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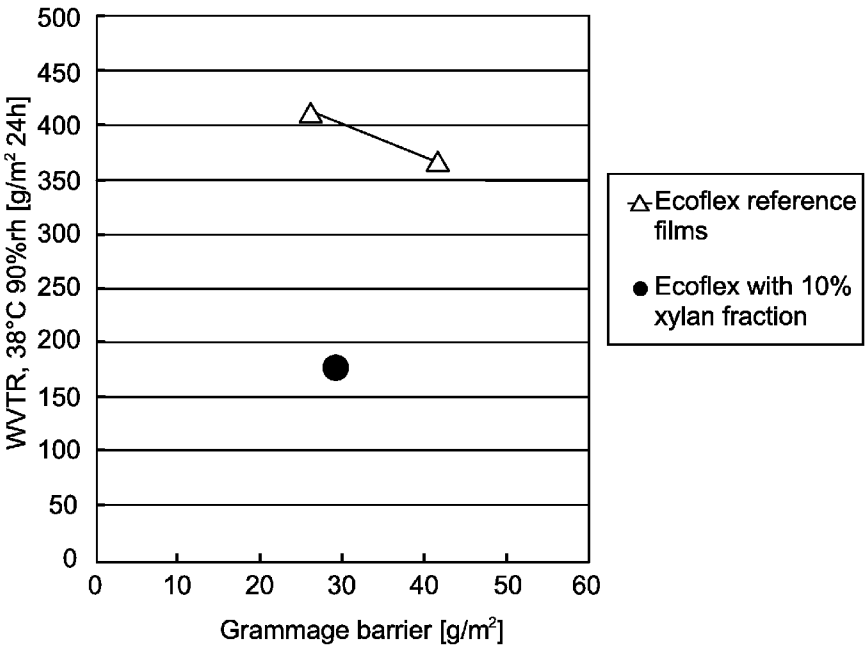


Fig. 1

(57) Abstract: The present invention provides a compounded polymeric product comprising a xylan compound and at least one biodegradable plastic. Further, the invention provides a polymeric film comprising such a compounded polymeric product and granules comprising such a compounded polymeric product. There is also provided a method for preparing a polymeric compound comprising: compounding a xylan compound with at least one biodegradable plastic to provide said polymeric compound.

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PLASTIC COMPOUNDING

Technical Field of the Invention

The present invention relates to the field of biodegradable plastics and compounds and methods for the production thereof.

Background Art

Plastic is the general common term for a wide range of amorphous solid materials suitable for the manufacture of industrial products. Plastics are typically polymers of high molecular weight, and may contain other substances to improve performance and/or reduce costs.

Bioplastics, which are also called organic plastics, are a form of plastics typically derived from renewable biomass sources, such as vegetable oil, corn starch or microbiota, rather than fossil fuel plastics which are derived from petroleum. Bioplastics may also refer to biologically degradable plastics, which are especially popular for disposable items. Biodegradable plastics may however also be produced from petroleum.

Corn based starch is today's largest renewable raw material for bioplastic production. With a growing population in the world it is however an ethic dilemma to use food as a raw material for bioplastic production. The high price of the commercially available bioplastics is another problem. Thus, there is a need in the art for alternative raw materials for bioplastics production.

Summary of the Invention

It is an objective of some aspects of the present invention to provide a biodegradable plastic product comprising an abundant renewable material.

As a first aspect of the invention, there is provided a product comprising a xylan compound and at least one biodegradable plastic, characterized in that the polymeric product is compounded.

As a second aspect of the invention there is provided a polymeric film comprising the compounded polymeric product according to the first aspect of the invention.

As a third aspect of the invention, there is provided a compounded melt or granules comprising the compounded polymeric product according to the first aspect of the invention.

As a fourth aspect of the invention, there is provided a method for preparing a polymeric compound comprising compounding a xylan compound with at least one biodegradable plastic to provide said polymeric compound

Brief description of the figure

Figure 1 is a graph showing the water vapor transmission rates (WVTFs) of a film containing a xylan compound and reference films.

Detailed description of the Invention

As a first aspect of the invention, there is thus provided a compounded polymeric product comprising a xylan compound and at least one biodegradable plastic.

Embodiments of the present invention allows for providing a compounded polymeric material with a high share of renewable polymers that may be suitable for production of biodegradable products, e.g. using blown film extrusion. Using a xylan compound in the compounded polymeric product provides a possibility to introduce a polymeric material, which is renewable, into the polymeric product without competing with agricultural food production since xylan may e.g. be extracted from a by-product from wood pulp production.

A “polymeric product” refers to a product comprising at least one polymer.

Compounding of two or more plastics involves melting and mixing the plastics at a controlled temperature and under pressure such that a blended compound is formed. Plastic compounding is well known in the art. “A compounded polymeric product” thus refers to a blended composition comprising the xylan compound and the biodegradable plastic, wherein the composition has been prepared by a method comprising compounding.

A “compounder” refers to the equipment used for compounding. A compounder may be a twin screw co-rotating compounder, a twin screw counter-rotating compounder, a single screw compounder, or kneader. A standard screw typically has three zones: a feed zone; a compression zone; and a metering zone. Material from a hopper enters at the feed zone where it is moved forward to the compression zone by the rotation of the screw(s). In the compression zone the material is subjected to elevated temperatures and pressures caused by the screw action and external heaters, electrical heaters. The material melts and is moved forward to the metering zone and finally through a die. The die may create a strand of the compounded

material. As it cools off the strand may be fed through a pelletizer in order to create granules. A compounder may optionally comprise one or several side feeders where material, such as a xylan compound, can be fed into the melted plastic stream.

"Xylan" is a generic term used to describe polysaccharides containing xylose monomeric units that may be found in plant cell walls and some algae. Xylan is generally obtained from a renewable source and is biodegradable. Depending on their source and preparation method, xylan molecules may have different molecular weights and different types and number of substituents. In comparison to traditional plastics, native xylan is a low molecular weight highly branched polymeric material. In the context of the present disclosure, a "xylan compound" refers to a compound comprising any type of xylan. The xylan compound may for example be derived from lignocellulose, such as wood.

The principle monomeric unit of the xylan compound is thus xylose. As understood by the skilled person, the chemical structure of the ends and/or side chains as well as the chain length of the polyxylose molecules may differ from one xylan compound to another, e.g. depending of the conditions of the extraction and purification of the xylan compound. For example, the structure of xylan isolated from a cooking liquor of a paper pulping process depends on the pH and the chemicals of the cooking liquor. Further, the xylan compound of the product of the first aspect may have been chemically modified, e.g. by etherification (e.g. hydroxypropylation or benzylation), esterification (e.g. acetylation or succinoylation), grafting, chain extension, or crosslinking, and thus contain additional chemical moieties (this is further described below).

It may be difficult to obtain an intimate and homogenous mixture by compounding two different polymers, especially if they have very different melting points. One problem may be that when the temperature is high enough for the polymer component having the higher melting temperature to melt, the polymer component having the lower melting point may e.g. degrade and/or evaporate. Native xylan has normally a T_g in the range of 167-180°C (Jain, 2001), which is a temperature range where thermal degradation of unmodified xylan compound may occur. The inventors have realized that it may be beneficial to chemically modify the xylan prior to compounding with another component to makes it compound more suitable for melt processing. Some examples of such chemical modifications of xylan are described in US patent application 2010044627 A1 and US patent 5,430,142.

Biodegradability is the chemical breakdown of materials by a physiological environment. “Biodegradable plastics” refers to plastics that can be decomposed in the natural environment aerobically (e.g. composting) or anaerobically (e.g. landfill). The biodegradable plastic may be composed of bioplastics, which contain components derived from renewable raw materials, and/or petroleum-based plastics.

The first aspect of the invention is based on the insight that a biodegradable plastic may be compounded with a xylan compound, which is advantageous in a number of ways. First of all, it facilitates a “dilution” of the biodegradable plastic with xylan. There is often a shortage of raw material for the production of biodegradable plastics, which makes the production of the biodegradable plastic expensive. With the possibility of compounding a xylan compound with a biodegradable plastic, the demand of raw material for production of biodegradable plastics is decreased. Further, compounding a biodegradable plastic with a xylan compound increases the percentage of renewable material of the final product. Degradation of the petroleum-based fraction of biodegradable plastics may release previously stored carbon as carbon dioxide. Thus, by compounding a biodegradable plastic with a xylan compound, the amount of petroleum-based plastics in the plastic product can be reduced, thereby reducing the net release of carbon dioxide upon degradation. Of particular benefit is the possibility to use a xylan compound originating from a pulping process of a lignocellulosic material. Xylan may be extracted from a by-product in such a process in which the by-product is otherwise burnt to harvest the energy. Lignin, which may also be extracted from a pulping process, has a higher energy value than xylan and therefore, it may be beneficial to separate the xylan from the lignin and find another application for it. As the xylan does not have an agricultural origin like starch, the ethical dilemma of competing with food production for raw material is avoided. Also, wood is normally not obtained from genetically modified plants/trees (GMO’s). Thus, another ethical dilemma is avoided when the xylan is obtained from a pulping process.

Further, biodegradable plastics are generally sensitive to water vapor due to the polar chemistry of the plastic. Therefore, at high moisture levels, the oxygen-barrier properties of the biodegradable plastic are generally decreased. With the possibility of compounding a biodegradable plastic with xylan, the moisture-barrier properties of the biodegradable plastic may be increased. Also, xylan has been shown by the inventors to be an efficient

oxygen-barrier. The incorporation of xylan compounds in other biodegradable plastics may result in a material having better barrier characteristics than the other biodegradable plastic by itself. The inventors have also found that a biodegradable plastic compounded with xylan may have satisfactory mechanical properties.

In embodiments of the first aspect, the compounded polymeric product comprises 1-60 % or 1-40 %, such as 3-30 % or 20-40 %, by weight of the xylan compound. Such polymeric products may have beneficial barrier properties. The compounded polymeric product may be produced in several steps, comprising e.g. the production of a master batch of a compounded polymeric product having a higher xylan compound content. Thus the compounded polymeric product may comprise 1-80% by weight of the xylan compound, such as 40-80 % or 40-60 %.

As the xylan compound in some embodiments is composed of a polyxylose skeleton having non-xylose substituents, it may in some cases be considered more appropriate to define the proportion of the compounded product that is composed of xylose monomeric units. An example of such a case is when it is desirable to define the proportion of the product that is derived from native xylan. Thus, in embodiments of the first aspect, 1-80 %, such as 1-40 %, 20-40 %, 40-80 % or 40-60 % of the compounded product is composed of xylose monomeric units.

The xylan compound may come from many different sources, but it has surprisingly been realized that a xylan compound that is especially suited for film extrusion or blowing, both in itself and compounded with a biodegradable plastic in accordance with the present invention, may be obtained from the paper pulping industry, such as from a lignocellulosic pulp cooking liquor.

In embodiments of the first aspect, the xylan compound originates from a xylan-containing fraction prepared by a method comprising subjecting a lignocellulosic material to a cooking liquor in a neutral sulphite semichemical (NSSC) cooking process and further separating the xylan-containing fraction from the cooking liquor.

Alternatively, in embodiments of the first aspect, the xylan compound originates from a by-product from hardwood Kraft pulping, and subsequent separation of the xylan-containing fraction from the cooking liquid. Kraft pulping, also known as the sulphate process, is a well-known process for the conversion of wood into wood pulp. The process comprises treating wood

material with a mixture of sodium hydroxide and sodium sulphide to break the bonds between lignin and cellulose.

Comparatively large quantities of xylan are released from the lignocellulosic raw material and dissolved in the cooking liquor. The inventors have found that xylan compounds extracted or obtained from a xylan fraction separated from NSSC or Kraft cooking of lignocellulosic material may be particularly suited for compounding with a biodegradable plastic. The xylan compound may e.g. be obtained from the liquor by ultrafiltration, possibly followed by washing with ethanol.

The xylan separated from cooking liquor may be obtained as a mixture with lignin or lignosulfonate. In some application, this lignin or lignosulfonate may provide beneficial properties. For example, lignin and lignosulfonate are less sensitive to heat than (unmodified) xylan. The inclusion of lignin or lignosulfonate may thus allow for higher temperatures during compounding and thereby a broader process window and a compounded product of better quality. Being able to use a product of less purity with respect to xylan compound concentration also reduces cost and complexity of the extraction process.

Thus, in embodiments of the first aspect, the xylan compound may be provided as a mixture with lignin or lignosulfonate. Also, lignin or lignosulfonate may be provided as a separate additive. In the product of the first aspect, the weight ratio of the xylan compound to the lignin or lignosulfonate may for example be between 5:1 and 1:2, such as between 4:1 and 1:1. Also, the lignin or lignosulfonate content of the product of the first aspect may for example be 1-30 %, (w/w) such as 1-20 % (w/w), such as 5-20 % (w/w).

As an example, the lignocellulosic material may be hardwood material. Hardwood is sometimes referred to as broadleaf wood or deciduous wood. Examples of hardwood are birch, aspen, poplar, elm, oak, maple, ash and beech. Other examples are teak, mahogany, ebony, lauan and yellow cedar. Due to relatively high content of xylan along with low lignin content and the localization of the lignin in the wood, hardwood is considered particularly suitable.

A xylan compound separated from NSSC cooking of birch has been found to be especially suitable for compounding with a biodegradable plastic, but other xylan sources are also contemplated.

Typically, the xylan-containing fraction separated from cooking liquor comprises between 30 and 70% (w/w) xylan (including carbohydrate substituents such as sugars), e.g. between 40 and 60%. Other components of the fraction are normally lignin or lignosulfonate and inorganic matter. In some cases, it may be beneficial to use a xylan-containing fraction having a higher xylan content, such as between 60 and 100% (w/w), e.g. between 80 and 90% (w/w). Fractions having a higher xylan content may be obtained purifying the fraction first separated from the cooking liquor. Such purification may involve filtration and/or precipitation.

The inventors have found that xylan molecules having almost no Hexenuronic Acid substituents may be obtained from NSSC cooking liquor, and such xylan may be well suited for compounding and film extrusion. In general, the type and frequency of the substituents of the xylan obtained from lignocellulose depend on the processing of the lignocellulose. Native xylan may comprise acetyl and/or 4-O-Methyl Glucuronic Acid substituents on the polysaccharide chain. The 4-O-Methyl Glucuronic Acid substituents are bound to the polysaccharide chain through glycosidic bonds while the acetyl substituents are bound through ester bonds. Native xylan normally comprises about 0.7 acetyl substituents per xylose unit and about 0.1 4-O-Methyl Glucuronic Acid substituents per xylose unit. When processing lignocellulose, the acetyl groups are typically cleaved off in alkaline conditions. Also, the 4-O-Methyl Glucuronic Acid may also be cleaved off to some degree in alkaline conditions. Further, methanol may be cleaved off from the 4-O-Methyl Glucuronic Acid substituents forming Hexenuronic Acid substituents. Without being bound by any specific scientific theory, the inventors believe that xylan molecules, having almost no Hexenuronic Acid substituents, may be obtained from cooking liquor because the relatively neutral conditions of the NSSC cooking decreases the extent to which methanol is cleaved off from the 4-O-Methyl Glucuronic Acid substituents. Further, the inventors have shown that the xylan obtained from the NSSC cooking may have some acetyl substituents left. Xylan obtained from a NSSC process may optionally be acetylated to increase the degree of acetylation as detailed below.

The inventors have found that xylan obtained from NSSC cooking typically is within a certain molecular weight range. In embodiments of the first aspect, regardless of the cooking/pulping method, a majority of the xylan molecules of the xylan compound may have a molecular weight of 300-10000 g/mol and 0.01-0.1 acetyl substituents per xylose unit, 0.05-0.2 4-O-Methyl

Glucuronic Acid substituents per xylose unit and less than 0.002 Hexenuronic Acid substituents per xylose unit.

As further examples, a majority of the xylan molecules of the xylan compound may have a molecular weight of 300-20000 g/mol, such as 300-10000 g/mol, and 0.01-0.1 acetyl substituents per xylose units, 0.05-0.2 4-O-Methyl Glucuronic Acid substituents per xylose unit and less than 0.002 Hexenuronic Acid substituents per xylose unit.

As further examples, a majority of the xylan molecules of the xylan compound may have 0.015-0.05 acetyl substituents per xylose unit.

Further, a majority of the xylan molecules of the xylan compound may have 0.075-0.125 4-O-Methyl Glucuronic Acid substituents per xylose unit.

Further, a majority of the xylan molecules of the xylan compound may have less than 0.001 Hexenuronic Acid substituents per xylose unit.

Further, a majority of the xylan molecules of the xylan compound may have an average of 0.01-0.1, such as 0.015-0.05, acetyl substituents per xylose unit.

Further, a majority of the xylan molecules of the xylan compound may have an average of 0.05-2, such as 0.075-0.125, 4-O-Methyl Glucuronic Acid substituents per xylose unit.

Further, a majority of the xylan molecules of the xylan compound may have an average of less than 0.002, such as less than 0.001, Hexenuronic Acid substituents per xylose unit.

Further, a majority of the xylan molecules of the xylan compound may have a weight average molecular weight (M_w) of about 5000-9000 g/mol.

Further, the number average molecular weight (M_n) of a majority of the xylan molecules of the xylan compound may be about 4000-6000 g/mol, especially for the NSSC process, alternatively about 6500-11500 g/mol, especially for the Kraft process.

Further, the polydispersity of a majority of the xylan molecules of the xylan compound may be 1.1-1.6, such as 1.2-1.4, such as 1.25-1.35.

The polydispersity of xylan refers to M_w divided by M_n. It may be advantageous to keep the polydispersity low since it reflects a homogenous xylan product, which is beneficial in some applications.

The above embodiments relating to structural characteristics are particularly relevant for a xylan compound which has not (yet) been chemically modified, e.g. according to the below.

Further, the xylan compound may have been pretreated before compounding with the biodegradable plastic.

As an example, the xylan compound may have been pretreated in a process comprising bleaching of the xylan compound or a mixture comprising the xylan compound, e.g. a fraction separated from cooking liquor. The bleaching may be performed by addition of peroxide and/or hypochlorite. Through bleaching, the xylan-containing material, e.g. a xylan-containing film, may be made whiter or lighter.

As another example, the xylan compound may have been pretreated in a process comprising acetylation of the xylan compound. An advantage of acetylation may be that the xylan is made less moisture sensitive and may be more thermo stabile and more thermoplastic which may be an advantage in compounding at an elevated temperature. Acetylation refers to a reaction that introduces acetyl functional groups to the xylan compound, typically using acetic acid anhydride as detailed in article “Effect of acetylation on the material properties of glucuronoxylan from aspen wood” (M. Gröndahl, Carbohydrate polymers 52 (2003) pp. 359-366). Patent US 2011/0009610A1 describes yet another method for acetylation of hemicelluloses.

Further, the xylan compound may have been pretreated in a process comprising hydroxypropylation of the xylan compound. Hydroxypropylation refers to a reaction that introduces hydroxypropyl groups to the xylan compound, e.g. by reacting the xylan with propylene oxide in alkali environment as detailed in patent US 5,430,142. The hydroxypropylated xylan compound may optionally be further peracetylated creating acetoxypropyl xylan that is melt processable. An advantage of hydroxypropylation may be that the xylan may become more thermo stabile and more thermoplastic which may be an advantage in compounding at an elevated temperature.

For the same reasons, the pretreatment may also comprise other chemical modifications of the xylan compound including esterification such as succinoylation, sulfation, tosylation, nitration, and xanthation, or etherification such as benzylation, carboxymethylation, sulfoalkylation and cyanoethylation.

The xylan compound may also be chemically altered in such a way that the polymeric structure is affected to provide better compatibility with the biodegradable polymer to be compounded with. Such chemical modifications includes grafting, cross-linking, and chain extention and may affect properties such as molecular weight, crystallinity, thermal properties, mechanical properties. Crosslinking using e.g. glyoxal may increase average molecular

weight of the xylan compound which may affect its thermal properties such as lowering glass transition temperature in comparison to unmodified xylan. Grafting may be used to create a graft copolymer where the grafted species may provide better interaction with other biopolymers and result in a more homogeneous compounded product. Chemical modification may be performed prior to or during compounding.

Thus, the xylan compound may have been pretreated by at least one process selected from bleaching, acetylation, succinoylation, sulfation, tosylation, nitration, xanthation, hydroxypropylation, benzylation, carboxymethylation, sulfoalkylation cyanoethylation, grafting, crosslinking, and chain extension of the xylan compound.

In embodiments of the first aspect, the compounded polymeric product further comprises at least one plasticizer, at least one chain extender and/or at least one crosslinking agent.

The at least one plasticizer, at least one chain extender and/or the at least one crosslinking agent may have been added during a pretreatment of the xylan compound prior to compounding with the biodegradable plastic. This is advantageous since such an addition to the xylan compound during a pretreatment of the xylan compound may affect/modifiy the xylan compound to facilitate a subsequent compounding with a biodegradable plastic.

Further, the at least one plasticizer, at least one chain extender and/or the at least one crosslinking agent may have been added during the compounding of the xylan compound with the biodegradable plastic.

A plasticizer refers to a compound that increases the plasticity or fluidity of the material to which it is added. Thus, the addition of a plasticizer may increase the flexibility, and the mixability, of the xylan compound as well as the compounded polymeric product, thereby enhancing processability and homogeneity of the blend. Further, addition of a plasticizer may lower the glass transition temperature of the xylan compound as well as the compounded polymeric product, thereby making it softer.

As an example, the at least one plasticizer may be selected from the group consisting of water, glycerine, diethylene glycol, polyethylene glycol, carbamide and sorbitol. Plasticizers have shown to improve the mechanical properties of a compounded film of a xylan compound and a biodegradable plastic. Sorbitol and glycerine may be considered to be particularly preferred. As an example, sorbitol and/or glycerine may be added in an amount of 10-55 g per 100 g xylan compound during pretreatment of the xylan compound,

typically 15-40 g or 20-40 g per 100 g xylan compound. The plasticizer may optionally be added during compounding.

A crosslinking agent refers to a compound that facilitates crosslinking between xylan compounds, within the biodegradable plastic or between the xylan compound and the biodegradable plastic. The addition of a crosslinking agent may lower the water solubility of a polymer and/or increase the plastic properties of a polymer. Adding a crosslinking agent to the xylan compound may improve the mechanical stability of the compound and make it less sticky and less sensitive to moisture, thus making it more suitable for compounding and film forming.

As an example, the crosslinking agent may be glyoxal. Glyoxal refers to the organic compound having the formula OCHCHO. The inventors have found that glyoxal is a suitable crosslinking agent for xylan, at least for some applications. As an example, glyoxal may be added in an amount of 4-20 g per 100 g xylan compound during pretreatment of the xylan.

Further crosslinking agents that may be used for crosslinking xylan include covalent crosslinkers such as glutaraldehyde, epichlorohydrin with ethanolamine/ethanol, citric acid and polymer resin e.g. PAE; and electrolytical crosslinkers such as polyamines e.g. kitosan or cationic starch, and polyvalent metal ions e.g. AZC. Suitable catalysts may be aluminium sulphate and/or borax (dinatriumtetraborate) which may be used alone or in combination.

A chain extender refers to a compound that extends the chain length of a polymeric material. In relation to biodegradable plastics, chain extenders are typically used to upgrade deteriorated material by reestablishing broken bonds in the polymer chain. Alternatively it may be used to change mechanical properties such as stiffness of the plastic. Adding a chain extender may thus create a copolymer between the xylan compound and the other biodegradable plastic. Chain extenders may also be used to improve the mechanical properties of the compound such as stiffness, thus making it more suitable for compounding and film forming. Examples of suitable chain extenders are Joncryl (BASF), BioAdimide (RheinChemie), and Allinco (DSM). A benefit of Joncryl and Allinco is that they do not require a separate pretreatment step, but may be added in the compounding.

Other additives that may be added to the polymeric product, either during pretreatment of the xylan compound or during compounding, are for example an antioxidant, a slipping agent, a wax, an anti-block agent, a nucleation

agent, a pigment and/or a hydrophobifying agent, e.g. AKD, ASA and/or a triglyceride.

For example, an anti-block agent for preventing film-to-film adhesion, a pigment for coloring the plastic product and/or an inorganic filler may also have been added to the product of the first aspect.

In embodiments of the first aspect, the at least one biodegradable plastic comprises a bioplastic. Bioplastics, or organic plastics, refers to a form of plastics typically derived from renewable biomass sources, such as vegetable oil, starch e.g. corn or potato starch, or microbiota, rather than fossil fuel plastics which are derived from petroleum. Typical bioplastics that are both biodegradable and based on renewable sources are starch based bioplastics and PHA (polyhydroxyalkanoate) based bioplastics. A bioplastic that is biodegradable but derived from petroleum, at least partially, is the aliphatic-aromatic branched copolyester Ecoflex from BASF.

Further, the biodegradable plastic may comprise a biodegradable aliphatic-aromatic branched copolyester. The biodegradable, aliphatic-aromatic branched copolyester may comprise aliphatic and aromatic dicarboxylic acids and an aliphatic dihydroxy compound as monomeric building blocks. The aliphatic-aromatic branched copolyester may for example contain 95-100 mol% of these three building blocks. In one example, the monomeric building blocks are selected from the group consisting of 1,4-butanediol, adipic acid and terephthalic acid. The 1,4-butanediol is an aliphatic dihydroxy compound, a diol having the formula $HOCH_2CH_2CH_2CH_2OH$. The adipic acid is an aliphatic dicarboxylic acid having the formula $(CH_2)_4(CO_2H)_2$. The terephthalic acid is an aromatic dicarboxylic acid with an benzene ring and is having the formula $C_6H_4(CO_2H)_2$.

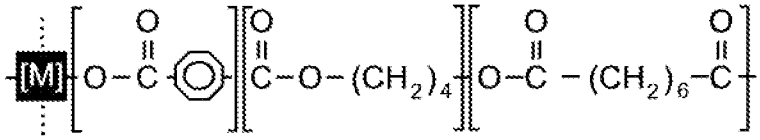
The inventors have found that a biodegradable plastic comprising a biodegradable aliphatic-aromatic branched copolyester is suitable for compounding with a xylan compound. A compounded polymeric product comprising aliphatic-aromatic branched copolyesters may provide satisfactory transparency, flexibility and anti-fogging performance.

In one example, the biodegradable, aliphatic-aromatic branched copolyester is poly(butyleneadipate terephthalate).

One example of a suitable aliphatic-aromatic branched copolyester is manufactured by BASF and sold under the trade name Ecoflex. Under this trade name there are a number of different grades. Each grade of polymer

has been designed with controlled branching and chain lengthening to possibly match its particular application. Ecoflex is a copolyester comprising 1,4-butanediol, adipic acid and dimethylterephthalate (DMT). In some cases, a diisocyanate is used as a chain lengthener.

The structure of Ecoflex is:



[M] is a modular component, e.g. a monomer with a branching or chain extension effect.

Ecoflex is transparent to translucent and has a semi-crystalline structure, and typically a melting point of about 110-120ºC. The copolyester may be used for film extrusion.

As an example, the biodegradable aliphatic-aromatic branched copolyester may be of the Ecoflex family, such as Ecoflex FS BX 7500 or Ecoflex F Blend A1200, as well as the different grades of the Ecovio family, which are mixtures of Ecoflex and PLA, such as Ecovio FS Film C2203, or Ecovio F Film C2203, or Ecovio F Film C2224 (all from BASF).

Another aliphatic-aromatic branched copolyester which may be used is manufactured by Eastman Chemical Company and is sold under the trade name Eastar Bio or Origo-Bi. The copolyester manufactured by Eastman is a copolyester derived from 1,4-butanediol, adipic acid and dimethylterephthalate (DMT). Under the trade name Eastar Bio there are a number of different grades. Each grade of polymer has been designed with controlled branching and chain lengthening to possibly match its particular application.

Another biodegradable plastic which may additionally or alternatively be used is polycaprolactone (PCL). PCL is for example sold under the name Celgreen by Daicel, Japan and TONE Polymer P-787 by Union Carbide Corp.. An advantage with PCL is its relatively low melting point of about 60-70ºC, allowing compounding to be performed at a lower temperature that reduces the risk of degradation of the xylan compound. Other biodegadrable plastics having a melting point of less than 100 °C, such as less than 90 °C or 80 °C, are advantageous for the same reason. The weight ratio of the xylan product to the low melting point bioplastic (e.g. PCL) may be between 10:1 and 1:2, such as 5:1 and 3:2. Also, the product of the first aspect may

comprise 1-99 % (w/w), such as 1-70 % (w/w) or 10-90 % (w/w), such as 50-70 % (w/w) or 5-50 % (w/w), such as 5-30 % (w/w) of the low melting point bioplastic.

As a specific example, the three main components of the product of the first aspect, together making up to at least 85 % (w/w) of the product, may be:
- a biodegradable aliphatic-aromatic branched copolyesters, such as Ecoflex;
- a biodegradable plastics having a melting point of less than 100 °C, such as PCL; and
- the xylan compound.

For example, each of these three main components may constitute at least 15 % (w/w) of the product.

A fourth component may in this case be lignin or lignosulfonate, which may constitute 1-15 % (w/w) or the product.

Examples of other commercially available polyesters that may be used in the present invention include: Bionolle (polybutylenesuccinate or polybutylenesuccinateadipate) from Showa Denko, Japan; GS-PLA (polybutylenesuccinate) from Mitsubishi Chemical, Japan; Capa 680 (polycaprolactone) from Solvay, UK; Tone Polymer787 (polycaprolactone), Union Carbide (DOW), USA; Mirel (polyhydroxybutyrate) from ADM/Metabolix; etc.

As a further example, the biodegradable, aliphatic-aromatic branched copolyester may comprise a monomeric building block selected from the group consisting of mononuclear isocyanurate, binuclear isocyanurate, trinuclear isocyanurate and a mixture thereof. The concentration of such a building block in the polymer may for example be 0.5-5 mol%.

As an example, the biodegradable, aliphatic-aromatic branched copolyester may comprise monomeric building blocks of

a) an acid component of at least one aliphatic or cycloaliphatic dicarboxylic acid or its ester-forming derivative or a mixture thereof and

b) an acid component of at least one aromatic dicarboxylic acid or its ester-forming derivative or a mixture thereof and

c) at least one dihydroxi compound or at least one amino alcohol or a mixture thereof and

d) optionally isocyanurate.

“Cycloaliphatic” refers to an aliphatic compound containing a cyclic ring.

Aliphatic dicarboxylic acids may have 2 to 10 carbon atoms, preferably 4 to 6 carbon atoms. They may be either linear or branched. The cycloaliphatic dicarboxylic acids which may be used in accordance with the present disclosure are for example those having 7 to 10 carbon atoms and, in particular, those having 8 carbon atoms. Specific examples of aliphatic dicarboxylic acids which may be used are: malonic acid, succinic acid, sebaic acid, fumaric acid, 2,2-methylglutaric acid, 1,3-cyclopentanedicarboxylic acid, adipic acid, glutaric acid, pimelic acid, azelaic acid, maleic acid and/or suberic acid. It may also be possible to use dicarboxylic acids having a larger number of carbon atoms, for example up to 30 carbon atoms.

Aromatic dicarboxylic acids which may be used in the present disclosure are for example those having 8 to 12 carbon atoms and preferably those having 8 carbon atoms. Examples of aromatic dicarboxylic acids which may beused are: terephthalic acid, isophtalic acid, 2,6-naphtalic acid and 1,5-naphtalic acid. The aromatic dicarboxylic acids or their ester-forming derivatives may be employed singly or as a mixture of two or more thereof.

It may be possible in principle to use all diols or amino alcohols able to form esters with the dicarboxylic acids. Examples of suitable alkanediols are: ethylene glycol, 1,2-propanediol, 1,5-pentanediol, 1,4-butanediol, cyclopentanediol.

As a further example, the biodegradable, aliphatic-aromatic branched copolyester may comprise monomeric building blocks of

a) an adipic acid or ester-forming derivatives thereof or a mixture thereof and

b) a terephthalic acid or ester-forming derivatives thereof or a mixture thereof

c) a dihydroxi compound selected from the group consisting of C_2-C_6-alkanediols and C_5-C_{10}-cycloalkanediols or a mixture thereof and

d) optionally a compound containing sulfonate groups.

The aliphatic-aromatic branched copolyester may thus contain other monomeric building blocks than aliphatic and aromatic dicarboxylic acids and an aliphatic dihydroxy compound. Examples of other components are epoxide, anhydrides, isocyantes and sulfonates. These other components may be used for extending the chain of the molecule.

As a further example, the biodegradable, aliphatic-aromatic branched copolyester has a glass transition temperature of from -35˚C to -25˚C and/or a melting point in the range of 105-125 ˚C, 105-115˚C.

In embodiments of the first aspect, the biodegradable plastic further comprises polylactide (PLA).

Polylactide, or polylactid acid (PLA) may be produced as a co-product of corn wet milling, and is a renewable resource. Thus, using a biodegradable plastic comprising PLA usually increases the percentage of renewable material of the polymeric product.

Yet another type of biodegradable bioplastic that may be used is polyhydroxyalkanoates (PHAs), such as poly-3-hydroxybutyrate (PHB), polyhydroxyvalerate (PHV) or polyhydroxyhexanoate (PHH). PHAs are produced by bacterial fermentation and are thus renewable. Normally, their melting range is 40-180 ˚C.

In an embodiment of the first aspect, the product comprises substantially no starch or starch-derived components. In another embodiment, the product of the first aspect comprises substantially no polysaccharides except for the xylan product.

In a similar embodiment, the other component of the product, *i.e.* the biodegradable plastic, is not starch or starch-based/starch-derived.

For example, less than 5 % (w/w), such as less than 1 % (w/w), such as less than 0.5 % (w/w) of the product of the first aspect is starch, starch-based or starch-derived. A reason for excluding starch is, as discussed above, to avoid ethical concerns.

As a second aspect of the invention there is provided a polymeric film comprising or consisting of the compounded polymeric product according to the first aspect of the invention. Thus, a film may be formed from the compounded polymeric product according to the first aspect of the invention, e.g. by blown film extrusion or by film casting or pressing. There are high requirements put on a polymeric material in order for it to be suitable for film production, especially film blowing. A suitable polymeric material will have rheological properties sufficient to yield a film which is homogenous with respect to material composition and thickness, the film being strong and flexible enough. Sensitivity to moisture and gas barrier properties are also of importance for some film applications. Surprisingly, it has been found that such films may be produced by a compounded polymeric material comprising xylan as discussed above.

The film may have a substantially homogenous thickness in the range of 5-500 micrometers, e.g 10-200 micrometers, 50-200 micrometers, 10-50 micrometers or 20-100 micrometers.

Preferably, the film has a thickness of less than 60 micrometers.

The film may have a tensile strength of more than 5 MPa, such as more than 10 MPa, such as in the range of 10-50 MPa or 10-30 MPa or 10-20 MPa, or more than 15 MPa, such as 15-50 MPa or 15-30 MPa, or more than 20 MPa, such as 20-60 MPa or 20-40MPa. Since the film may be anisotropic, the mentioned strength may be in either the flow direction or perpendicular thereto.

The film may have a tensile (Young's) modulus in the range of 0.01-1 GPa, such as 0.1-1 GPa or 0.2-0.8 GPa or 0.4-0.6 GPa. Since the film may be anisotropic, the mentioned modulus may be in either the flow direction or perpendicular thereto.

The film may have an elongation at break of more than 50%, such as in the range of 50-1000%, 50-700%, or 50-500%, or of more than 100%, such as in the range of 100-1000%, 100-700%, or 100-500%, or of more than 200%, such as in the range of 200-1000%, 200-700%, or 200-500%. Since the film may be anisotropic, the mentioned elongation may be in either the flow direction or perpendicular thereto.

The film may be used as a cling film (sometimes referred to as a cling wrap or plastic wrap), comprising the composition is thus provided in the present disclosure. The film may thus be used for sealing e.g. fruits or vegetables arranged in trays, which also may be biodegradable. Consequently, a unit consisting of food arranged in a biodegradable container sealed with a film according to the present invention may be biodegradable in its entirety. Thus, if a piece of food in such a unit is to be disposed, the different components of the unit may not have to be separated from each other before composting. Accordingly, a piece of fruit wrapped in a film according to the present disclosure may not have to be separated from the film before composting.

Another area of use of the cling film is plastic wrapping of pallets, especially loaded pallets loaded with goods, such as timber pallets.

Further, the film, possibly thicker than when used as cling film, may be used for making plastic bags of many different sizes, such as small bags e.g. for fruit in a grocery store, larger bags for carrying groceries from the store or even larger plastic sacks.

A bag composed of the film of the second aspect is biodegradable. It may thus beneficially be used for collecting and/or transporting compostable waste as it may be composted together with such waste. Xylans are the constituents of biomass that degrade most rapidly when biomass rots in natural environment, and, without being bound by any specific scientific theory, the inventors believe that the xylan content of the film may allow for a faster degradation/composting of the whole film/bag as the degraded xylan may leave a more porous structure of the film that increases the surface available for further degradation processes. Further, the plastic film according to the second aspect may naturally have a beige to dark brown color, in particular if its xylan product is provided as a cooking liquor-derived mixture with lignin or lignosulfonate, and compostable plastic bags having such a color are demanded on the market. The ability to control the color of the product by the addition of a xylan compound reduces the need for other, potentially less environmentally friendly, pigments.

The film may also be used as a mulching film to suppress weeds and conserve water in crop production. Films produced from a compounded product comprising a xylan compound and at least one other biodegradable plastic according to the invention are biodegradable. Thus, in contrast to non-biodegradable pastics, after the xylan comprising film has fulfilled its purpose as weed suppressant, the film will disintegrate and disappear naturally.

The film may also be used for lamination. The film may e.g. be laminated or adhered to paper e.g. for providing moisture and/or air barrier properties. The paper may e.g. be the paper or cardboard of a container for liquid, e.g. a milk carton, or food. The film may be particularly suitable for the packaging of vegetables.

The surface of the film of the second aspect may in some embodiments naturally have a somewhat granular surface. Such a surface may be beneficial when the film is applied to a paper as it prevents slipping and thus facilitates intentional tearing of a product, e.g. a bag, composed of the laminate. For example, a user may want to tear a bag composed of the laminate to of access or empty the contents of the bag. Also, the granular

surface may provide a laminate having a more “natural” feeling, which is demanded on the market.

A xylan-containing film has been shown to have beneficial water vapor transmission properties. A particularly interesting application of the film of the second aspect is thus its use as a moisture barrier in paper sacks. Accordingly, a film of the second aspect may be arranged in a paper sack for the protection of the contents of the sack against water. Normally, such a sack comprises at least two paper plies and the film is arranged between two plies. If the sack comprises three plies, the film may be arranged between the outermost ply and the middle ply or between the innermost ply and the middle ply. However, there are also sacks having only one paper ply as an outer layer and a film as an inner layer.

The sack comprising the film may be used for holding a powdery or granularly material, such as cement, powdered goods for the construction industry, ready-mix building materials, chemicals, fertilizers, foodstuff or fodder.

A paper sack comprising a film according to the second aspect may be completely biodegradable. Further, the paper as well as at least a substantial part of the film components may be obtained from renewable sources, such as lignocellulose. In fact, the very same pulping process may be the source of the paper of the sack and the xylan compound of the film.

As a third aspect of the invention, there is provided granules comprising the compounded polymeric product according to the first aspect of the invention. The compounded polymeric product may be dried and granulated according to conventional methods in the art. The granules may then e.g. be used as material for film production.

The granules may thus be ready for further processing, such as blow film extrusion, without any need of the addition of further components. Alternatively, the granules may be a master batch for being mixed or compounded with other components. Thus, the content of the xylan compound is higher in the master batch than in the final product, e.g. the film. For example, the film manufacturer may not have the equipment needed to efficiently compound xylan with other components. In such case, the film manufacturer may use precompounded master batch granules and one or

more additional components as starting materials in a conventional blown film extrusion, cast film extrusion, or extrusion coating process.

The master batch may also have the form of a compounded melt. Just as the master batch granules, the master batch compounded melt may be used together with one or more additional components as starting materials in blown film extrusion processes.

Whether it is in the form of granules or a compounded melt, the master batch normally has a comparatively high content of the xylan compound, such as at least 10 % (w/w), such as at least 30 % (w/w), such as at least 40 % (w/w). Likewise, at least 10 % (w/w), such as at least 30 % (w/w), such as at least 40 % (w/w), of the master batch may be composed of xylose monomeric units.

It has been shown that the addition of a plastic component having a melting point of less than 100 °C may allow for a higher content of the xylan compound in the compounded product. This is because lower compounding temperatures can be used in such cases, which reduces risk of thermal degradation of the xylan compound. It is thus particularly beneficial to add such a component in the production of a master batch where it is desired to maximize the xylan compound content. Accordingly, the granulate or compounded melt of the third aspect may thus comprise at least 5 %, such as at least 10 %, such as at least 20 %, such as at least 50%, such as at least 80% of a biodegradable plastic having a melting point below 100 °C, such as below 80 °C. As mentioned above, PCL is an example of such a plastic.

In one embodiment, the two main components, together making up at least 80 % (w/w) or 90 % (w/w), of a master batch may be the xylan compound and one or more biodegradable plastic(s) having a melting point of less than 100 °C. In such an embodiment, the content of the xylan compound may typically be 30-75 % (w/w), such as 40-65 % (w/w). Likewise, 30-75 % (w/w), such as 40-65 % (w/w), of the master batch may be composed of xylose monomeric units. A third component may for example be lignin or lignosulfonate, which may for example account for 1-15 % (w/w) of the master batch.

As a fourth aspect of the invention, there is provided a method for preparing a polymeric compound comprising: compounding a xylan compound with at least one biodegradable plastic to provide the polymeric compound.

The terms and definition used in relation to the fourth aspect are as defined in the other aspects above. For the avoidance of doubt, the various embodiments of aspect one to three apply to the fourth aspect *mutatis mutandis*.

Thus, the inventors have surprisingly found that xylan may be compounded with biodegradable plastics to form plastic compounds.

As understood from the above, the method of the fourth aspect may be part of a blown film extrusion, a cast extrusion, an extrusion coating, such as direct extrusion paper lamination or dye-cut coating, or a production of granules or a compounded melt. The film may also be co-extruded with another material having a different composition.

In one embodiment of the fourth aspect, water steam is added prior to or during the compounding. The water added in such a manner acts as a plasticizer and facilitates the compounding process providing a more homogeneous product. Preferably, the steam is added directly to the xylan compound/xylan-containing mixture before feeding it into the compounder or during the first half of the compounding process.

The xylan compound and/or the biodegradable plastic may e.g. be in the form of granules, a powder, a paste, a slurry, a solution or a melt when added in the method.

In embodiments of the fourth aspect, compounding may comprise mixing the xylan compound and the at least one biopolymer during heating to a temperature in the range of about 100-200°C, such as about 110-160°C or 130-190ºC or about 110-140ºC such as 115-135ºC. It may be desirable to keep the temperature relatively low in order to prevent the degradation and/or evaporation of the xylan. However, the temperature should be sufficient for compounding of the xylan as well as the biodegradable plastic. The inventors have found that temperatures of about 100-200°C, such as about 110-160°C, during compounding of a xylan compound and a biodegradable plastic facilitates the formation of a plastic product with satisfactory mechanical and barrier properties. However, if a biodegradable plastic with a lower melting point is used, e.g. PCL, a lower compounding temperature may be used, such as a temperature of in the range of 60-100ºC, such as 70-90ºC or 70-80ºC.

For example, a temperature range of 150-200ºC may be preferred if the xylan compound is chemically modified by e.g. acetoxypropylation, while a temperature range of 110-190, 110-160 or 80-150 ºC may be preferred if the xylan compound is unmodified. This is because the chemical modifications of

the xylan often improves heat resistance. It is understood that any temperature settings will be influenced by a number of factors besides the properties of the xylan compound, including properties of other biopolymers used, compression in the compression zone of the compounder, screw configuration and speed, retention times, additives etc.

In order to compensate for the relatively poor heat stability of native xylan, the xylan may be pretreated as discussed herein and/or the temperature or time of the compounding may be decreased.

The time period during which the xylan compound is subjected to elevated temperatures, which may risk degradation of the xylan, may be reduced by reducing the time period of the compounding, e.g. the retention time in a compounder, such as a screw compounder. However, the time period should still be enough to achieve sufficient compounding. Contemplated time periods range from about 5 seconds to 10 minutes. However, it has been found that a time period of less than 5 minutes, such as in the range of 5-60 seconds, 10-40 seconds or 20-30 seconds, may be sufficient for compounding. If a screw compounder is used, the retention time may be adjusted e.g. by adding the xylan compound to the compounder at different positions along the screw compounder.

In embodiments of the fourth aspect, the mixing is performed with single or twin screw-means or in a co-kneader, e.g. of an extrusion device.

In embodiments of the fourth aspect the ratio of the xylan compound and the at least one biodegradable plastic may be between 1:20 and 2:1, such as between 1:20 and 1:1, such as between 1:20 and 2:1, such as between 1:10 and 1:5 or between 1:4 and 1:2, such as about 3:7.

In embodiments of the fourth aspect, the method is further comprising preparation of a film from the compounded polymeric product by means of blown film extrusion. In the blown film extrusion, the compounded polymeric product may for example be processed at temperatures of 60-250°C, preferable 100-160°C or 140-190°C. The blow-up ratio may for example be in the range of 1.5-5. In a similar embodiment, a film is produced from the product of the first aspect by means of blown film extrusion.

The compounded polymeric product, which comprises the xylan compound, may for example be coextruded with at least one other polymer composition comprising substantially no xylan compound, e.g. less than 1 % (w/w). Such a configuration may improve bubble stability in case of

unfavorable mechanical properties of a film made from the xylan-containing product alone.

Further, the blown film extrusion may for example be performed using a low compression screw, such as a conventional low compression screw with conventional mixing top. When such a configuration is used, damage of the xylan compound during blown film extrusion may be avoided. Pressures may for example be less than 200 bar, such as less than 100 bar or less than 50 bar.

Also, the blown film extruder employed may for example be equipped with a double lip cooling air ring in order to provide better stability of the bubble.

In embodiments of the fourth aspect, the xylan compound is as defined in any example or embodiment of the first aspect above.

Further, in embodiments of the fourth aspect, the biodegradable plastic is as described in any example or embodiment of the first aspect of the invention above.

As an example, the biodegradable plastic may comprise a biodegradable aliphatic-aromatic branched copolyester.

In embodiments of the fourth aspect, the method is further comprising pretreating the xylan compound prior to compounding the xylan compound with the at least one biodegradable plastic.

As examples, the pretreatment of the xylan compound may comprise at least one process selected from bleaching, eterification (e.g. hydroxypropylation or benzylation), esterification (e.g. acetylation or succinoylation), grafting, chain extension, or crosslinking of the xylan compound.

In embodiments of the fourth aspect, the method is further comprising addition of a at least one plasticizer and/or at least one crosslinking agent during pretreatment of the xylan compound or during compounding of the xylan compound with the at least one biodegradable plastic.

As examples, the at least one plasticizer may be selected from glycerine and sorbitol. Further, the crosslinking agent may be glyoxal.

An extension of the xylan compound chains can be achieved during the compounding reaction. Thus, in one embodiment of the fourth aspect, a chain extender, such as Joncryl, BioAdimide, or Allinco, is co-compounded with the xylan compound and the at least one biodegradable plastic. Thus, in such an embodiment, no separate pretreatment step is required to obtain the desired

chemical modification of the xylan compound. This may make the process more convenient and efficient.

As a further aspect of the invention, there is provided the use of glyoxal for crosslinking xylan.

Exemplary embodiment

Methods for pretreating a xylan compound suitable for compounding with a biodegradable plastic

A xylan fraction comprising a xylan compound is separated from cooking liquor e.g. by means of ultrafiltration.

The xylan fraction is pretreated according to at least one of the following pretreatment processes (1-10):

1. The xylan fraction is purified with water and then concentrated or dried.
2. The xylan fraction is sequentially purified with water, ethanol and water before concentrated or dried.
3. The xylan fraction is sequentially purified with water, ethanol and water before bleaching, preferably with peroxide or hypochlorite, and then concentrated or dried.
4. The xylan fraction is purified with water, bleached, preferably with peroxide or hypochlorite, and then concentrated or dried.
5. The xylan fraction is purified with water, bleached, preferably with peroxide or hypochlorite, purified with ethanol and then water before being concentrated or dried.
6. The xylan fraction is purified with water, bleached, preferably with peroxide or hypochlorite, concentrated, crosslinked with glyoxal or other crosslinking agents, purified with ethanol and water, and then concentrated or dried.
7. The xylan fraction is purified with water, hydroxypropylated, and then concentrated or dried.
8. The xylan fraction is purified with water, hydroxypropylated, purified with ethanol and water, and then concentrated or dried.
9. The xylan fraction is purified with water, hydroxypropylated, concentrated, crosslinked with a crosslinking agent such as glyoxal or others, purified with ethanol and water, and then concentrated or dried.

10. The xylan fraction is purified with water, hydroxypropylated, bleached with peroxide or hypochlorite or others, concentrated, crosslinked with a crosslinking agent such as glyoxal or others, purified with ethanol and water, and then concentrated or dried.

Since the ultrafiltration may be performed at alkalic pH, it may be an advantage to perform the hydroxypropylation after the filtration since it may also be performed at alkalic pH (see e.g. US patent 5,430,142). The addition of a crosslinker, such as glyoxal, may advantageously be made at acidic pH. It may thus be advantageous to perform the pretreatment steps in this order to reduce the number and/or magnitude of pH adjustments.

A xylan compound that has been pretreated according to any of the pretreatment processes 1-10 may be further pretreated by any one or several of the following further pretreatment processes:

11. The xylan fraction is further dried using methods including methods such as spray drying and freeze drying.
12. The xylan fraction is further wet milled.
13. The xylan fraction is further chemically modified by etherification such as hydroxypropylation or benzylation.
14. The xylan fraction is further chemically modified by esterification such as acetylation or succinoylation.
15. The xylan fraction is further chemically modified by grafting.
16. The xylan fraction is mixed with plasticizers, such as glycerine or sorbitol.
17. The xylan fraction is diluted in water and mixed with plasticizers, such as glycerine or sorbitol, and then dried.
18. The xylan fraction is diluted in water and mixed with a plasticizer, such as glycerine or sorbitol, and then mixed with a crosslinking agent such as glyoxal or others, and then dried.
19. The xylan fraction is diluted in water and mixed with a plasticizer, such as glycerin or sorbitol, the pH is adjusted before addition of a crosslinking agent such as glyoxal or others, and then dried.
20. The xylan fraction is diluted in water and mixed with a crosslinking agent such as glyoxal or others before it is dried.

21. The xylan fraction is diluted in water, mixed with a crosslinking agent such as glyoxal or others. A plasticizer, such as glycerine or sorbitol is added, before the xylan fraction is dried.
22. The xylan fraction is diluted in water. The pH is adjusted, for instance with sodium hydroxide, followed by crosslinking with a crosslinking agent, such as glyoxal or others. The xylan compound is then dried.
23. The xylan fraction is diluted in water. The pH is adjusted prior to a sequential addition of a crosslinking agent and a plasticizer. The xylan fraction is then dried.

Further, antioxidants may be added to the fraction compound in any one of the further pretreatment processes 11-23.

Examples

The following non-limiting examples will further illustrate the present invention.

Materials:

Xylan fraction – NSSC fraction from birch, comprising about 50% (w/w) xylan compound
Commercial xylan – Sigma Aldrich (X4252), Beech, >90% (w/w) xylan
Sorbitol – Sigma Aldrich (53755), 97%
Glycerin – Sigma Aldrich (655/6), 99%
Barrisurf™ – kaolin clay from IMERYS
Glyoxal – 40% from BASF
Ecoflex – Ecoflex F Blend A1200 from BASF
PCL – TONE Polymer P-787 from Union Carbide Corp

Example 1: Composition and properties of a NSSC xylan fraction

A non-limiting example of properties of a xylan fraction, comprising xylan compounds, extracted from a NSSC cooking process. The xylan fraction has been pretreated by bleaching.

Composition of the xylan fraction:

60.2% Carbohydrates (Primary xylan compounds)
10.9% Lignin and lignosulfonates
16.6% Extractives (Primary fatty acids)

6.5% Ash
5.8% Other (Primary salts)

Molecular weight distribution of the xylan fraction:
M_p 11300 g/mol (Peak MW)
M_n 8800 g/mol (Number average MW)
M_w 10900 g/mol (Weight average MW)
PD 1.2 (Polydispersity)

Thermal properties of the xylan fraction:
Analysis (TGA) of thermal stability showed that the xylan fraction starts to decay around 150°C with a maximum rate of weight loss between 250°C and 300°C. The dry xylan fraction showed no thermoplastic behavior between 20°C and 200°C (conventional DSC).

Example 2: Pretreatment of xylan fraction by wet milling in ethanol

A non-limiting pretreatment method to produce a fast drying, white fine powder suitable for compounding with a biodegradable plastic is as follows.

The xylan fraction, comprising xylan compounds as detailed in example 1 and having a dry content of approximately 50%, was wet milled in ethanol at a ratio of 3:10 by weight (xylan fraction:ethanol) for 20 minutes using an Ultra-Turrax T45. The solution was left in a container for 24 hours, allowing the xylan compound to settle. After excess ethanol had been decanted, the material was vacuum filtered to further lower the solvent content. The remaining solvent evaporated quickly, leaving a white xylan comprising material that easily fell apart into a fine powder. The wet milled xylan fraction may optionally be further dried by e.g. electrical heaters and/or grinded in dry state.

The pretreatment according to example 2 will produce a fine powder with low water content suitable for compounding. A further advantage is that the pretreatment will lower the amount of extractives, in this example from 16,6% to 6,7%, having a positive effect on particle dispersion. In comparison, without wet milling pretreatment, millimeter sized dark brown particles are formed when the xylan compound is left to dry in ambient atmosphere.

In addition to wet milling as described above, spray drying and freeze drying have successfully been used to produce a powder from the xylan fraction with low water content and small particle size. The inventors have

however observed advantages from using a wet milled xylan fraction during compounding over using spray dried xylan fraction, including reduced/removed stickiness of granules and a slightly higher limit for the amount of xylan fraction possible incorporate during compounding.

Example 3: Pretreatment of a xylan fraction by addition of plasticizers and crosslinking agent

Example 3a, b, c, d, g and h describe non-limiting pretreatments of a xylan fraction originating from a cooking liquor of a pulping process by addition of plasticizers and/or crosslinking with glyoxal. Example 3e and f are included for comparative reasons.

The pretreatments in example 3a-e and h are done by mixing a xylan fraction in water with appropriate plasticizers and a crosslinker. Heat is typically raised to 70-95°C during the pretreatment. Cast films prepared from the material by solvent evaporation. The films were dried in room temperature for 3 days.

The films have been evaluated in relation to their barrier properties and mechanical properties (example 3a-e):

OTR (oxygen transmission rate) is measured with a Mocon Oxtran 2/21 MH according to ASTM D 3985. Measurements were done at 23ºC and 0% RH.

The mechanical properties are measured according to ISO 527-27/120. Measurements were conducted on conditioned samples, 23ºC, 50% RH, conditioned more than 24 h. Pull velocity was 100 mm/min, a clamping distance of 40 mm, and a minimum width of the tensile sample bar of 4 mm.

Example 3a: Pretreatment with plasticizer (no crosslinker):

100 g xylan fraction + 900 g water + 37 g glycerine.

OTR measurements: 20.5 cc/m^2 24h with a film thickness of 123 micrometers.

Mechanical measurements: Film thickness 140 micrometers; E-module 44.4 N/mm^2; Breaking stress 1.6 N/mm^2; Elongation at break 11.9%.

Example 3b: Pretreatment with plasticizer and crosslinker

100 g xylan fraction + 900 g water + 20 g glyoxal (40%) + 25 g glycerine.

OTR measurements: 12.7 cc/m^2 24 h with a film thickness of 73 micrometers.

Mechanical measurements: Film thickness 110 micrometers; E-module 141.7 N/mm^2; Breaking stress 4.7 N/mm^2; Elongation at break 10.5%.

Example 3c: Pretreatment with alternative plasticizer and crosslinker

100 g xylan fraction + 900 g water + 18 g glyoxal (40%) + 37 g sorbitol.

Mechanical measurements: Film thickness 180 micrometers; E-module 282 N/mm^2; Breaking stress 7.7 N/mm^2; Elongation at break 17.2%.

Example 3d: Pretreatment with plasticizer, crosslinker and additive

100 g xylan fraction + 383 g water + 11 g glyoxal (40%) + 51 g glycerine + 25 g Barrisurf (25%).

OTR measurements: 11.8 cc/m^2 24 h with a film thickness of 99 micrometers.

Mechanical measurements: Film thickness 250 micrometers; E-module 31.3 N/mm^2; Breaking stress 1.1 N/mm^2; Elongation at break 12.9%.

Example 3e: Pretreatment with alternative xylan compound and plasticizer

100 g commercially available beech xylan (Sigma Aldrich, X4252) + 900 g water + 20 g glycerine.

It was not possible to do any measurements on the films due to their brittleness, demonstrating the importance of xylan source.

Example 3f: Mixability with a bioplastic without pretreatment

A film was made from dry unmodified xylan fraction in powder form and Ecoflex F Blend A1200 at a ratio of 1:1 (by weight) by pressing the materials between two heated metal blocks. Temperature was 130ºC. The resulting film was folded and again pressed into a film. This was repeated twice. The final film was not homogeneous in the sense that particles consisting of the xylan fraction were visible.

The described “heat pressing” method is used for evaluating thermal properties of a material and its compatibility with the compounding process.

Example 3g: Mixability with a bioplastic with added plasticizer

A film was made from dry unmodified xylan fraction in powder form, glycerine and Ecoflex F Blend A1200 at a ratio of 1:1:2 (by weight) by pressing the materials between two heated metal blocks. Temperature was 130ºC. The resulting film was folded and again pressed into a film. This was

repeated twice. In contrast to example 3f, the final film was homogeneous and no larger particles were visible. The inventors have interpreted the behavior as the added plasticizer lowers glass transition temperature of the xylan fraction enabling easier processing.

Example 3h: Mixability with a bioplastic with crosslinking pretreatment

A film was prepared as described in example 3b. The film was cut into smaller pieces and pressed between two heated metal blocks (110 ºC) together with PCL at a ratio of 1:1 by weight. The resulting film was folded and again pressed into a film. This was repeated twice. In contrast to example 3f, the resulting film was homogeneous and no particles were visible. The same procedure was repeated with Ecoflex at 130 ºC with similar results but a slightly darker color of the film.

Example 3i: Mixability with a bioplastic with crosslinking pretreatment

900g water + 100g xylan fraction + 2 g $Al_2(SO_4)_3$ + 50g Glyoxal + 40 g glycerine. Xylan fraction was reacted with glyoxal, $Al_2(SO_4)_3$ (which is used as a catalyst for the crosslinking reaction with glyoxal) and glycerine in water in order to increase crosslinking. A transparent clear film was cast from the solution.

The cast film was cut in small pieces and mixed with Ecoflex granules (1:1 by weight). The mixture was heat pressed at 130 ºC, cut in small pieces and pressed again to give a flexible and homogeneous brownish film. The xylan fraction content in the final product was approximately 25%.

Example 4: Compounding with biodegradable plastics

Example 4a-c describe non-limiting examples of compounding a xylan fraction, comprising xylan compounds and originating from a cooking liquor of a pulping process, together with a biodegradable plastics according to the invention. Compounding was done under industrial conditions and produced granules suitable for e.g. blown film extrusion.

Compounding was done using a 26 mm co-rotating twin screw compounder (LTE26-48) from LabTech Engineering Co., Ltd. The compounder had 12 barrel zones equipped with individually controllable heating. Gravimetric feeders supplied material at zone 1 (main feeder) and zone 3 (side feeder). Side feeder is equipped with Teflon coated co-rotating

screws. Vacuum is applied at zone 10. The die produces two 5 mm strands that are cooled in a water bath (LW-100) at room temperature and pelletized in a standard strand pelletizer (LZ-120).

The xylan fraction used in the examples has been pretreated by bleaching and unless stated otherwise also by wet milling in ethanol according to example 2.

It has been an objective for the inventors to maximize the content of xylan fraction in the granules, thus maximizing the xylan compound content and creating so called master batches. Master batches may have a significantly higher content than what is envisioned in a final extruded film.

Example 4a: Compounding xylan fraction with Ecoflex.

Ecoflex F Blend A1200 has been successfully compounded with 5-30% xylan fraction. Wet milled as well as spray dried xylan fraction have been compounded successfully with Ecoflex. Here, process settings using spray drayed xylan fraction is exemplified. The xylan fraction used had a moisture content of less than 5% and an average particle size of 50µm as it was added to the compounder.

The xylan fraction was fed into the Ecoflex melt through a side feeder at zone 3. Retention time for the xylan fraction was approximately 30 seconds. Other process settings are shown in table 4-1. The compounded material was cooled in a water bath and granulated.

With a xylan fraction content of up to 20% by weight the result was homogeneous uniform beige to brown granules. With xylan fraction content of 25-30% granules became increasingly porous, which is undesirable and should be avoided.

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	DIE	
Set value	135	125	120	115	110	115	115	115	115	110	110	115	°C
Melt temp		135		127		132		126		122		124	°C

Side feeder (Zone 1)	Xylan fraction
Main feeder (Zone 3)	Ecoflex F Blend A1200

Die pressure	39	bar	Screw speed	485	rpm
Vacuum	-0.2	bar	Output	15	kg/h

Table 4-1

Films for evaluation were produced from the granules both using blown film extrusion as detailed in example 5, and by pressing granules between two heated (130 ºC) metal blocks under high pressure. From the produced films, it was found that the xylan fraction content surprisingly did not have such a negative effect on mechanical properties as could be expected, although at higher concentrations there was a noticeable impairment.

Another favorable effect seen from compounding was that water had minimal effect on the compounded films, which was not the case for films prepared by solvent evaporation as described below, indicating that Ecoflex encapsulates the xylan fraction reasonable well during compounding. When immersed in water a cast film, produced by blending Ecoflex dissolved in dichloromethane with the xylan fraction and letting the solvent evaporate, the incorporated xylan fraction would partially dissolve.

Example 4b: Compounding with biodegradable plastics in the presence of a plasticizer

Plasticizers may have a positive effect on the compounding process. The inventors have found that by adding a plasticizer, glass transition temperature of a xylan fraction may be altered allowing for easier compounding and better properties of the end product, such as homogeneity. Effect on the xylan fraction with a glycerine content of 5-50% has been tried. A positive effect seen from the addition of glycerine during compounding is the ability to incorporate a larger amount of xylan fraction into the compounded product while maintaining desirable properties. It is understood that the maximum limit is influenced by a number of parameters besides the addition of plasticizers, such as choice of biopolymer, process temperatures, screw configuration, moisture content, etc.

In one example, the xylan fraction was pre-blended with glycerine at a ratio of 9:1 by weight and compounded with the biodegradable plastic Ecoflex F Blend A1200. For reference purposes, granules were also produced using identical process settings but using xylan fraction without added glycerine. With compounding settings as detailed in table 4-2, it was found possible to produce granules with negligible porosity with up to 35% xylan fraction with glycerine in comparison to 27% xylan fraction without glycerine, showing the benefit of adding plasticizer.

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	DIE	
Set value	135	125	125	120	115	110	115	115	115	110	110	115	°C
Melt temp		132		124		133		126		120		125	°C

Side feeder (Zone 1)	Xylan fraction:Glycerine (9:1)
Main feeder (Zone 3)	Ecoflex F Blend A1200

Die pressure	31	bar	Screw speed	485	rpm
Vacuum	-0.2	bar	Output	15	kg/h

Table 4-2

Example 4c: Compounding with biodegradable plastics having a low melt temperature

Due to poor thermal stability of certain xylan compounds it is desirable to maintain as low process temperatures as possible during compounding and extrusion. Ecoflex F Blend A1200 has a melting point of 110-120°C and becomes increasingly more difficult to process at temperatures close to its melting point. To be able to lower process temperatures below Ecoflex's normal process window it has been found favorable to blend Ecoflex with a biopolymer with lower melting point, such as PCL (polycaprolactone) with a melting point of 60-70°C. In one example PCL (TONE Polymer P-787, Union Carbide Corp.) granules was mixed with Ecoflex granules at a ratio of 1:3 and compounded. This compound was possible to process at temperatures around 100°C of the melt, i.e. 20-30°C below what has been achieved for pure Ecoflex. The lowered temperatures were found to have a favorable effect on the result when compounding the Ecoflex:PCL mixture with xylan fraction using settings detailed in table 4-3. A reduced tendency to aggregate into larger particle clusters was observed for the xylan fraction, giving a more homogeneous xylan fraction distribution in the granules. Reduced temperature also produced granules with less coloration, indicating less influence on the xylan fraction from the process. In this example, compounded material has been produced with xylan fraction content from 10% to 30%.

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	DIE	
Set value	130	115	110	110	100	90	95	95	90	90	90	95	°C
Melt temp		112		100		106		107		102		109	°C

Side feeder (Zone 1)	Xylan fraction
Main feeder (Zone 3)	Ecoflex:PCL (3:1)

Die pressure	34	bar	Screw speed	500	rpm
Vacuum	-0.25	bar	Output	20	kg/h

Table 4-3

In yet another example comprising PCL but no Ecoflex, i.e. pure PCL, compounding temperatures could be maintained at even lower temperatures than in the example above, i.e. below 100°C of the melt for the most part. Such low process temperature was seen to have a positive effect on the maximum amount of xylan fraction possible to incorporate into the film. In one example 50% xylan fraction was compounded with PCL with settings according to table 4-4. With increased xylan fraction content, the strand became increasingly more brittle and at 65% the strand would not hold.

The compounded PCL:xylan fraction blend showed significantly less darkening of the product compared to compounds processed at higher temperatures, indicating less damage to the xylan compound in the xylan fraction. Films produced by pressing the compounded material (50% xylan fraction content) between heated metal blocks showed that the xylan fraction present in the compounded material would have a noticeable impact on mechanical properties of the material such as lowered tear strength, elongation at break, breaking stress, etc compared to a pure PCL film. Still, PCL may be a suitable carrier plastic when producing master batches due to the ability of carrying a substantial amount of xylan fraction.

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	DIE	
Set value	120	115	110	90	90	90	90	90	90	90	90	85	°C
Melt temp		107		93		100		97		99		92	°C

Side feeder (Zone 1)	Xylan fraction
Main feeder (Zone 3)	PCL (TONE Polymer P-787)

Die pressure	11	bar	Screw speed	392	rpm
Vacuum	-0.2	bar	Output	15	kg/h

Table 4-4

Example 5: Blown film extrusion using compounded granules

A conventional non-oscillating co-extrusion film blowing line has been used to produce films from granules comprising xylan fraction under industrial conditions. The extruder had a 70mm tool and 25mm screws. Slip and anti-block additives have been added to enhance the film properties and lower the load on the screws during extrusion. Screw speed and extruder temperatures according to table 5-1.

Pre-compounded granules of Ecoflex F Blend A1200 (BASF) and xylan fraction as described in example 4a were fed into the film blowing line along with slip and anti-block additives (talc and erucamid). For reference, xylan-free reference films were also produced.

				Screws							Tool			
				Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6		Zone 1	Zone 2	Zone 3	
Left	Screw speed:	25	rpm	145	148	148	148	148	148	°C	148	145	145	°C
Right	Screw speed:	25	rpm	145	148	148	148	148	148	°C				

Table 5-1

Material composition of the xylan fraction comprising film was as follows:

86.5% Ecoflex F Blend A1200
10% Xylan fraction
3% Talc
0.5% Erucamid

Material composition of the reference films were as follows:

96.5% Ecoflex F Blend A1200
3-4% Talc
0.2-0.5% Erucamid

Thicknesses, calculated from weight and area of the film and densities of each component in the films, were produced in the range from 15 to 50 micrometer.

The reference film was uncolored while the xylan fraction comprising film had a beige color. As the xylan fraction used in this example had not been chemically modified in order to enhance thermal properties and no plasticizer was added, the xylan fraction would not blend fully with Ecoflex. The xylan fraction could be seen predominantly as particles or small clusters evenly distributed in the film.

Mechanical properties were tested according to ISO 527-3 with 50 mm sample length. Breaking stress was found to be 36MPa in TD (transverse direction) and 34MPa in MD (machine direction), which is comparable with the reference film. Elongation at break was found to be 580% in TD and 320% in MD. In TD elongation at break is comparable with the reference film, while in MD the reference film had a significantly higher value of approximately 550%. The difference in MD is likely caused by inhomogeneities from particles.

The WVTR barrier property of the film was found to be excellent, exceeding that of the reference film and other bioplastic films based on aliphatic-aromatic branched copolyesters. WVTR measurements were conducted according to ASTM E 96, ISO 2528, and TAPPI T448 at a temperature of 38°C and 90% RH on the front side of the sample and 0% RH on the back side. Three parallel measurements on each sample. Samples consisted in constructions where the polymer film is sandwiched between two standard paper plies. Figure 1 shows the results from the WVTR measurements where a low value is better. The film comprising the xylan fraction has a significantly lower value than the two reference films.

The above examples surprisingly show that it is possible to form a compounded material from a biodegradable plastic and a xylan compound, and also produce films with satisfactory mechanical properties and barrier properties.

CLAIMS

1. A polymeric product comprising:
a xylan compound originating from a cooking liquor of a pulping process of a lignocellulosic material; and
at least one biodegradable plastic,
characterized in that the polymeric product is compounded.

2. A compounded polymeric product according to claim 1, comprising 1-80 wt%, such as 1-40 wt% or 40-80 wt%, of said xylan compound.

3. A compounded polymeric product according to any previous claim, wherein pulping process neutral sulphite is semichemical pulping (NSSC pulping) or Kraft pulping.

4. A compounded polymeric product according to any previous claim, wherein said lignocellulosic material is hardwood material.

5. A compounded polymeric product according to any previous claim, wherein the xylan compound has been extracted from the cooking liquor by ultrafiltration and optional washing with ethanol.

6. A compounded polymeric product according to any previous claim, wherein the xylan compound has been pretreated by at least one process selected from bleaching, esterification including acetylation, succinoylation, sulfation, tosylation, nitration, and xanthation, etherification including hydroxypropylation, benzylation, carboxymethylation, sulfoalkylation and cyanoethylation, and grafting with polymeric species.

7. A compounded polymeric product according to any previous claim, further comprising at least one crosslinking agent and/or chain extender, e.g. a crosslinking agent selected from the group consisting of glyoxal, glutaraldehyde, epichlorohydrin with ethanolamine/ethanol, polymer resins, polyamines and cationic starch and polyvalent metal ions and/or a chain extender selected from Joncryl, BioAdimide, and Allinco.

8. A compounded polymeric product according to any previous claim, further comprising at least one plasticizer, e.g. a plasticizer selected from the group consisting of glycerine, sorbitol, diethylene glycol, polyethylene glycol, urea and water.

9. A compounded polymeric product according to any previous claim, further comprising an additive selected from the group consisting of antioxidants, slipping agents, hydrophobifying agents, anti-block agents, waxes, nucleation agents, inorganic and organic fillers and pigments.

10. A compounded polymeric product according to any previous claim, further comprising lignin or lignosulfonate.

11. A compounded polymeric product according to any previous claim, further comprising an additive having a melting point of less than 100 °C, such as PCL.

12. A compounded polymeric product according to any previous claim, wherein the at least one biodegradable plastic is/are selected from the group consisting of biodegradable aliphatic-aromatic branched copolyesters, such as Ecoflex, polylactide/polylactide acid (PLA), polycaprolactone (PCL), poly(butylene succinate) (PBS), starch-based bioplastics and polyhydroxyalkanoates (PHAs), such as poly-3-hydroxybutyrate (PHB), polyhydroxyvalerate (PHV), polybutylenesuccinate (PBS) or polyhydroxyhexanoate (PHH), or blends thereof.

13. A compounded polymeric product according to any previous claim, wherein the biodegradable plastic(s) is/are not starch or starch-based.

14. A compounded polymeric product according to any previous claim, wherein the biodegradable plastic(s) is/are not a polysaccharide.

15. A compounded polymeric product according to any previous claim comprising less than 5 % by weight of non-xylan polysaccharides.

16. A polymeric film composed of the compounded polymeric product according to any one of claims 1-15.

17. A polymeric film according to claim 16, which is produced by blown film extrusion, cast film extrusion or extrusion coating.

18. A polymeric film according to claim 16 or 17 having a thickness of less than 500 µm, such as less than 100 µm, such as less than 60 µm, such as less than 30 µm.

19. A sack having a wall comprising at least one paper ply and a film according to any one of claims 16-18.

20. A sack according to claim 19, wherein the wall comprises two paper plies and the film is arranged between the plies.

21. Use of a film according to any one of claims 16-18 for mulching.

22. A plastic bag composed of a film according to any one of claims 16-18.

23. Use of a plastic bag according to claim 22 for enclosing compostable waste.

24. A laminate comprising a layer of a film according to any one of claims 16-18 adhered to a paper ply.

25. A bag composed of the laminate according to claim 24.

26. A compounded melt or granules comprising the compounded polymeric product according to any one of claims 1-15.

27. A compounded melt or granules according to claim 26, which comprises at least 10 % (w/w), such as at least 30 % (w/w), such as at least 40 % (w/w) of the xylan compound.

28. A method of producing a film, comprising blown film extrusion of a compounded polymeric product according to any one of claims 1-15.

29. A method according to claim 28, wherein a pressure below 200 bar, such as below 100 bar or 50 bar is used in the blown film extrusion process.

30. A method according to claim 28 or 29, wherein an extruder equipped with a double lip cooling air ring is employed for the blown film extrusion process.

31. A method according to any one of claims 28-30, wherein the the blow-up ratio is in the range of 1.5-5, such as 2-3.

32. A method according to any one of claims 28-31, wherein the temperatures are in the range of 60-250°C, such as or 100-160°C or 140-190°C, in the blown film extrusion process.

33. A method for preparing a polymeric product comprising: compounding a xylan compound originating from a cooking liquor of a pulping process of a lignocellulosic material with at least one biodegradable plastic to provide said polymeric compound.

34. A method according to claim 33, wherein said compounding comprises mixing said xylan compound and said at least one biodegradable plastic during heating at an elevated temperature in the range of 70-250 °C, such as 110-190 °C or 80-150 °C.

35. A method according to claim 34, wherein said xylan compound is compounded at the elevated temperature during less than 5 minutes, such as less than 60 seconds, such as less than 40 seconds.

36. A method according to any one of claims 33-35, wherein the xylan compound is as defined in any one of claims 3-5.

37. A method according to any one of claims 33-36, wherein the at least one biodegradable plastic is/are as defined in any one of claims 11-14.

38. A method according to any one of claims 33-37, further comprising pretreating said xylan compound prior to compounding, wherein the pretreatment comprises at least one process selected from bleaching,

esterification including acetylation, succinoylation, sulfation, tosylation, nitration, and xanthation, etherification including hydroxypropylation, benzylation, carboxymethylation, sulfoalkylation and cyanoethylation, and grafting with polymeric species.

39. A method according to claim 38, wherein said crosslinking pretreatment comprises reacting the xylan compound with a crosslinking agent, e.g. a crosslinking agent selected from the group consisting of glyoxal, glutaraldehyde, epichlorohydrin with ethanolamine/ethanol, polymer resins, polyamines and cationic starch and polyvalent metal ions.

40. A method according to any one of claims 33-39, wherein a chain extender, such as Joncryl, BioAdimide or Allinco, is co-compounded with the xylan compound and the at least one biodegradable plastic to provide said polymeric product.

41. A method according to any one of claims 33-40, wherein at least one plasticizer is co-compounded with the xylan compound and the at least one biodegradable plastic to provide said polymeric product.

42. A method according to claim 41, wherein the plasticizer is selected from the group consisting plasticizer, e.g. a plasticizer selected from the group consisting of glycerine, sorbitol, diethylene glycol, polyethylene glycol, urea and water.

43. A method according to any one of claims 33-42, wherein steam is added prior to or during the compounding.

44. A method according to any one of claims 33-43, further comprising addition of an additive selected from the group consisting of antioxidants, slipping agents, hydrophobifying agents, anti-block agents, waxes, nucleation agents, inorganic and organic fillers and pigments.

45. A method according to any one of claims 33-44, wherein the compounding is part of a blown film extrusion, a cast extrusion, an extrusion coating, such as direct extrusion paper lamination or dye-cut coating, or a production of granules.

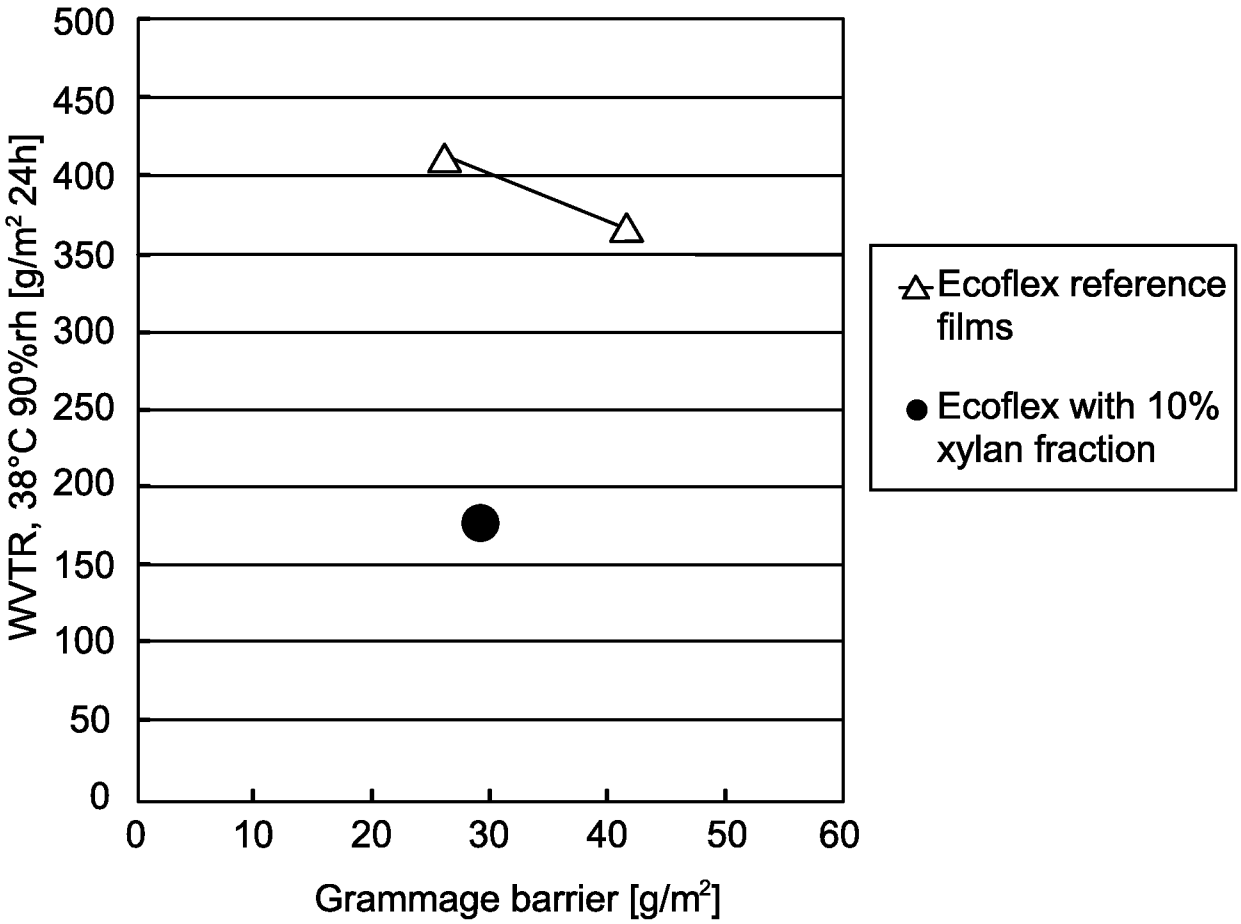

500
450
400
350
300
250
200
150
100
50
0
WVTR, 38°C 90%rh [g/m² 24h]
0
10
20
30
40
50
60
Grammage barrier [g/m²]
Ecoflex reference films
Ecoflex with 10% xylan fraction

Fig. 1