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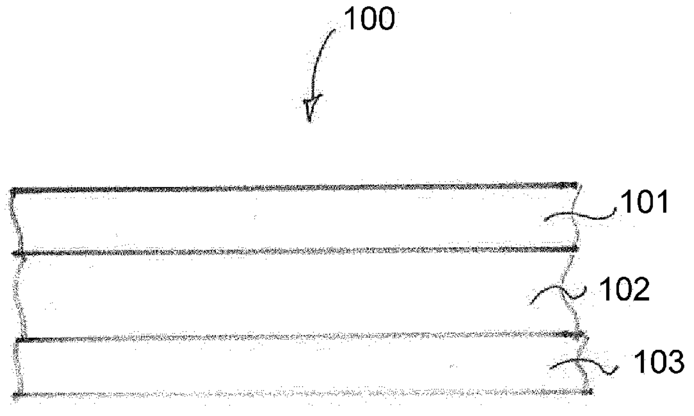

Figure 1

(57) Abstract: There is provided a polyethylene-based film useful in the production of silage, said film comprising polyethylene at a content of 60-90 % by weight of the film, wherein the polyethylene is selected from linear low density polyethylene (LLDPE) and low density polyethylene (LDPE) and combinations thereof, and a dicyclopentadiene hydrocarbon resin at a content of 3-20 % by weight of the film. The film has good oxygen barrier properties and is useful in production of silage.

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POLYETHYLENE-BASED BARRIER FILM USEFUL IN THE PRODUCTION OF SILAGE

Field of the invention

The present invention relates to protective films for use in agriculture, in particular silage production.

Background

Plastic film is used for many different purposes. For example, plastic stretch film is frequently used in different fields of application, in particular for wrapping various products, for example wrapping goods for shipping or storing, or for wrapping agricultural bulk products, such as grass, straw, various crops, etc. In agricultural applications, stretch film may for instance be used as fodder protection and silage film. For the production of silage, anaerobic conditions are desirable, and so the film should provide a barrier against moisture and oxygen.

Silage can be produced and stored in the form of bales or in a bunker silo or a pit silo. In the production of baled silage, a baler is first used to form a compact bale of the crop/vegetable product intended to be ensiled, and the bale is subsequently wrapped tightly with net, twine or film to retain the shape of the bale. Once the net, twine or film is lying around the bale, the formed bale is ejected from the baling chamber. The bale is then wrapped with an agricultural stretch wrap film using a bale wrapper. In the bale wrapper the agricultural stretch wrap film is stretched, typically in the range of 50-75% and the stretched agricultural stretch wrap film is wrapped multiple turns around the bale to form an airtight and waterproof bale suitable for silage production. For production of silage in silos, a large volume of crop (e.g. grass) is deposited in an open bunker, or formed into a heap on the ground, and subsequently covered with a protective silage film to provide an airtight cover. The crop may be compacted prior to covering with the protective film. The film is often secured by placing heavy objects, such as tyres, on top of the film.

Conventionally, agricultural silage films are made primarily of one or more polymers, in particular polyolefins (e.g. polyethylene). The polyolefin is extruded and blown to form a tubular film. Usually various additives such as pigments, tackifiers, UV stabilizers, etc, are added to the film composition in order to meet the requirements of the intended use. Silage films typically contain UV stabilizers, and often pigments to reflect sunlight and/or to reduce transmission of sunlight into the bale or silo. Stretch film for baled silage also requires high cling, and high mechanical performance in terms of good resistance to puncturing and tearing. Also for use in bunker or pit silos the mechanical properties of the film are of importance.

Conventionally, silage films have consisted of a single layer, although in recent years multilayer films for silage applications have emerged. Nevertheless, current silage films allow leakage of oxygen into the bale which results in undesirable aerobic decomposition of the crop. Even under good conditions, up to 5 % of the nutritional value of the silage may be lost due to such oxygen leakage. This also means a considerable economic loss for the farmer. For baled silage, one or more extra turns of wrapping film can be applied around the bale to increase protection and reduce oxygen leakage into the bale. However, using more film increases the materials cost, and a more time-consuming wrapping procedure also means an economic loss.

As an alternative, special oxygen barrier films are available, containing a core layer of an oxygen barrier material such as ethylene-vinyl alcohol or polyamide. However, such films are relatively expensive and may be difficult to produce, process and/or recycle due to the content of ethylene-vinyl alcohol or polyamide.

Hence, there is a demand for silage films with improved barrier properties.

Summary of the invention

It is an object of the present invention to at least partly overcome the problems in the prior art, and to provide a film with mechanical properties suitable for use as a silage film and which offers desirable barrier properties.

According to a first aspect of the invention, this and other objects are achieved by a polyethylene-based film useful in the production of silage, said film comprising polyethylene at a content of 60-90 % by weight of the film, wherein the polyethylene is selected from linear low density polyethylene (LLDPE) and low density polyethylene (LDPE) and combinations thereof, and a dicyclopentadiene hydrocarbon resin at a content of 3-20 % by weight of the film.

The present inventors surprisingly found that by including dicyclopentadiene hydrocarbon resin in a film based on linear low density polyethylene (LLDPE) and optionally low density polyethylene (LDPE), considerably improved oxygen barrier property was obtained, while preserving the excellent mechanical properties of polyethylene of low density making the film useful as a silage film. It was found that the oxygen transmission rate was reduced by up to 35-40 % compared to films that did not contain the dicyclopentadiene hydrocarbon resin. Meanwhile, the strength at break (MD and TD, respectively) was largely unaffected or only slightly decreased, elongation at break was largely unaffected or slightly increased, and Elmendorf tear strength was largely unaffected.

As used herein, “low density” when referring to polyethylene typically refers to a density of 0.930 g/cm^3 or less, such as 0.925 g/cm^3 or less.

In addition, the it was found that during production of the film using a blown film co-extrusion process that the extruder engine intensity decreased by 15 % in the three screws used, and the pressure before the filter also decreased in all three screws used. This may allow a further increase of the output of one or more of the screws, so as to produce layer(s) of higher thickness. Increasing the relative thickness of a layer comprising mainly mLLDPE may improve the mechanical properties of the film. Alternatively, a reduced engine intensity means energy savings.

Advantageously, a film according to the present invention is readily recyclable, and the polyethylene content can be recycled in its entirety. The films according to the invention may further be free of conventional barrier materials such as, for instance, ethylene vinyl alcohol (EVOH) or polyamide, which are not easily recyclable and/or obstructs recycling of the polyethylene content of such conventional barrier films.

At least part of the polyethylene content of the film may originate from regranulated polyethylene, that is, recycled polyethylene. The regranulated polyethylene may contain a combination of linear low density polyethylene (LLDPE) and low density polyethylene (LDPE), and may have a density of up to 930 g/cm^3 s, such as in the range of from 0.860 to 0.930 g/cm^3.

According to preferred embodiments, the dicyclopentadiene hydrocarbon resin has a softening point in the range of 100-145 °C, preferably 130-145 °C. A dicyclopentadiene hydrocarbon resin having a softening point above 130 °C, such as between 130-145 °C, may have increased barrier properties.

In embodiments, the film comprises a dicyclopentadiene hydrocarbon resin at a content of 4.5-15 % by weight of the film, such as 5-15 % by weight of the film, such as 6-13 % by weight of the film. A film having more than

In embodiments, the dicyclopentadiene hydrocarbon resin is at least 90 % hydrogenated.

In embodiments, the dicyclopentadiene hydrocarbon resin originates from thermal cracking of hydrocarbons, such as naphtha.

In embodiments, the film comprises at least one layer containing a mixture of linear low density polyethylene and dicyclopentadiene.

In embodiments, the dicyclopentadiene hydrocarbon resin is present at a content of 5-13 % by weight of the film.

In embodiments, the film has an oxygen gas transmission rate (OTR) of 250 $cm^3/m^2/24h$ or less, as measured according DIN 53380-3 using air instead of oxygen gas. As an example the film may have an OTR of 200 $cm^3/m^2/24h$ or less, such as an OTR of 160 $cm^3/m^2/24h$ or less. A film having such OTR levels may have a thickness of about 90-150 µm, such as about 100-120 µm, such as about 110 µm.

In embodiments, the film is a multilayer film, preferably comprising at least a first outer layer, a second outer layer, and a core layer arranged between said first outer layer and said second outer layer.

In embodiments, the film has a thickness in the range of from 15 to 180 µm. As an example, the film may have a thickness that is more than 70 µm, such as more than 80 µm.

The film may further comprise pigments. The film may further comprise dyes. The film may further comprise fillers. The film may further comprise UV stabilizers. The film may further comprise tackifiers. The film may further comprise slip agents. The film may further comprise nucleating agents. The film may further comprise processing aids. Thus, in embodiments, the film further comprises one or more additives selected from pigments, dyes, fillers, UV stabilizers, tackifiers, slip agents, nucleating agents, and processing aids.

In embodiments, the film comprises one or more pigments at a content of from 3 to 10 % by weight of the film, such as from 5 to 7 % by weight of the film.

In embodiments, the film has a density in the range of from 0.920 to 1.00 kg/m^3.

In embodiments, the film has a thickness in the range of from 80 to 180 µm, preferably from 90 to 125 µm and optionally a width in the range of 5-20 m, preferably 6-18 m.

In embodiments, the film is cut to a length of 400 m or less, preferably 100 m or less.

In embodiments, the film has a thickness in the range of from 15 to 30 µm and optionally a width in the range of from 500 to 1500 mm, preferably 500-750 mm or 1100 to 1500 mm.

As an example, the film may be cut to a length of 1500-2500 m, preferably 1800-2200 m.

In embodiments, the film is prestretched.

In embodiments, the film is a stretch film.

Typically, the film according to embodiments of the present invention allows an anaerobic environment to be formed and thereby nutrients and energy content of the silage to be preserved during storage. A silage film should form a gas barrier, in particular an oxygen barrier. The oxygen barrier properties can be measured according to known standards, such as ASTM D3985 or DIN 53380-3. A silage film as disclosed herein may have an oxygen transmission rate (OTR) of 10 000 cm^3/m^2/24h or less as determined according to DIN 53380-3.

A silage film according to embodiments of the present invention suitable for use as a stretch wrap silage film for baling may have an oxygen permeability of less than 10 000 cm^3/m^2/day, such as within the range of from 1 000 to

10 000 $cm^3/m^2/24$ h measured according to DIN 53380-3 Stretch wrap films are thin, but are wrapped multiple turns around a bale.

Silage films for bunker or pit silos, on the other hand, are typically thicker than stretch wrap silage films, and as such may have an OTR which is considerably lower than a thin stretch wrap film. Silage films according to the invention suitable for use in such applications may have an OTR of 250 cm^3/m^2/day or less as determined according to DIN 53380-3.

The film may be a monolayer film or a multilayer film, and may be produced by conventional means, such as cast extrusion or blow extrusion. According to an embodiment, the polyethylene film is a coextruded multi-layer blown film comprising at least two layers. Preferably, the polyethylene film is a multi-layer film comprising at least three layers: at least one core layer arranged between two exterior layers.

Thus, the multilayer film may comprise at least a first outer layer, a second outer layer, and a core layer arranged between said first outer layer and said second outer layer. The core layer may comprise low density polyethylene (LDPE), such as LDPE originating from regranulated polyethylene.

Furthermore, at least two layers of the multilayer film may comprise the dicyclopentadiene hydrocarbon resin. As an example, all layers of the film may comprise the dicyclopentadiene hydrocarbon resin. It has been found that it is advantageous to put dicyclopentadiene in all layers since too much dicyclopentadiene in the same layer may decrease the tear resistance of the film.

In embodiments, no single layer of the multilayer film comprises more than 20 % of the dicyclopentadiene hydrocarbon resin. As an example, all layers of the film comprise the dicyclopentadiene hydrocarbon resin and no single layer of the multilayer film may comprise more than 20 % of the dicyclopentadiene hydrocarbon resin.

In embodiments, the dicyclopentadiene hydrocarbon resin is present in an amount that is less than 20% such as less than 15%, in all layers of the film. Thus, dicyclopentadiene may be present in all layers but to an amount that is less than 20%, such as less than 15%, in each layer. Having an amount of dicyclopentadiene hydrocarbon resin in an amount that is above 20 % in a single layer may lead to a decrease in tear resistance of the film.

As an example, the dicyclopentadiene hydrocarbon resin may be present at a content of 5-13 % by weight of a multilayer film.

As an example, the multilayer film may be polyethylene-based film consisting of a first outer layer, a second outer layer, and a core layer arranged between said first outer layer and said second outer layer; wherein said outer layers comprises linear low density polyethylene (LLDPE) and said dicyclopentadiene hydrocarbon resin. The LLDPE may give the film desired mechanical properties and bubble stability.

The core layer arranged between said first outer layer and said second outer layer may comprise low density polyethylene (LDPE). Further, the core layer may also comprise the dicyclopentadiene hydrocarbon resin. The low density polyethylene (LDPE) of the core layer may originate from regranulated polyethylene. Furthermore, when using LDPE that originates from regranulates, it is advantageous to have the dicyclopentadiene in all layers since too much dicyclopentadiene in the same layer may decrease the tear resistance of a film with regranulates.

Consequently, the polyethylene-based film may be a multilayer film having a three-layer structure, in which the first and second outer layers comprises LLDPE and the dicyclopentadiene hydrocarbon resin and wherein the core layer comprises the dicyclopentadiene hydrocarbon resin and LDPE that originates from regranulated polyethylene.

By the term “mechanical properties” or “mechanical performance” is herein mainly meant the mechanical strength of the material, measured in terms of at least one of tensile strength, tear strength and puncture resistance. Tensile strength, measured as force per unit area, is defined as the maximum stress that a material can withstand while being stretched or pulled before failing or breaking. Tear strength, typically measured as force per unit length, is defined as the resistance of a material to the growth of e.g. a cut when under tension. Elongation at break is defined as the ultimate elongation (given as percentage of the initial length) of a material before it breaks under tension. Puncture resistance, typically measured as mass per unit length, is defined as the relative ability of a material to withstand a falling dart without breaking.

According to an embodiment, the prestretched polyethylene film is a silage film, such as an agricultural bale wrap film or a silage cover film for use in a bunker silo or a pit silo.

In another aspect, the invention provides use of a film as defined herein as a protective film for the production of silage.

In embodiments, the use of the film is for covering a pit silo or a bunker silo.

In embodiments, the use of the film is for wrapping of silage bales.

It is noted that the invention relates to all possible combinations of features recited in the claims.

Brief description of the drawings

The invention will hereinafter be described in detail by reference to exemplary embodiments as illustrated in the following drawings, in which:

Fig. 1 is a schematically illustrates, in cross-section, a multilayer film according to embodiments of the present invention.

Fig. 2 is a schematic illustration of a production line for producing a film according to embodiments of the invention.

Detailed description

Preferred embodiments of the invention will now be described in more detail. The invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided for thoroughness and completeness, and fully convey the scope of the invention to the skilled person.

Fig. 1 schematically illustrates, in cross-section, a film, for instance a silage film, according to embodiments of the present invention. the film 100 is a multilayer film comprising three layers: a first outer layer 101, a middle layer or core layer 102, and a second outer layer 103. The first and second outer layers are arranged on opposing sides of the core layer, and in this embodiment having only three layers, are in contact with the core layer while each outer layers forms an exterior surface of the film. The outer layers 101, 102 may be referred to as outermost layers or skin layers. However, in embodiments having more than three layers, e.g. five or seven layers, additional skin layers may be provided outwardly of the outer layers 101, 103 in relation to the core layer. Alternatively, or additionally, additional layers may be provided in the form of additional core layers, e.g. on opposing sides of the core layer 102 but in between the outer layers 101, 103.

The layers 101, 102, 103 may have the same or different composition. Each of the layers 101, 102, 103 may comprise, as a base material, a polyethylene or a blend of polyethylenes, having a density of up to 0.930 g/cm^3, such as from 0.860 to 0.930 g/cm^3 or to 0.925 g/cm^3. The polyethylene or blend of polyethylenes may include virgin polyethylene material such as metallocene catalyzed LLDPE (mLLDPE) or Ziegler-Natta catalyzed LLDPE (znLLDPE), or recycled polyethylene material, which may comprise a blend of LLDPE and LDPE. The outer layers 101, 103 may contain mLLDPE as base material.

The core layer(s) may contain as base material a blend of LLDPE and LDPE obtained from recycled polyethylene.

Linear low density polyethylene ("LLDPE") comprises, in polymerized form, a majority weight percent of ethylene based on the total weight of the LLDPE. LLDPE can be an interpolymer of ethylene and at least one ethylenically unsaturated comonomer. The comonomer can be a C3-C20 α-olefin. Alternatively, the comonomer can be a C3-C8 α-olefin. The C3-C8 a-olefin can be selected from propylene, 1- butene, 1-hexene, or 1-octene. The LLDPE used in the present invention may be selected from the following copolymers: ethylene/propylene copolymer, ethylene/butene copolymer, ethylene/hexene copolymer, and ethylene/octene copolymer. In a further embodiment, the LLDPE is an ethylene/octene copolymer.

LLDPE typically has a density in the range from about 0.890 g/cm^3 to about 0.940 g/cm^3, or from about 0.91 g/cm^3 to about 0.94 g/cm^3. LLDPE may have a melt index (MI) from about 0.1 g/10 min to about 10 g/10 min, or about 0.5g/10 min to about 5g/10 min.

LLDPE can be produced with Ziegler-Natta catalysts, or single-site catalysts, such as vanadium catalysts and metallocene catalysts (mLLDPE). In an embodiment, the LLDPE is produced with a Ziegler-Natta type catalyst. LLDPE is linear and is different than low density polyethylene ("LDPE") which is branched or heterogeneously branched polyethylene. LDPE has a relatively large number of long chain branches extending from the main polymer backbone. LDPE can be prepared at high pressure using free radical initiators, and typically has a density from 0.915 g/cc to 0.940 g/cc.

The film may contain, as a whole, polyethylene a content of 60-95 % by weight of the film, for instance from 70 to 90 %, or from 75 to 88 %. In embodiments, any one layer 101, 102 or 103 may contain from 40 to 99 % of polyethylene base material having a density of 0.930 g/cm^3 or less, such as 0.860-0.930 g/cm^3. The film may contain mLLDPE at a content of from 20 to

90 % by weight of the film. In embodiments, the film may contain mLLDPE at a content of from 20 to 40 % by weight of the film, and regranulated polyethylene material at a content of from 20 to 75 % by weight of the film.

In addition to a polyethylene base material, at least one layer of the film 100 contains a dicyclopentadiene hydrocarbon resin. In an embodiment, the core layer 102 contains a dicyclopentadiene hydrocarbon resin. In another embodiment, each of the layers 101, 102, 103 contains a dicyclopentadiene hydrocarbon resin. The total content of the dicyclopentadiene hydrocarbon resin is typically from 3 to 15 % by weight of the film. Where the dicyclopentadiene hydrocarbon resin is present in more than one layer, the content of the dicyclopentadiene hydrocarbon resin may be the same in each layer, or the content may be different in the different layers. In an embodiment, the outer layers 101, 103 may be free of dicyclopentadiene hydrocarbon resin. In embodiments of the film having more than three layers, any skin layer may be free of dicyclopentadiene hydrocarbon resin.

Dicyclopentadiene hydrocarbon resins are known and may be obtained e.g. by from thermal polymerization of olefin feeds rich in dicyclopentadiene (DCPD), or by other means e.g. as described in WO 98/55537 A1. The dicyclopentadiene hydrocarbon resin may be provided in the form of a masterbatch mixed with polyethylene, such as LLDPE. Preparation of a masterbatch is known and is described e.g. in WO 98/55537 A1. Masterbatches containing dicyclopentadiene hydrocarbon resin are commercially available.

The dicyclopentadiene hydrocarbon resin may originate from thermal cracking of hydrocarbons, such as naphtha. The hydrocarbon may be a higher hydrocarbon, such as a hydrocarbon having 5-12 carbon atoms, such as 6-12 carbon atoms. The dicyclopentadiene hydrocarbon resin may be produced by fractionating C6-C12 products produced in the process of ethylene manufacturing.

The dicyclopentadienes of the dicyclopentadiene hydrocarbon resin may comprise less than 50 %, such as less than 20 %, such as less than 10 %, such as less than 5 %, of polydicyclopentadienes (PDCPD). As an example, the dicyclopentadiene hydrocarbon resin may be free of poly-dicyclopentadienes (PDCPD)
The dicyclopentadiene hydrocarbon resin for use in the present invention may have a softening point in the range of from 100 to 140 °C, or about 140 °C. The dicyclopentadiene hydrocarbon resin may be at least partially hydrogenated, for instance at least 90 % hydrogenated. In embodiments, the dicyclopentadiene hydrocarbon resin may be at least 95 %, 99 %, or fully hydrogenated. The dicyclopentadiene hydrocarbon resin may be provided in the form a masterbatch e.g. blended with polyethylene.

One or more of the layers of the film may comprise a pigment. Suitable pigments for use in polyethylene films e.g. for silage making, are known to persons of skill in the art and include, for instance, titanium dioxide and carbon black. Different layers of the film may contain different pigments and/or amounts of pigment. In general, silage films may include a pigment providing a light colour, such as white, light blue or light green, to the side of the film intended to face outwards, such that sunlight is reflected. Hence, at least an outer layer, e.g. layer 101 may contain a pigment providing a light color. Further, silage films, in particular film intented for use in bunker or pit silos, may have a dark colored second side intended to face the crop, in order to prevent light transmission into the silo. Hence, a layer, such as the layer 103, may contain a dark pigment, such as a black pigment.

The film may optionally contain a UV stabilizer, present in one or more of the layers, e.g. in outer layer 101, and optionally in each of the layers 101, 102, 103. By the term “UV stabilization” is meant protection of a material from the long-term degradation effects from light, most frequently ultraviolet radiation (UV). A UV stabilizer may be advantageous for preventing chain reactions caused by e.g. radicals within the polyolefin layer(s) of the prestretched polyethylene film e.g. during storage outdoors of the prestretched polyethylene film.

The film may optionally contain other conventional additives, such as fillers, slip agents, tackifiers, processing aids, nucleating agents, and the like.

The film 100 may be a silage film, e.g. intended as a cover for a bunker silo or a pit silo. For this purpose, certain mechanical properties are desirable or required. The film may have one or more of the following properties: an Elmendorf tear strength (machine direction, MD) of at least 400 cN, preferably at least 500 cN; an Elmendorf tear strength (transverse direction, TD) of at least 1500 cN, preferably at least 2000 cN; a strength at break (MD and/or TD) of at least 17 MPa, preferably at least 23 MPa; an elongation at break (MD) of at least 250 %, preferably at least 500 %; an elongation at break (TD) of at least 250 %, preferably at least 500 %; and a dart resistance of at least 200 g, preferably at least 400 g.

Bunker silo films and pit silo films typically have a thickness in the range of from 80 to 180 μm, such as from 90 to 130 μm, or from 100 to 120 μm, or about 110 μm. In order to cover such a silo with a single film, the film may have a width in the range of from 5 to 20 meters, such as from 10 to 18 meters or from 12 to 18 meters. For instance, for a 12 m wide film, the film weight per meter of film may be in the range of from 1.0 to 1.5 kg/m, or from 1.2 to 1.4 kg/m. The film may be supplied at a film length up to 400 m, e.g. from 50 to 400 m.

Furthermore, the bunker silo film may be a multilayer film, such as a multilayer film comprising two outer layers sandwiching at least one core layer. As an example, the multilayer film may consist of a single core layer sandwiched between two outer layers (skin layers). The at least one core layer of a silage film may have a thickness that is between 40-60% of the whole film thickness. For example, the at least one core layer may have a thickness that is between 40-80 μm, such as between 50-70 μm, such as about 60 µm, whereas the outer layers each may have a thickness that is between 15-35 µm, such as between 15-25 µm or between 25-35 µm. The outer layers may have the same thickness or have different thicknesses.

Moreover, since a silage film of the present disclosure has a lower oxygen permeability, i.e. better barrier properties, than conventional silage films, the silage film of the present disclosure may be thinner than conventional silage films for the same application, but still have the same barrier properties as a conventional film. It may be advantageous to have a thinner silage film since such a film may be of lower weight, and therefore easier to handle and use. Therefore, a bunker or pit silo film of the present disclosure may have a thickness that is less than 100 µm, such as between 60-100 µm, such as between 70-90 µm.

In other embodiments, the film may be a stretch wrap film intended for wrapping of silage bales, also referred to as a bale wrap film. Such films are typically thinner than the abovementioned silo films, having a thickness typically in the range of from 15 to 30 µm. bale wrap films are typically provided in the form of rolls, having a film width to match the operating width of the wrapper, often from 500 to 750 mm. The length of the film on a single roll may be at least 1000 m, or at least 1500 m and up to 2500 m, or up to 2200 m.

In embodiments, the film may be prestretched. The expression prestretched film means that the film is stretched in the longitudinal direction during the film production process before being wound to a roll. Stretching is typically performed in a prestretch unit of the production line and involves passing the film between two or more stretching rollers rotating at different speeds. The prestretching may preferably be performed directly after the extrusion or film blowing steps, while the film is still hot. The degree of prestretching is intended to mean the difference in speed, in percent, between the stretching rollers in the prestretch unit. The difference in speed corresponds to the elongation of the prestretched film between the stretching rollers in the prestretch unit.

According to some embodiments, a prestretched polyethylene film may have a longitudinal degree of prestretching above 70%. The longitudinal degree of prestretching of the prestretched polyethylene film may for example be between 70% and 150%, such as between 70% and 125%, between or 70% and 100%. According to some embodiments, a prestretched polyethylene film may have a longitudinal degree of prestretching between 70% and 85%, preferably between 71% and 79%, preferably between 73% and 77%, preferably about 75%. According to some embodiments, the prestretched polyethylene film has a remaining longitudinal elongation capability of at least 320%, preferably at least 340%, as determined according to ASTM D882.

The term elongation capability as used herein means the elongation percentage at break, as measured in accordance with the ASTM D882 standard, wherein a strip of film with a width of 20 mm, clamped between two clamps at a distance of 50 mm from each other is stretched at a rate of 500 mm/min until the film breaks. At least five strips of the film must be measured, and the elongation capability corresponds to the mean value of the measurements.

According to some embodiments, the stress required in order to stretch the prestretched polyethylene film by 70% in the longitudinal direction is less than 19 MPa, preferably less than 18 MPa, as determined according to ASTM D882. The stress required in order to stretch the prestretched film by 70% in the longitudinal direction can be read from the tensile strength graph obtained when measuring the elongation percentage at break in accordance with the ASTM D882 standard as described herein. At least five strips of the film must be measured, and the stress at 70% elongation corresponds to the mean value of the measurements.

According to an embodiment, at least one outer layer, or if present, a skin layer, of the film 100 may comprise a soft polymer. A soft polymer may provide a relatively soft surface to the outer surface of the film which may increase friction and reduce slip in a direction substantially parallel to the film surface. A soft polymer may particularly be advantageous in a stretch wrap film, which in use is wrapped with an overlap such that the film may adhere, or cling, to itself. By the term “cling” is meant the ability of a material to adhere to itself or an adjacent object. The adjacent object may be a layer of the same or a different film.

According to an embodiment, the film may comprise a tackifier. By the term “tackifier” is herein meant an agent that provides cling to a film. Such an agent may be added to a layer of the polyethylene film in order to increase the cling of the layer. For instance, a tackifier may be a soft polymer, or a migrating tackifier. A tackifier thus serves to increase the cling of the polyethylene film, in particular, one or both of the outer layers or skin layers.

According to an embodiment, the tackifier is a migrating tackifier. By the term “migrating tackifier” is herein meant a tackifier which is soluble in the film material, e.g. in polyethylene. If a migrating tackifier is added to a film (or film layer) in an amount exceeding the solubility level of the film (or film layer), the excess can migrate within the film material to the film surface (including also migrating from a first layer to and through another layer, when the first layer has been saturated with the migrating tackifier). A migrating tackifier may thus provide an adhesive surface which increases the friction in a direction substantially perpendicular to the film surface. A migrating tackifier may be advantageous when the film is e.g. wrapped, such that an exterior layer of a first portion of the polyethylene film adhere, or cling, to an exterior layer of a second portion of the same, or a different, polyethylene film.

According to an embodiment, the migrating tackifier is present at a content of from 1 to 15% by weight based on the total weight of the core layer. The content of migrating tackifier added to the at least one core layer typically exceeds the content of migrating tackifier required to saturate the at least one core layer with regard to the migrating tackifier. The content required to saturate the at least one core layer may depend on the content of polyethylene and other polyolefins, in which the migrating tackifier is soluble, in the at least one core layer.

According to an embodiment, the film is produced by a blown film process, known to persons of skill in the art. In embodiments where the film is a multilayer film, the film may be a coextruded blown film comprising at least two layers, and typically at least three layers.

A monolayer or multilayer polyethylene film according to embodiments of the invention may be produced by a manufacturing process involving the following steps:

a) providing at least a first extrudible composition comprising polyethylene having a density of 0.930 g/cm^3 or less;
b) providing a dicyclopentadiene hydrocarbon resin;
c) mixing dicyclopentadiene hydrocarbon resin with said first extrudible composition;
d) optionally providing one or more additional extrudible compositions comprising polyethylene having a density of 0.930 g/cm^3 or less;
e) optionally mixing dicyclopentadiene hydrocarbon resin with said additional extrudible composition;
f) extruding the first composition obtained in step c) to form at least one first layer;
g) optionally extruding the at least one additional extrudible composition of step d) or step e) to form at least one outer layer on adjacent the first layer.

The first layer may be a core layer, and the at least one additional extrudible composition, optionally mixed with dicyclopentadiene hydrocarbon resin, may form one or more additional layers, such as two outer layers sandwiching the core layer. For instance, a second extrudible composition, optionally mixed with dicyclopentadiene hydrocarbon resin masterbatch, may form an outer layer 101 as described above. A third extrudible composition, optionally mixed with dicyclopentadiene hydrocarbon resin may form a second outer layer 103 as described above.

The steps of extruding the first extrudible composition to form a first layer (e.g. core layer) and the one or more additional extrudible compositions to at least one outer layer, respectively, may be performed separately from each other e.g. by monoextrusion, or simultaneously e.g. by coextrusion. Typically, the multilayer film is prepared by co-extrusion, using one extruder per layer simultaneously. Monoextrusion and coextrusion are techniques generally known to the person skilled in the art.

Optionally, several extrudible compositions may be provided to form a plurality of core layers, at least one of which is mixed with the dicyclopentadiene hydrocarbon resin masterbatch. The step of extruding the first composition obtained in step a) to form at least one core layer may imply that the first composition is extruded to a single core layer or to multiple core layers. Typically, in the case of multiple core layers, the multiple core layers are extruded simultaneously by coextrusion and adhere to each other due to substantially identical chemical properties.

The dicyclopentadiene hydrocarbon resin may be provided in the form of a masterbatch mixed with polyethylene, such as LLDPE. The masterbatch may be mixed with the first extrudible composition and optionally with one or more additional extrudible composition(s) as described above. Preparation of a masterbatch containing a hydrocarbon resin derived by thermally polymerizing olefin feeds rich in dicyclopentadiene (DCPD) is known and is described e.g. in WO 98/55537 A1. Masterbatches containing dicyclopentadiene hydrocarbon resin are also commercially available.

A blown film production line, such as prestretched balewrap, is schematically depicted in Fig. 2. A film composition as described above is extruded from a blow extruder 1 to form a blown film bubble that is advanced through primary nip rollers 1a. The nip roller nips together the blown film. From the primary nip rollers, the tubular film 2 is passed via guide rollers to a stretch unit 3, where stretching is performed between two rollers, first draw roller 4 and second draw roller 5, having different speeds. The stretch unit 3 may be omitted, in which case the film is not prestretched. Silage films intended for use in bunker silos or pit silos are typically not prestretched.

Next, the tubular film is passed to a dividing station 6 where the edges of the film 2 may be cut to provide two individual sheets of film. Next, the film 2 is passed to the secondary nip rollers 7 where the individual sheets of film 8 may be separated. Each film sheet 8 may optionally pass through a second dividing station (not shown) where the sheet may be divided longitudinally into two or more parallel sections of desired width. Finally, the film sheets, or film sheet sections, are wound onto the winders 9. In embodiments of the invention where the edges of the tubular film are not cut in the dividing station 6, the tubular film is typically wound onto one of the winders 9.

In embodiments, the film may be a prestretched stretch wrap film having a degree of prestretching above 70 %, for instance in the range from 75 to 100 %.

The film according to the invention may be used in the production of silage. In embodiments, the film is used in a method producing silage using a bunker silo or a pit silo, comprising the step of
i) arranging a volume of bulk crop material in a bunker or on the ground;
ii) optionally compacting the bulk crop material; and
iii) covering the bulk crop material with a film as described herein.
Preferably, the film is arranged over the crop to provide an airtight protective barrier.

In other embodiments, the film is used in a method of wrapping a bale of crop for the production of silage bales, comprising the steps of:
i) compacting bulk crop material to form a bale; and
ii) wrapping the bale with the film as described above.

Silage can be produced from grasses as well as numerous other crops, including grains (barley, oats, rice, wheat, rye, millet), corn, cornstalk, legumes, beans, soybeans, and vegetables.

Examples

Examples 1-5

Test films (monolayer) were produced polyethylene base material (mLLDPE or LDPE or medium density polyethylene, MDPE) of various suppliers as presented in Table 1, mixed, at different loading contents with a dicyclopentadiene hydrocarbon resin. The “A” sample of each series represented a reference, without dicyclopentadiene hydrocarbon resin. The films were extruded using a lab extruder LABTECH LF 250. Series 1 was made using medium density polyethylene.

Table 1

Sample series	**Polyethylene base material**	**Film thickness (approx.)**
1A-G	HF 513 (MDPE, density 0.934 g/cm^3, Total)	49 µm
2A-G	FE 3000 (LDPE, Qapco)	50 µm
3A-G	Regranulated PE (Trioplast)	110-120 µm
4A-G	Exceed XP 6026ML (mLLDPE, Exxon)	50 µm
5A-G	Exceed XP 6026ML (mLLDPE, Exxon)	107-115 µm

The films were subjected to the following test: oxygen transmission rate (DIN 53380-3 using air instead of oxygen gas for testing), strength at break (ASTM D882 or ISO 527-3), elongation at break (ASTM D882 or ISO 527-3), Elmendorf tear strength (ASTM D1922 or ISO 6383-2). Additionally, the pressure before and after the extruder filter was recorded as well as engine intensity.

Table 2a. Polyethylene base material: HF 513 (Total), density 0.934 g/cm^3. Film characteristics and oxygen transmission data.

Film No.	Total PE material (wt %)	DCPD (wt%, approx.)	Thickness by weight (µm)	OTR (cm3/m2/day)	Pressure before filter (bar)	Pressure After filter (bar)	Engine (%)
1A	100	0	49.5	423	378	346	78
1B	96.7	3.1	49.3	362	358	330	75
1C	93.7	6.3	48.2	311	338	311	72
1D	90.6	9.4	49.1	217	311	287	68
1E	87.5	12.5	49.7	193	294	HS	64
1F	84.4	15.6	50.5	169	275	HS	58
1G	81.2	18.8	49.1	152	245	HS	58

Table 2b. Polyethylene base material: HF 513 (Total). Mechanical properties.

Film No.	Strength at break MD (%)	Strength at break TD (%)	Elongation at break MD (%)	Elongation at break TD (%)	Elmendorf MD (cN)	Elmendorf TD (cN)
1A	44.3	46.7	644	774	224	1184
1B	46.6	43.3	673	797	224	1296
1C	42.4	43.1	663	790	208	1288
1D	41.1	40.5	691	793	192	1336
1E	42.3	36.6	707	799	144	1264
1F	36.1	32.8	684	782	112	992
1G	35.2	33.1	668	827	96	464

Table 3a. Polyethylene base material: FE 3000 (Qapco). Film characteristics and oxygen transmission data.

Film No.	**Total PE-material (wt %)**	**DCPD (wt%, approx.)**	**Thickness by weight (µm)**	**OTR (cm3/m2/day)**	**Pressure before filter (bar)**	**Pressure After filter (bar)**	**Engine (%)**
2A	100	0	49.8	709	208	187	58
2B	96.7	3.1	49.4	588	196	178	58
2C	93.7	6.3	50.4	511	183	166	55
2D	90.6	9.4	50.4	430	171	156	55
2E	87.5	12.5	50.5	372	159	144	52
2F	84.4	15.6	49.3	365	150	135	50
2G	81.2	18.8	49.6	284	131	120	50

Table 3b. Polyethylene base material: FE 3000 (Qapco). Mechanical properties.

Film No.	**Strength at break MD (MPa)**	**Strength at break TD (MPa)**	**Elongation at break MD (%)**	**Elongation at break TD (%)**	**Elmendorf MD (cN)**	**Elmendorf TD (cN)**
2A	28.9	27.3	417	497	88	168
2B	24.4	27.4	382	504	128	208
2C	26.6	27.6	451	521	136	248
2D	24.8	26.0	412	445	264	296
2E	24.4	25.1	460	572	336	336
2F	22.5	22.8	428	544	352	352
2G	23.8	22.2	476	581	40	448

Table 4a. Polyethylene base material: Regranulated PE (Trioplast) with MFI: 0.3, density: 0.92. Film characteristics and oxygen transmission data.

Film No.	Total PE-material (wt %)	DCPD (wt%, approx.)	Thickness by weight (µm)	OTR (cm3/m2/day)	Pressure before filter (bar)	Pressure After filter (bar)	Engine (%)
3A	100	0	119.9	226	296	268	75
3B	96.7	3.1	110.7	188	275	250	68
3C	93.7	6.3	111.2	141	249	227	67
3D	90.6	9.4	109.4	128	232	211	63
3E	87.5	12.5	111.5	102	205	188	58
3F	84.4	15.6	112.4	86	180	165	58
3G	81.2	18.8	110.7	81	171	157	55

Table 4b. Polyethylene base material: Regranulated PE (Trioplast). Mechanical properties.

Film No.	Strength at break MD (MPa)	Strength at break TD (MPa)	Elongation at break MD (%)	Elongation at break TD (%)	Elmendorf MD (cN)	Elmendorf TD (cN)
3A	21.6	25.5	567	637	512	880
3B	21.8	22.8	562	570	528	872
3C	22.8	23.2	610	611	576	1064
3D	22.3	23.7	607	623	576	1096
3E	21.4	21.7	619	644	512	768
3F	20.2	18.8	643	631	280	424
3G	19.9	18.9	635	624	264	368

Table 5a. Polyethylene base material: Exceed XP 6026ML (Exxon) with film thickness approx. 50µm. Film characteristics and oxygen transmission data.

Film No.	Total PE-material (wt %)	DCPD (wt%, approx.)	Thickness by weight (µm)	OTR (cm3/m2/day)	Pressure before filter (bar)	Pressure After filter (bar)	Engine (%)
4A	100	0	50.1	777	384	349	85
4B	96.7	3.1	50.2	651	362	328	78
4C	93.7	6.3	50.3	584	330	302	75
4D	90.6	9.4	50.1	503	310	283	72
4E	87.5	12.5	49.7	444	270	248	67
4F	84.4	15.6	50.2	394	245	223	63
4G	81.2	18.8	50.0	350	235	210	63

Table 5b. Polyethylene base material: Exceed XP 6026ML (Exxon) with film thickness approx. 50µm. Mechanical properties.

Film No.	Strength at break MD (MPa)	Strength at break TD (MPa)	Elongation at break MD (%)	Elongation at break TD (%)	Elmendorf MD (cN)	Elmendorf TD (cN)
4A	67.2	62.7	707	654	416	608
4B	61.9	61.1	630	641	464	672
4C	63.8	62.7	665	669	552	816
4D	61.9	65.7	666	702	624	920
4E	58.2	58.3	667	717	672	1048
4F	56.2	54.4	702	671	840	1096
4G	54.0	50.4	688	681	776	1160

Table 6a. Polyethylene base material: Exceed XP 6026ML (Exxon) with film thickness 107-117 µm. Film characteristics and oxygen transmission data.

Film No.	**Total PE-material (wt %)**	**DCPD (wt%, approx.)**	**Thickness by weight (µm)**	**OTR (cm3/m2/day)**	**Pressure before filter (bar)**	**Pressure After filter (bar)**	**Engine (%)**
5A	100	0	115.6	297	422	387	91
5B	96.7	3.1	114.6	261	385	355	85
5C	93.7	6.3	115.7	207	350	322	78
5D	90.6	9.4	116.9	177	315	290	72
5E	87.5	12.5	112.7	155	285	265	67
5F	84.4	15.6	107.9	134	260	241	67
5G	81.2	18.8	107.2	121	235	217	63

Table 6b. Polyethylene base material: Exceed XP 6026ML (Exxon) with film thickness approx. 107-117 µm. Mechanical properties.

Film No.	**Elmendorf MD (cN)**	**Elmendorf TD (cN)**
5A	1320	1456
5B	1256	1415
5C	1560	1856
5D	1824	1920
5E	1832	2216
5F	1832	2264
5G	1936	1928

The above examples demonstrate that the use of dicyclopentadiene hydrocarbon resin in at least one layer of a polyethylene film of low density yields a significant decrease in oxygen transmission rate. Additionally, the mechanical properties were generally maintained at a desirable level or even improved as tear resistance increased. Elongation at break and strength at break were not significantly affected. Finally, is was surprisingly found that the pressure in the screw decreased and the screw engine intensity decreased. However, it was noted that the tear strength (MD) of all the samples based on medium density polyethylene was undesirably low for use in silage applications (Table 2b).

Example 6

Exemplary films and reference films were produced using a full scale blown film co-extrusion process. The exemplary films had three layers, formed from first, second and third extrudible compositions having the content as shown in Table 7.

Table 7.

Extrud. composition/ Layer	Material	Content by weight of the respective composition/layer	Layer thickness
A	mLLDPE, density 0.921 g/cm^3	75 %	20 µm
	other LLDPE	5-6 %	
	Dicyclopentadiene hydrocarbon resin	9.5 %	
	coloring agent	7 %	
	Processing aid	1 %	
	Slip agent	1%	
	UV stabilizer	1 %	
B	Regranulated polyethylene, density <0.930 g/cm^3	77 %	60 µm
	Other LLDPE	5.5 %	
	Dicyclopentadiene hydrocarbon resin	9.5 %	
	Coloring agent	7 %	
	UV stabilizer	1 %	
C	mLLDPE density 0.921 g/cm^3	75 %	30 µm
	Other LLDPE	5.5 %	
	Dicyclopentadiene hydrocarbon resin	9.5 %	
	Coloring agent	7 %	
	Processing aid	1 %	
	Slip agent	1 %	
	UV stabilizer	1 %	

The extrudible compositions were each mixed separately using blending devices or mixing devices generally known to a person skilled in the art. By means of coextrusion, a film having an ABC layer structure was formed, wherein a core layer (B) was formed of the first extrudible composition and two exterior layers (A and C, respectively) sandwiching the core layer were formed of the second extrudible composition (A) and the third extrudible composition (C), respectively. During the extrusion process the bubble stability was excellent. 55 rolls were produced.

The total film composition was as shown in Table 8.

Table 8.

Material	**Weight content (approx.)**
Polyethylene with density <0.930 g/cm^3, (regranulated LLDPE/LDPE)	81.5 % (42 %)
Dicyclopentadiene hydrocarbon resin	9.5 %
Coloring agent	7 %
Processing aid	0.45 %
Slip agent	0.45 %
UV stabilizer	1 %

The film had a width of 12 m, a length of 50 m, a thickness of 110 µm and an overall density of 0.970 g/cm^3.

A reference film was produced in the same manner as described above for the exemplary film, except that instead of dicyclopentadiene hydrocarbon resin the film contained a blend of mLLDPE and regranulated polyethylene. The film had a width of 12 m, a length of 50 m, a thickness of 110 µm and an overall density of 0.958 g/cm^3.

The OTR and mechanical properties of the films were analyzed. The results of the tests are summarized in Table 9.

Table 9.

Sample (roll) no.	Comment	OTR cm^3/m^2/24h	Dart (g) after 48 h	Elmendorf tear strength (cN)		Strength at break (MPa)		Elongation at break (%)	
				MD	TD	MD	TD	MD	TD
reference	Without DCPD hydrocarbon resin	270	520	666	2321	28.0	29.1	563	641
1	With DCPD hydrocarbon resin	180	467	910	2677	-	-	-	-
21	With DCPD hydrocarbon resin	170	-	942	2652	-	-	-	-
31	With DCPD hydrocarbon resin	172	421	1080	2777	29.5	29.4	623	693
41	With DCPD hydrocarbon resin	168	-	916	2663	-	-	-	-
51	With DCPD hydrocarbon resin	164	346	912	2730	-	-	-	-

The person skilled in the art realizes that the present invention by no means is limited to the preferred embodiments described above. On the contrary, many modifications and variations are possible within the scope of the appended claims. Additionally, variations to the disclosed embodiments can be understood and effected by the skilled person in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measured cannot be used to advantage.

CLAIMS

1. A polyethylene-based film useful in the production of silage, said film comprising

polyethylene at a content of 60-90 % by weight of the film, wherein the polyethylene is selected from linear low density polyethylene (LLDPE) and low density polyethylene (LDPE) and combinations thereof, and

a dicyclopentadiene hydrocarbon resin at a content of 3-20 % by weight of the film.

2. The polyethylene based film according to claim 1, wherein the dicyclopentadiene hydrocarbon resin is at least 90 % hydrogenated.

3. The polyethylene based film according to claim 1 or 2, wherein the dicyclopentadiene hydrocarbon resin originates from thermal cracking of hydrocarbons, such as naphtha.

4. The polyethylene based film according to any one of the preceding claims, wherein the film comprises at least one layer containing a mixture of linear low density polyethylene and dicyclopentadiene.

5. The polyethylene based film according to any one of the preceding claims, wherein the dicyclopentadiene hydrocarbon resin is present at a content of 5-13 % by weight of the film.

6. The polyethylene based film according to any one of the preceding claims, wherein the film has an oxygen gas transmission rate (OTR) of 250 $cm^3/m^2/24h$ or less, as measured according DIN 53380-3 using air instead of oxygen gas.

7. The polyethylene based film according to any one of the preceding claims, wherein the film is a multilayer film.

8. The polyethylene based film according to claim 6 comprising at least a first outer layer, a second outer layer, and a core layer arranged between said first outer layer and said second outer layer.

9. The polyethylene based film according to claim 7 or 8, wherein at least two layers of the multilayer film comprises the dicyclopentadiene hydrocarbon resin.

10. The polyethylene based film according to claim 9, wherein all layers of the film comprise the dicyclopentadiene hydrocarbon resin.

11. The polyethylene based film according to claim 10, wherein the dicyclopentadiene hydrocarbon resin is present at a content of 5-13 % by weight of the film.

12. The polyethylene based film according to claim 10 or 11, comprising at a first outer layer, a second outer layer, and a core layer arranged between said first outer layer and said second outer layer; wherein said outer layers comprises linear low density polyethylene (LLDPE) and said dicyclopentadiene hydrocarbon resin.

13. The polyethylene based film according to claim 12, wherein the core layer comprises low density polyethylene (LDPE).

14. The polyethylene based film according to claim 13, wherein the low density polyethylene (LDPE) originates from regranulated polyethylene.

15. The polyethylene film according to any one pf claims 7-14, wherein no single layer of the multilayer film comprises more than 20 % of said dicyclopentadiene hydrocarbon resin.

16. The polyethylene based film according to claim 15, wherein all layers of the film comprise the dicyclopentadiene hydrocarbon resin.

17. The polyethylene based film according to any one of the preceding claims, wherein the film has a thickness in the range of from 15 to 180 µm.

18. The polyethylene based film according to any one of the preceding claims, wherein the film further comprises one or more additives selected from pigments, dyes, fillers, UV stabilizers, tackifiers, slip agents, nucleating agents, and processing aids.

19. The polyethylene based film according to any one of the preceding claims, wherein the film comprises one or more pigments at a content of from 3 to 10 % by weight of the film, such as from 5 to 7 % by weight of the film.

20. The polyethylene based film according to any one of the preceding claims, wherein the film has a thickness in the range of from 80 to 180 µm, preferably from 90 to 125 µm and optionally a width in the range of 5-20 m, preferably 6-18 m.

21. The polyethylene based film according to claim 20, wherein the film is cut to a length of 400 m or less, preferably 100 m or less.

22. The polyethylene based film according to any one of the claims 1 to 19, wherein the film has a thickness in the range of from 15 to 30 µm and optionally a width in the range of from 500 to 1500 mm, preferably 500-750 mm or 1100 to 1500 mm.

23. The polyethylene based film according to claim 22, wherein the film is cut to a length of 1500-2500 m, preferably 1800-2200 m.

24. The polyethylene based film according to claim 22 or 23, wherein the film is prestretched.

25. The polyethylene based film according to any previous claim, wherein the film is a stretch film.

26. Use of a film according to any one of the claims 1 to 25 as a protective film for the production of silage.

27. Use of a film according claim 26, wherein the use is for covering a pit silo or a bunker silo.

28. Use of a film according claim 26, wherein the use is for wrapping of silage bales.

29. A method for producing silage using a bunker silo or a pit silo, comprising the steps of
i) arranging a volume of bulk crop material in a bunker or on the ground;
ii) optionally compacting the bulk crop material; and
iii) covering the bulk crop material with a polyethylene based film according to any one of claims 1-25.

30. A method according to claim 29, wherein the bulk crop material is covered in step iii) to form an airtight protective barrier.

31. A method of wrapping a bale of crop for the production of silage bales, comprising the steps of:
i) compacting bulk crop material to form a bale; and
ii) wrapping the bale with a polyethylene based film according to any one of claims 1-25.

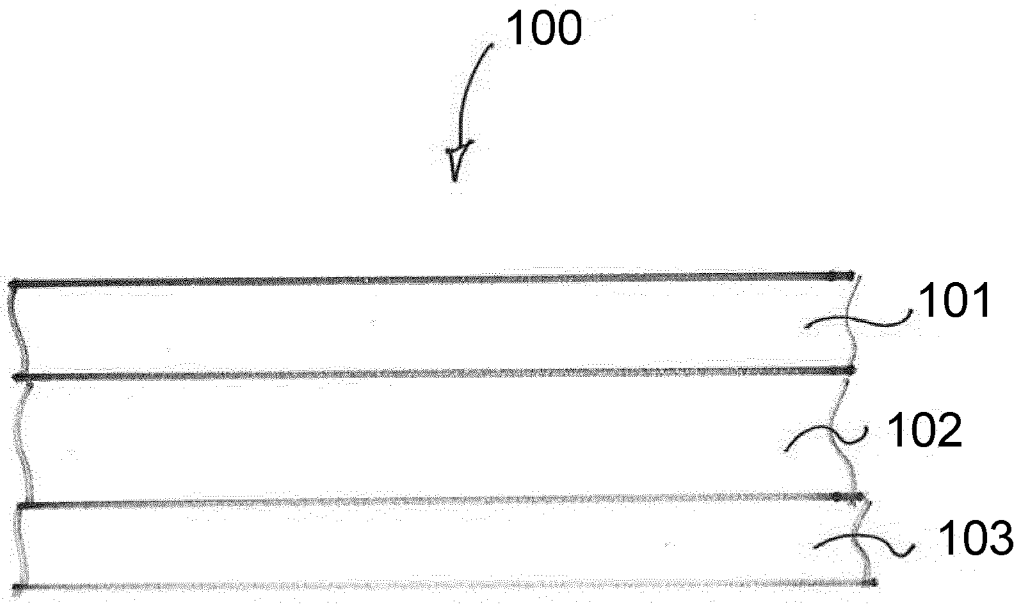

Figure 1

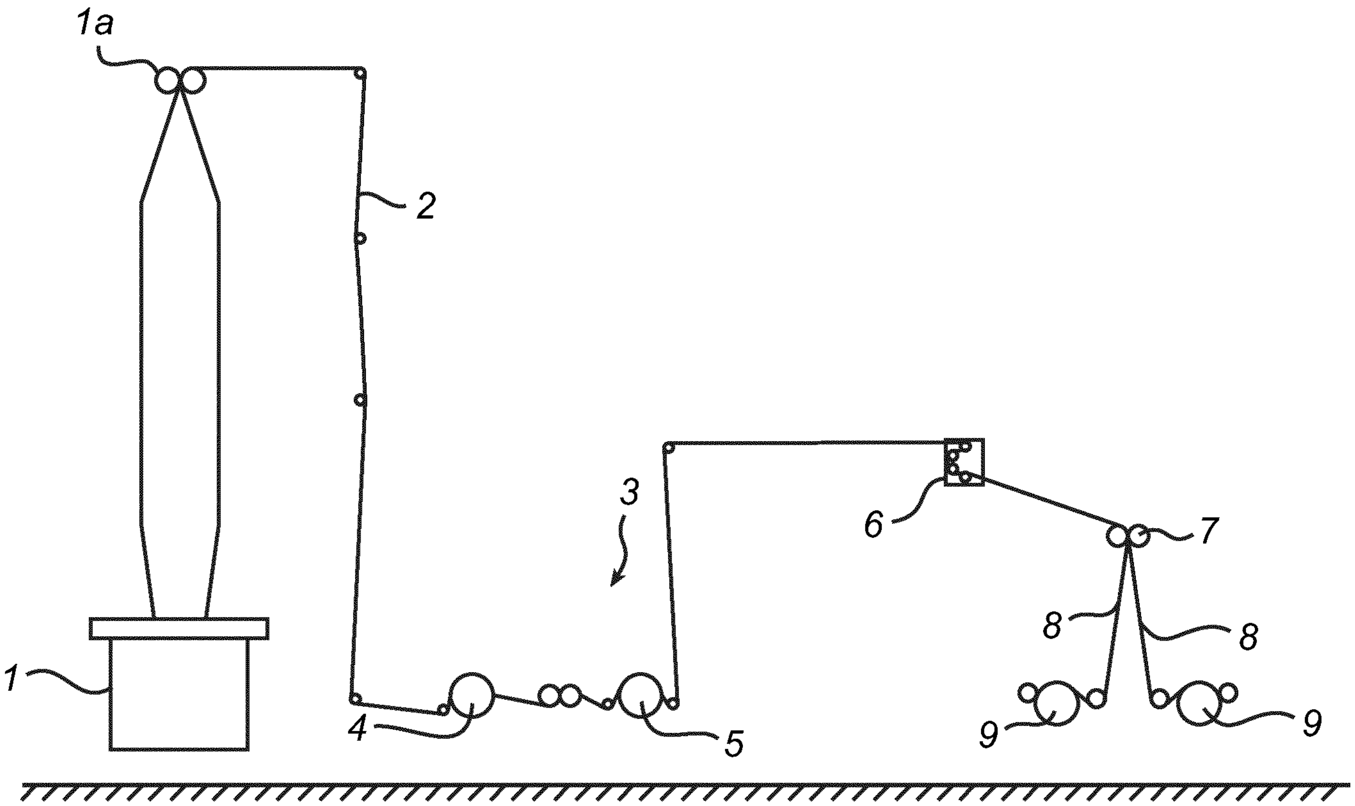

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/080604

A. CLASSIFICATION OF SUBJECT MATTER
INV. C08J5/18 A01F25/13
ADD. B32B27/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C08J A01F B32B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/125469 A1 (GOLZE GRAY A [US] ET AL) 3 July 2003 (2003-07-03)	1-8,10, 11, 15-18, 20-23
Y	paragraphs [0018] - [0020], [0032], [0033], [0036], [0037] example 6 figures 1, 2 claims 49-52 -----	19,24
X	US 4 668 575 A (SCHINKEL INGO [DE] ET AL) 26 May 1987 (1987-05-26)	1-3, 6-11, 15-18, 20-23,25
Y	Example claims 1, 5 ----- -/--	19,24

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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1

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 2014 0040520 A (LOTTE CHEMICAL CORP [KR]) 3 April 2014 (2014-04-03) abstract example 1; table 3 claims 1, 2, 9, 10	1,2,4,5, 7,8,15, 18
Y	US 2010/205910 A1 (HUYGHE MICHAEL [NL]) 19 August 2010 (2010-08-19) paragraphs [0001], [0026] - [0028], [0070] - [0072] Films A-E	19,24
Y	EP 3 009 263 A1 (TRIOPLAST AB [SE]) 20 April 2016 (2016-04-20) paragraphs [0007], [0030] - [0032]	19,24
A	US 5 075 156 A (TANAKA TOHRU [JP] ET AL) 24 December 1991 (1991-12-24) column 3, lines 5-10 tables 1, 3 example 11; table 8 Sample No. 15; column 18; example 6 example 8 claim 1	1-31
A	US 5 145 728 A (ITABA YASUSHI [JP] ET AL) 8 September 1992 (1992-09-08) examples 1-21 claims 1, 2	1-31
A	US 2003/055175 A1 (KLOSIEWICZ DANIEL W [US]) 20 March 2003 (2003-03-20) cited in the application examples 1, 4-6, 14, 15, 17, 20, 21, 24, 25 claims 1, 4	1-31
A	US 6 824 864 B2 (EXXONMOBIL OIL CORP [US]) 30 November 2004 (2004-11-30) column 10, lines 9-37 examples 1, 2 claims 1-4	1-31

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2018/080604

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003125469 A1	03-07-2003	AU 2002245689 A1	03-10-2002
		CA 2440270 A1	26-09-2002
		EP 1373400 A2	02-01-2004
		HU 0303527 A2	28-01-2004
		NO 20034085 A	07-11-2003
		PL 364661 A1	13-12-2004
		US 2003125469 A1	03-07-2003
		US 2004249047 A1	09-12-2004
		WO 02074854 A2	26-09-2002
US 4668575 A	26-05-1987	AU 5712286 A	18-12-1986
		BR 8602090 A	06-01-1987
		CA 1241263 A	30-08-1988
		DD 247181 A5	01-07-1987
		DE 3520944 A1	18-12-1986
		DK 217586 A	13-12-1986
		EP 0208075 A2	14-01-1987
		ES 8900112 A1	16-12-1988
		FI 861954 A	13-12-1986
		JP S61284437 A	15-12-1986
		NO 861686 A	15-12-1986
		TR 22842 A	22-08-1988
		US 4668575 A	26-05-1987
		YU 75186 A	31-12-1990
		YU 196787 A	28-02-1989
		ZA 8604364 B	25-02-1987
KR 20140040520 A	03-04-2014	NONE	
US 2010205910 A1	19-08-2010	BE 1017770 A3	02-06-2009
		CA 2700668 A1	02-04-2009
		DK 2193026 T3	12-08-2013
		EP 2193026 A2	09-06-2010
		ES 2424444 T3	02-10-2013
		PT 2193026 E	22-07-2013
		SI 2193026 T1	30-08-2013
		US 2010205910 A1	19-08-2010
		WO 2009040129 A2	02-04-2009
EP 3009263 A1	20-04-2016	NONE	
US 5075156 A	24-12-1991	AU 611268 B2	06-06-1991
		DE 68917962 D1	13-10-1994
		DE 68917962 T2	11-05-1995
		DK 125489 A	16-09-1989
		EP 0333294 A2	20-09-1989
		US 5075156 A	24-12-1991
US 5145728 A	08-09-1992	NONE	
US 2003055175 A1	20-03-2003	AU 8176698 A	21-12-1998
		BR 9804956 A	24-08-1999
		CA 2261961 A1	10-12-1998
		CN 1228101 A	08-09-1999
		DE 69832866 T2	22-06-2006
		DE 69837573 T2	06-09-2007
		EP 0925324 A1	30-06-1999
		EP 1609811 A2	28-12-2005

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		JP 2000516298 A	05-12-2000
		JP 2009102651 A	14-05-2009
		KR 20000068063 A	25-11-2000
		TW 531548 B	11-05-2003
		US 2002103300 A1	01-08-2002
		US 2003055175 A1	20-03-2003
		WO 9855537 A1	10-12-1998
US 6824864 B2	30-11-2004	CA 2464441 A1	01-05-2003
		EP 1439956 A1	28-07-2004
		US 2003082392 A1	01-05-2003
		WO 03035394 A1	01-05-2003