size of the mould will depend on the product to be produced.

The mould may be heated by attaching heaters to the mould or passing the mould through an oven. The pressure may be provided by any known means including a hydraulic press, pneumatic press or mechanical press. Typically, the pressure is provided by a hydraulic press as these presses provide a consistent pressure.

The valves enable the steam to be removed from the mould so that the product will dry out faster. Further, the steam is removed more quickly and the product is less likely to be burnt.

The valves are mechanically operated. Once the temperature in the mould has risen above the boiling point of the water, this indicates that mixture will be spread evenly throughout the mould and the valves can be opened to release the steam. By the time that the mixture has spread evenly throughout the mould, it will have hardened just enough so that it does not enter into the valve with the steam. The valves are closed when the mixture is placed into the mould and when the pressure is applied to the mould, thus the mould is totally closed except the gap between the top and bottom parts of the mould. As the water or moisture in the mixture is converted into steam, this steam will rush upward forcing the mixture to move into all the open spaces thus filling up the whole mould. Extra or excess mixture will be squeezed out of the mould. Normally the mould will be opened in process step (d) when the temperature reaches between 100 and 200 °C and preferably at about 110°C. The valves shorten the time for the product to be dried and thus shorten the processing time. Further without using this valve, the steam will take longer to escape through the side and out through the gap between the top and bottom parts of the mould, and if the steam takes too long to remove, the heat would cook or burn the center portion of the product while the sides are only just dry.

Preferably, there is one valve every 4 square inches. The valves cannot be placed in the sides of the mould as this would impede the proper spreading of the mixture to be moulded. If the valve was fixed to the side of the mould, steam would escape through it, thus reducing the pressure inside. This reduced steam pressure may cause the mixture not to flow to the space above the valve and create an incomplete product.

This invention enables the processing of a certain prescribed mixture to form products of various shapes and sizes suitable for protective packaging such as boxes and receptacles and coverings for electronic goods, cushioning packaging for delicate and fragile electronic and computer systems and components, food and beverage containers such as cups, plates, lunchboxes etc, building material and prefabricated boards such as partitions, ceiling boards and other shaped products eg garment hangers, horticultural and agricultural planters and pots, and disposable golf tees.

All proportions in this specification are in percentage weight.

Description of the drawings

The invention will now be further explained and illustrated by reference to the accompanying drawings in which:

Figure 1 is a flow diagram of a process suitable for forming a product according to the invention; and

Figure 2 is a schematic of an overview of the process of figure 1;

Figure 3 is a perspective view of a mould suitable for producing the product of the present invention, the mould being in the open position;

Figure 4 is a perspective view of the mould in Figure 3 filled with the mixture;

Figure 5 is a perspective view of the mould in Figure 4 closed and under pressure with the valve closed;

Figure 6 is a perspective view of the mould in Figure 5 with the valve now open;

Figure 7 is a perspective view of the mould in Figure 6 opened with the product removed; and

Figure 8 is a cross-sectional view of another type of mould suitable for producing the product of the present invention.

The use of a mould as shown in the drawings will now be described in relation to following example of a preferred embodiment of the product provided by the invention.

Preferred Compositions

Moulding mixtures having compositions according to the present invention were prepared. The proportions of components present in the mixture are set out as examples 1 to 40 in the following table:

Example	Flour/starch (gm)	Binder (gm)	Water (gm)	Fiber (gm)	Calcium carbonate (gm)	Total (gm)	% of starch
	Tapioca Flour	Latex water base (degradable)	Tap water	Sugar cane pulp			
1	6.0	10.0	30.0	40.0	0.0	86.0	7.0%
2	6.0	8.0	30.0	40.0	0.0	84.0	7.1%
3	4.0	8.0	28.0	40.0	0.0	80.0	5.0%
4	1.5	8.0	28.0	40.0	0.0	77.5	1.9%
5	1.2	8.0	28.0	40.0	0.0	77.2	1.6%
6	1.0	8.0	28.0	40.0	0.0	77.0	1.3%
7	0.0	8.0	28.0	40.0	0.0	76.0	0.0%
8	0.0	8.0	28.0	40.0	10.0	86.0	0.0%
		Latex solvent base					
9	6.0	10.0	30.0	40.0	0.0	86.0	7.0%
10	6.0	8.0	30.0	40.0	0.0	84.0	7.1%
11	4.0	8.0	28.0	40.0	0.0	80.0	5.0%
12	1.5	8.0	28.0	40.0	0.0	77.5	1.9%
13	1.2	8.0	28.0	40.0	0.0	77.2	1.6%
14	1.0	8.0	28.0	40.0	0.0	77.0	1.3%
15	0.0	8.0	28.0	40.0	0.0	76.0	0.0%
16	0.0	8.0	28.0	40.0	10.0	86.0	0.0%
		Water base wax binder					
17	6.0	10.0	30.0	40.0	0.0	86.0	7.0%
18	6.0	8.0	30.0	40.0	0.0	84.0	7.1%

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19	4.0	8.0	28.0	40.0	0.0	80.0	5.0%
20	1.5	8.0	28.0	40.0	0.0	77.5	1.9%
21	1.2	8.0	28.0	40.0	0.0	77.2	1.6%
22	1.0	8.0	28.0	40.0	0.0	77.0	1.3%
23	0.0	8.0	28.0	40.0	0.0	76.0	0.0%
24	0.0	8.0	28.0	40.0	10.0	86.0	0.0%

**Solvent base
wax binder**

25	6.0	10.0	30.0	40.0	0.0	86.0	7.0%
26	6.0	8.0	30.0	40.0	0.0	84.0	7.1%
27	4.0	8.0	28.0	40.0	0.0	80.0	5.0%
28	1.5	8.0	28.0	40.0	0.0	77.5	1.9%
29	1.2	8.0	28.0	40.0	0.0	77.2	1.6%
30	1.0	8.0	28.0	40.0	0.0	77.0	1.3%
31	0.0	8.0	28.0	40.0	0.0	76.0	0.0%
32	0.0	8.0	28.0	40.0	10.0	86.0	0.0%

**Solvent base
vinyl binder**

33	6.0	10.0	30.0	40.0	0.0	86.0	7.0%
34	6.0	8.0	30.0	40.0	0.0	84.0	7.1%
35	4.0	8.0	28.0	40.0	0.0	80.0	5.0%
36	1.5	8.0	28.0	40.0	0.0	77.5	1.9%
37	1.2	8.0	28.0	40.0	0.0	77.2	1.6%
38	1.0	8.0	28.0	40.0	0.0	77.0	1.3%
39	0.0	8.0	28.0	40.0	0.0	76.0	0.0%
40	0.0	8.0	28.0	40.0	10.0	86.0	0.0%

The moulding mixtures of examples 1 to 40 were used to make golf tees according to the moulding process of the present invention. The golf tees were of good quality and suitable for their intended use. Further moulding mixtures were prepared, analogous with the

compositions of examples 1 to 40, except that the sugar cane pulp added as a source of fibre was replaced with fibre chosen from the group comprising wheat stalks, tea leaves, rice stalks, rice husks mixed with rice stalks, corn cobs including the leaves and the carbonaceous residue of burnt coconut shells.

The molding mixtures comprising each of the listed sources of fibre were used to make golf tees according to the moulding process of the present invention. The golf tees comprising each different type of fibre were compared with the aforementioned golf tees comprising sugar cane pulp. While there were differences in quality of the golf tees depending on the type of fibre used, these differences did not have any significant effect on the performance of the golf tees.

Of the aforementioned sources of fibre, only rice husks have any inherent starch content. The rest of the listed fibre sources have no inherent starch content and therefore make no contribution to the starch content of the moulding mixture. Accordingly, when rice husks were used to make the moulding mixtures of examples 1 to 40, the proportion of starch present was slightly greater than the quantities listed in the table.

It is noted that for examples comprising a given type of fibre, varying the nature of the binder does not affect the quality of the product produced according to the present invention. However, based on environmental considerations, water soluble binders are preferred for use in the moulding mixture because they are biodegradable, whereas binders soluble in non-aqueous solvents are generally not biodegradable.

Preparation of the Mixture

Individual mixtures were prepared using fibers of wheat stalks or rice stalks or sugar cane pulp or corn leaves in combination with corn pulp. The mixtures were ground by a grinding machine to a size in the range of from 0.1mm to 5.0 mm. The ground fiber was combined with the starch of tapioca flour, sweet potato flour and corn flour thoroughly in a mixer (a container with fan like blade spinning at a speed of 500 to 700 rpm) to form a moulding mixture. Care was taken to ensure that the starch did not form into lumps when the liquid ingredients were added. Any lumps which do form should be broken up because when the water forms steam, such lumps of starch will be cooked and will foam which will cause an air trap or hole in the mould product. A water soluble adhesive with a latex base is then added together with water and the mixture further stirred until the whole mixture is mixed evenly. This mixture can be used to produce a cup, box or tray.

The Mould

The mould 20 shown in the drawings has a top mould part 21 and a bottom mould part 22. The top mould part 21 has a valve 23 located in its upper surface 24. The bottom mould part has a cavity 25 to receive mixture 26. When mould 20 is closed, there is a gap 27 of about 1 mm between the top mould part 21 and the bottom mould part 22. Once closed, pressure is applied to upper surface 24. The valve 23 is operated either manually or automatically via a controller (not shown). Typically, the valve 23 is opened (see Figure 6) when the temperature of the mould 20 is at about 110°C. Once the article 28 has dried, the mould 20 is opened and the article 28 removed.

Manufacturing an Article from the Mixture

In the flow diagram of Figure 1, the process commences at A with pre-heating the mould 20 to 70°C. This heating is only required the first time that the mould 20 is used because in a continuous process the mould 20 would be at about 140°C from forming the last article 28 and is actually cooled to 70°C at B. Once formed the article 28 is removed from the mould 20 at C to be trimmed, sealed and further treated as desired.

Once the mould 20 is brought to about 70°C, the mould 20 is opened (see D of Figure 2) and overfilled with mixture 26 (see E). Ideally the mixture is kept at ambient temperature (about 25 °C) or at least within the range of 15 to 40 °C. The mould 20 is intentionally overfilled to ensure that there is sufficient mixture to evenly and completely fill the mould 20. The mould 20 is not left cold because when the mixture 26 is compressed under pressure, the solids in the mixture would be forced and compressed to the bottom of the mould and water would separate from the mixture and be squeezed out through the gap or air vent. If the temperature goes above 100°C, the moisture will turn into steam too quickly and can cause an explosion. However when the mould 20 is hot (70°C to 100°C) and the materials are compressed, the moisture will immediately transform into vapor and start to look for a space or gap to escape. This action will move the solids in the mixture into all the open spaces in the mould 20 with excess mixture seeping out of the mould 20. This action typically takes 5 to 10 seconds.

The mould 20 is then closed (see F of Figure 2). When closed, there is typically a gap 27 of about 1 mm between the top 21 and bottom 22 parts of the mould through which steam and excess mixture can escape. Once the mould 20 is closed, a pressure of about 4000 PSI is applied to the top of the mould 20 (see G) for about 3 to 10 seconds until excess mixture

starts coming out of the gap 27 between the mould parts 21 and 22. The appearance of the excess material indicates that the mixture 26 has spread evenly throughout the mould 20 – this is especially important where the product is not flat and the mixture will need to move up the sides of the mould 20. The pressure also ensures that the shape of the product is maintained (that is, there is no foaming), and controls the desired density/porosity of the product.

Upon seeing the mixture stop overflowing out of the mould 20, the pressure is reduced to atmospheric and then increased back to a pressure in the range of from 500 to 1500 PSI. In the examples we used a pressure of about 1000 PSI. Then the temperature was increased to about 140°C. The pressure is reduced to prevent an explosion due to the water turning into steam too quickly.

At this point, the steam will be rushing out through all openings and the faster the steam can escape, the faster the product will cure and this reflects the importance of having a valve 23 being operated to let the steam escape. Once the temperature has reached about 110°C, the valve 23 is opened to increase the rate of steam escaping (see H).

When it has been observed that the escape of steam has effectively ceased, approximately after one to five minutes at a temperature of 140°C (depending the number of valves), the mould 20 is opened and the substantially dried article 28 removed (see I). As there is overflow, the edge of the article has to be trimmed using a die cutting machine or manually (see J).

The article is then optionally coated with further adhesive by spraying or dipping (see K) and heated at 100°C to 140°C for about 10 seconds to 10 minutes to cure the adhesive. In the example we used temperature of about 130°C for about 8 minutes.

The article may be further coated with Neoprene to further enhance its water resistance (see L). Typically about 3 grams of Neoprene is used per square foot of the product. The coating is applied by spraying or dipping.. In addition, a decorative painting or print can be added to the surface of the product.

The following mixtures were prepared by the above method and the suitability for moulding assessed by applying the above process to them.

Mixture	A	B	C
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Flour	3%	10%	6%
Adhesive	2%	10%	4.7%
Fiber	52%	40%	47.6%
Water	43%	40%	41.7%

Mixture B provided a workable product. Mixture C is useful for packaging for heavy products such as televisions or table tops or as a special cushioning with greater porosity. Mixture A is economical and good for products which do not need a high density such as cups, bowls, industrial packaging for appliances.

Figure 8 shows a top part of a mould (100) comprising mould part (101) and valve (102). Valve (102) sits in a complementarily shaped cavity (103) in mould part (101) and is free to move relative to mould part (101). Cavity (103) end in release hole (104) and valve end (105) is adapted to seal release hole (104) when the valve (102) in its closed position (not shown). Valve (102) is closed by pressure being applied to top end (106). When valve (102) is in its open position as shown in Figure 8, steam can escape from the mould (100).

The word 'comprising' and forms of the word 'comprising' as used in this description and in the claims does not limit the invention claimed to exclude any variants or additions.

Modifications and improvements to the invention will be readily apparent to those skilled in the art. Such modifications and improvements are intended to be within the scope of this invention.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A moulded product formed from a moulding mixture including:
 - (i) 40 to 60 wt% plant fibre pieces and optionally 0 to 10 wt% added starch; and
 - (ii) 10 to 55 wt % water and 3 to 10 wt % one or more water-soluble binding agents or adhesives.
2. A moulded product formed from a moulding mixture according to claim 1 wherein the length of the plant fibre pieces is in the range of from 1 to 5 mm
3. A moulded product formed from a moulding mixture according claim 1 having adhesives content is in the range of from 2 to 5 wt %.
4. A moulded product formed from a moulding mixture according to claim 3 wherein the adhesives content is about 4.7 wt %.
5. A moulded product formed from a moulding mixture according to claim 1 wherein the fibre content is in the range from 45 to 55 wt %.
6. A moulded product formed from a moulding mixture according to claim 5 wherein the fibre content is about 52 wt %.
7. A moulded product formed from a moulding mixture according to claim 1 wherein the water content is in the range from 40 to 45 wt %.
8. A moulded product formed from a moulding mixture according to claim 7 wherein the water content is about 43 wt %.
9. A moulded product formed from a moulding mixture including:
 - (i) 40 to 60 wt% plant fibre pieces and optionally 0 to 2 wt% added starch; and
 - (ii) 10 to 55 wt % water and 3 to 10 wt % one or more water-soluble binding agents or adhesives.
10. A moulded product formed from a moulding mixture according to claim 9 wherein the length of the plant fibre pieces is in the range of from 1 to 5 mm
11. A moulded product formed from a moulding mixture according claim 9 having adhesives content is in the range of from 2 to 5 wt %.

12. A moulded product formed from a moulding mixture according to claim 11 wherein the adhesives content is about 4.7 wt %.
13. A moulded product formed from a moulding mixture according to claim 9 wherein the fibre content is in the range from 45 to 55 wt %.
14. A moulded product formed from a moulding mixture according to claim 13 wherein the fibre content is about 52 wt %.
15. A moulded product formed from a moulding mixture according to claim 9 wherein the water content is in the range from 40 to 45 wt %.
16. A moulded product formed from a moulding mixture according to claim 15 wherein the water content is about 43 wt %.
17. A moulded product formed from a moulding mixture including:
 - (i) 40 to 60 wt% plant fibre pieces and optionally 2 to 10 wt% added starch; and
 - (ii) 10 to 55 wt % water and 3 to 10 wt % one or more water-soluble binding agents or adhesives.
18. A moulded product formed from a moulding mixture including:
 - (i) 40 to 60 wt% plant fibre pieces combined with 2 to 10 wt% starch; and
 - (ii) 25 to 55 wt% water and 2 to 10 wt% one or more water-soluble and biodegradable binding agents or adhesives.
19. A moulded product formed from a moulding mixture according to claim 17 or 18 wherein the length of the plant fibre pieces is in the range of from 1 to 5 mm
20. A moulded product formed from a moulding mixture according claim 17 or 18 having adhesives content is in the range of from 2 to 5 wt %.
21. A moulded product formed from a moulding mixture according to claim 20 wherein the adhesives content is about 4.7 wt %.
22. A moulded product formed from a moulding mixture according to claim 17 or 18 wherein the fibre content is in the range from 45 to 55 wt %.
23. A moulded product formed from a moulding mixture according to claim 17 or 18 wherein the water content is in the range from 40 to 45 wt %.

- 24 A moulded product formed from a moulding mixture according to claim 23 wherein the water content is about 43 wt %.
- 25 A moulded product formed by a process having the following steps:
- (a) preparing a moulding mixture by:
 - (i) taking 40 to 60 wt% plant fibre pieces and optionally combining 0 to 10 wt% added starch with the plant fibre pieces; and
 - (ii) adding thereto 10 to 55 wt % water and 3 to 10 wt % one or more water-soluble binding agents or adhesives;
 - (b) pouring the mixture into a mould the mould being at a temperature of at least 60°C;
 - (c) subjecting the mixture in the mould to a temperature in the range of 15 to 60 °C and a pressure in the range from 1000 to 7000 PSI for a period of time such that a portion of the water in the mixture is converted to steam which causes the mixture to fill the mould while remaining in a mouldable state;
 - (d) reducing the pressure so that steam continues to form within the mould without causing an explosion whilst maintaining the mixture in a mouldable state;
 - (e) increasing the temperature and pressure to a temperature in the range from 100 to 200°C and a pressure in the range of 500 to 1500 PSI ;
 - (f) removing the steam or allowing the steam to escape until the moulded product is substantially dry;
 - (g) removing the substantially dried and moulded product from the mould;
26. A product according to claim 25 wherein the process further includes the steps of:
- (h) at least partially coating the moulded product with one or more binding agents or adhesives; and
 - (i) heating the coated moulded product to substantially dry and cure the coating.
- 27 A product according to claim 26 wherein the process further comprises the step of trimming the product from step (e) prior to coating the product in step (f).

- 28 A product according to claim 26 wherein the process further comprises step (j) of treating the product from step (i) with a water resistance material or decorative materials.
- 29 A product according to claim 25 wherein the length of the plant fibre pieces in the moulding mixture is in the range of from 1 to 5 mm
- 30 A product according to claim 25 wherein the adhesives content of the moulding mixture is in the range of from 2 to 5 wt %.
- 31 A product according to claim 30 wherein the adhesives content of the moulding mixture is about 4.7 wt %.
- 32 A product according to claim 26 wherein the fibre content of the moulding mixture is in the range from 45 to 55 wt %.
- 33 A product according to claim 32 wherein the fibre content of the moulding mixture is about 52 wt %.
- 34 A product according to claim 25 wherein the water content of the moulding mixture is in the range from 40 to 45 wt %.
- 35 A product according to claim 34 wherein the water content of the moulding mixture is about 43 wt %.
- 36 A product according to claim 25 wherein latex-based adhesives are used in the moulding mixture.
- 37 A product according to claim 36 wherein the latex-based adhesive used in the moulding mixture is Neoprene.
- 38 A product according to claim 25 wherein step (a) occurs at a temperature below about 25°C.
- 39 A product according to claim 25 wherein the pressure applied within the mould in step (c) is about 4000 PSI.
- 40 A product according to claim 25 wherein the period of time in step (c) is in the range of from 3 to 10 seconds.
- 41 A product according to claim 25 wherein the reduced pressure in step (d) is in the range from 500 to 1500 PSI.

- 42 A product according to claim 25 wherein the increased temperature in step (d) is about 140°C.
- 43 A product according to claim 26 wherein the heating in step (h) occurs for a period of time in the range of from 10 seconds to 10 minutes at a temperature in the range of from 100°C to 180°C.
44. A product according to claim 25 wherein the product is chosen from the group comprising packaging, food and beverage containers, building materials, horticultural and agricultural planters and pots, garment hangers and disposable golf tees.
- 45 A moulded product formed by a process having the following steps:
- (a) preparing a moulding mixture by:
 - (i) taking 40 to 60 wt% plant fibre pieces and optionally combining 0 to 2 wt% added starch with the plant fibre pieces; and
 - (ii) adding thereto 10 to 55 wt % water and 3 to 10 wt % one or more water-soluble binding agents or adhesives;
 - (b) pouring the mixture into a mould the mould being at a temperature of at least 60°C;
 - (c) subjecting the mixture in the mould to a temperature in the range of 15 to 60 °C and a pressure in the range from 1000 to 7000 PSI for a period of time such that a portion of the water in the mixture is converted to steam which causes the mixture to fill the mould while remaining in a mouldable state;
 - (d) reducing the pressure so that steam continues to form within the mould without causing an explosion whilst maintaining the mixture in a mouldable state;
 - (e) increasing the temperature and pressure to a temperature in the range from 100 to 200°C and a pressure in the range of 500 to 1500 PSI ;
 - (f) removing the steam or allowing the steam to escape until the moulded product is substantially dry;
 - (g) removing the substantially dried and moulded product from the mould;

46. A product according to claim 45 wherein the process further comprises the steps of
- (h) at least partially coating the moulded product with one or more binding agents or adhesives; and
 - (i) heating the coated moulded product to substantially dry and cure the coating.
- 47 A product according to claim 46 wherein the process further comprises the step of trimming the product from step (g) prior to coating the product in step (h).
- 48 A product according to claim 46 wherein the process further comprises step (j) of treating the product from step (i) with a water resistance material or decorative materials.
- 49 A product according to claims 45 wherein the length of the plant fibre pieces in the moulding mixture is in the range of from 1 to 5 mm
- 50 A product according to claim 45 wherein the adhesives content of the moulding mixture is in the range of from 2 to 5 wt %.
- 51 A product according to claim 50 wherein the adhesives content of the moulding mixture is about 4.7 wt %.
- 52 A product according to claims 45 wherein the fibre content of the moulding mixture is in the range from 45 to 55 wt %.
- 53 A product according to claim 52 wherein the fibre content of the moulding mixture is about 52 wt %.
- 54 A product according to claims 45 wherein the water content of the moulding mixture is in the range from 40 to 45 wt %.
- 55 A product according to claim 54 wherein the water content of the moulding mixture is about 43 wt %.
- 56 A product according to claim 45 wherein latex-based adhesives are used in the moulding mixture.
- 57 A product according to claim 56 wherein the latex-based adhesive used in the moulding mixture is Neoprene.

- 58 A product according to claim 45 wherein step (a) occurs at a temperature below about 25°C.
- 59 A product according to claims 45 wherein the pressure applied within the mould in step (c) is about 4000 PSI.
- 60 A product according to claim 45 wherein the period of time in step (c) is in the range of from 3 to 10 seconds.
- 61 A product according to claim 45 wherein the reduced pressure in step (d) is in the range from 500 to 1500 PSI.
- 62 A product according to claim 45 wherein the increased temperature in step (d) is about 140°C.
- 63 A product according to claim 46 wherein the heating in step (h) occurs for a period of time in the range of from 10 seconds to 10 minutes at a temperature in the range of from 100°C to 180°C.
- 64 A product according to claim 45 wherein the product is chosen from the group comprising packaging, food and beverage containers, building materials, horticultural and agricultural planters and pots, garment hangers and disposable golf tees.
- 65 A moulded product formed by a process having the following steps:
- (a) preparing a moulding mixture by:
 - (i) taking 40 to 60 wt% plant fibre pieces and optionally combining 2 to 10 wt% added starch with the plant fibre pieces; and
 - (ii) adding thereto 10 to 55 wt % water and 3 to 10 wt % one or more water-soluble binding agents or adhesives;
 - (b) pouring the mixture into a mould the mould being at a temperature of at least 60°C;
 - (c) subjecting the mixture in the mould to a temperature in the range of 15 to 60 °C and a pressure in the range from 1000 to 7000 PSI for a period of time such that a portion of the water in the mixture is converted to steam which causes the mixture to fill the mould while remaining in a mouldable state;

- (d) reducing the pressure so that steam continues to form within the mould without causing an explosion whilst maintaining the mixture in a mouldable state;
- (e) increasing the temperature and pressure to a temperature in the range from 100 to 200°C and a pressure in the range of 500 to 1500 PSI ;
- (f) removing the steam or allowing the steam to escape until the moulded product is substantially dry;
- (g) removing the substantially dried and moulded product from the mould;

66 A moulded product formed by a process comprising the following steps:

- (a) preparing a moulding mixture by:
 - (i) taking 40 to 60 wt% plant fibre pieces and optionally combining 2 to 10 wt% added starch with the plant fibre pieces; and
 - (ii) adding thereto 25 to 55 wt% water and 2 to 10 wt% one or more water-soluble binding agents or adhesives;
- (b) pouring the mixture into a mould the mould being at a temperature of from 70 to 100°C;
- (c) subjecting the mixture in the mould to a temperature in the range of 15 to 60°C and a pressure in the range from 1000 to 7000 PSI for a period of time such that a portion of the water in the mixture is converted to steam which causes the mixture to fill the mould while remaining in a mouldable state;
- (d) reducing the pressure so that steam continues to form within the mould without causing an explosion whilst maintaining the mixture in a mouldable state;
- (e) increasing the temperature and pressure to a temperature in the range from 100 to 200°C and a pressure in the range of 500 to 1500 PSI;
- (f) removing the steam or allowing the steam to escape until the moulded product is substantially dry;
- (g) removing the substantially dried and moulded product from the mould.

- 67 A product according to claim 65 or 66 wherein the process further comprises the step of :
- (h) at least partially coating the moulded product with one or more binding agents or adhesives; and
 - (i) heating the coated moulded product to substantially dry and cure the coating.
- 68 A product according to claim 67 wherein the process further comprises the step of trimming the product from step (g) prior to coating the product in step (h).
- 69 A product according to claim 67 wherein the process further comprises step (j) of treating the product from step (i) with a water resistance material or decorative materials.
- 70 A product according to claims 65 or 66 wherein the length of the plant fibre pieces in the moulding mixture is in the range of from 1 to 5 mm
- 71 A product according to claim 65 or 66 wherein the adhesives content of the moulding mixture is in the range of from 2 to 5 wt %.
- 72 A product according to claim 65 or 66 wherein the fibre content of the moulding mixture is in the range from 45 to 55 wt %.
- 73 A product according to claim 72 wherein the fibre content of the moulding mixture is about 52 wt %.
- 74 A product according to claim 65 or 66 wherein the water content of the moulding mixture is in the range from 40 to 45 wt %.
- 75 A product according to claim 74 wherein the water content of the moulding mixture is about 43 wt %.
- 76 A product according to claim 65 or 66 wherein latex-based adhesives are used in the moulding mixture.
- 77 A product according to claim 76 wherein the latex-based adhesive used in the moulding mixture is Neoprene.
- 78 A product according to claim 65 or 66 wherein step (a) occurs at a temperature below about 25°C.

- 79 A product according to claim 65 or 66 wherein the pressure applied within the mould in step (c) is about 4000 PSI.
- 80 A product according to claim 65 or 66 wherein the period of time in step (c) is in the range of from 3 to 10 seconds.
- 81 A product according to claim 65 or 66 wherein the reduced pressure in step (d) is in the range from 500 to 1500 PSI.
- 82 A product according to claim 65 or 66 wherein the increased temperature in step (d) is about 140°C.
- 83 A product according to claim 65 or 66 wherein the heating in step (e) occurs for a period of time in the range of from 10 seconds to 10 minutes at a temperature in the range of from 100°C to 180°C.
84. A product according to claim 65 or 66 wherein the product is chosen from the group comprising packaging, food and beverage containers, building materials, horticultural and agricultural planters and pots, garment hangers and disposable golf tees.
- 85 A product manufactured according to the process of any one of claims 25, 45, 65 or 66 wherein the mould comprises one or more valves in the top and/or bottom ends of the top and/or bottom parts of the mould to enable steam to be removed from the interior of the mould during a moulding process.
- 86 A product manufactured according to any of the preceding claims which product is biodegradable

