Material ***Biopolymers***

Biopolymers are polymers that are generated from renewable natural sources, are often biodegradable, and not toxic to produce.

They can be produced by biological systems (i.e. micro-organisms, plants and animals), or chemically synthesized from biological starting materials (e.g. sugars, starch, natural fats or oils, etc.).

Biopolymers are an alternative to petroleum-based polymers (traditional plastics).
(Bio)polyesters have properties similar to traditional polyesters.
Starch-based polymers are often a blend of starch and other plastics (e.g PE), which allows for enhanced environmental properties.

Polyesters

Biopolymer type	Price (DKK/kg)	Density (kg/liter)
Aliphatic-aromatic copolymer	-	-
Aliphatic polyesters	-	-
CPLA	25-50	1.25
PCL	-	-
PHA	15-60	1.25
PLA	30-70	1.26

Starch-based polymers

Biopolymer type	Price (DKK/kg)	Density (kg/liter)
10 % Starch	-	-
50 % Starch	-	-
90 % Starch	20-40	-
Foamed starch	-	-

Others

Biopolymer type	Price (DKK/kg)	Density (kg/liter)
Casein formaldehyde	-	1.33
Celluose acetate	-	-
Horn	-	-

Environmentals notes

Some polymers degrade in only a few weeks, while others take several months.
Biodegradability and other plastic properties strongly depend on the polymer structure. By changing the structure, these properties can be altered.

Price

The above-mentioned prices are from December 1997.
The price of biopolymers is still fairly high compared to oil-based polymers. This is due to lower production-volumes than petroleum-based polymers.
However, the growing environmental consciousness and the application of life-cycle evaluations in the material circuit may help biomass-based raw materials to become mass-produced and cheaper, replacing traditional plastics in a number of applications.
Significant price reductions can be expected within the next two years.

References

Links:
Biodegradable Polymers and Plastics in Japan
DTI, Centre for Product Development
GBF - Enviromental Biochemical Engineering
Proterra - International Centre for Agro-based Materials
How green are green plastics?

Companies:
Biotec GmbH
National Starch & Chemical

Books, Magazines & Papers:
Biopolymers (journal)
Biopolymers (paper)

Photo

Thomas Nissen (Computer graphics)

Copyright

Horn

Return to
materials description

Material *Aliphatic-aromatic copolymer*

This copolymer combines the excellent material properties of aromatic PET, and the biodegradability of aliphatic polyesters. It is soft, pliable (producing low noise) and has a good touch. Melting-points are high for a degradable material (around 200°C).

Depending on the application, up to three aliphatic monomers are incorporated into the PET structure. The monomers create weak spots in the polymeric chains, thereby making them susceptible to degradation through hydrolysis.

Applications include disposal bags, diapers and eating utensils. It can be used to create geo-textiles and plant pots, and it is suitable for thermoformed blown bottles and injection moulded objects.

Category Biopolymers

Processes
Blow moulding
Injection moulding
Extrusion

References
Dupont
GBF - Enviromental Biochemical Engineering

Price It is only marginally more expensive to produce than PET itself because it can be manufactured with existing equipment using existing bulk monomers. Currently available degradable materials can cost twice as much.

Environmental notes

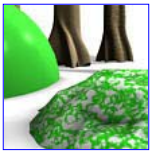
Disposal: It can be recycled, incinerated or landfilled, but is intended mainly for disposal composting and in-soil degradation. If properly disposed, it degrades in eight weeks.
The large polymer molecules are cleaved by moisture into smaller molecules, which are then consumed by naturally occurring microbes and converted to carbon dioxide and water.

Photo

Thomas Nissen (Computer graphics)

Copyright

Material *Aliphatic polyesters*



Aliphatic polyesters have properties similar to those of PE and PP. They are odorless and can be used for trash bags, diapers, and cosmetic and beverage bottles.

They can be processed on conventional processing equipment at 140-260 °C, in blown and extruded films, foams, and injection moulded products.

Aliphatic polyesters are biodegradable but often lack in good thermal and mechanical properties. Vice versa, aromatic polyesters, like PET, have excellent material properties, but are resistant to microbial attack.

Category	Biopolymers
Products	Pot for plants
Processes	Blow moulding Injection moulding Extrusion
Similar materials	PET (aromatic polyester)
References	Showa Highpolymer Co. Ltd. (Bionolle®)

Environmental notes

Creation: Made from polycondensation reaction of glycol and aliphatic dicarboxylic acids. Both components can be obtained from renewable resources (e.g. glycol from glycerol by fermentation).

Disposal: It biodegrades to water and carbon dioxide in soil as well as fresh and ocean water areas.
The rate of degradation depends on grade, shape of the product, and level of microbiological activity. Typically, degradation of a 0.04 mm thick film takes two months.
When coated with coconut-shell powder, and buried in soil, it decomposes within five days. In fact, coconut-shell powder absorbs water and swells, helping microorganisms to live on the biodegradable film.

Photo

Thomas Nissen (Computer graphics)

Material *CPLA - Polylactide aliphatic copolymer*

Biodegradable CPLA is a mixture of lactide and aliphatic polyesters. It can be either a hard plastic (similar to PS) or a soft flexible one (similar to PP) depending on the amount of aliphatic polyester present in the mixture.

Possible applications will include compost bags, cushioning materials, food wrapping materials, fishing nets, etc.
It is easy to process with stability up to 200 °C.

Category Biopolymers

Processes Most conventional plastic processes like:
Blow moulding
Injection moulding
Extrusion
Vacuum forming
Fibre spinning

Similar materials Aliphatic polyesters

References Dainippon Ink and Chemicals Inc. (DIC)

Price DIC plans to produce several tons per year at a price ranging from 25 to 50 DKK/kg.

Environmental notes *Creation:* CPLA is made by copolymerising lactide (made by fermenting cornstarch, cheese whey, etc.) with aliphatic polyester (e.g dicarboxylic acid or glycol made from fermentation of glycerol). All are renewable resources.

Disposal: If incinerated, no toxic substances are generated.
The heating value and carbon dioxide generated during combustion are lower, by almost half the level, of that generated by PE or PS.

Although CPLA has a high molecular weight and

	high melting-point, it begins breaking down into a low-molecular weight polymer, in natural environments, after 5-6 months. Complete decomposition after 12 months. When composted with food garbage, it begins breaking down into a low-molecular weight after 2 weeks.
Additional Info	CPLA does not dissolve in alcoholic solvents, oils, and diluted solution of strong acids. It does dissolve in aromatic hydrocarbon, concentrated acids, and caustic soda.
Photo	Thomas Nissen (Computer graphics)
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Material *PCL - Polycaprolactone*

Polycaprolactone is a biodegradable thermoplastic polymer derived from the chemical synthesis of crude oil. Although not produced from renewable raw materials, it is fully biodegradable.

Polycaprolactone has good water, oil, solvent and chlorine resistance. It has a low melting-point (58-60 °C) and low viscosity, and it is easy to process.

It is used mainly in thermoplastic polyurethanes, resins for surface coatings, adhesives and synthetic leather and fabrics. It also serves to make stiffeners for shoes and orthopedic splints, and fully biodegradable compostable bags, sutures, and fibres.

Category

Biopolymers

References

Solvay Caprolactones (CAPA®)
Union Carbide Corp. (Tone)

Environmental notes

Disposal: Fully biodegradable.
The low melting-point makes the material suited for composting as a means of disposal, due to the temperature obtained during composting routinely exceeding 60 °C.

Degradation time is very short. In Sweden there has been an attempt to produce PCL bags, but they degraded before reaching the customers.

Additional Info

Polycaprolactone is often mixed with starch to obtain a good biodegradable material at a low price (~20 DKK/kg lower than other aliphatic polyesters).
The mix has been successefully used for making trash bags in Korea (Yukong Company).

Photo

Thomas Nissen (Computer graphics)

Material ***PHAs - Polyhydroxyalkanoates***

PHAs are linear polyesters produced in nature by bacterial fermentation of sugar or lipids.
More than 100 different monomers can be combined within this family to give materials with extremely different properties.

They can be either thermoplastic or elastomeric materials, with melting-points ranging from 40 to 180°C. The most common type of PHAs is PHB (poly-beta-hydroxybutyrate). PHB has properties similar to those of PP, however it is stiffer and more brittle.

A PHB copolymer called PHBV (polyhydroxybutyrate-valerate) is less stiff and tougher, and it is used as packaging material.

Category
Biopolymers

Products
Bone plate
Razor, biodegradable (PHA)
Shampoo bottle, biodegradable (PHBV)
Surgical sutures

Processes
Blow moulding
Injection moulding
Extrusion

Keywords
PHB
PHBV

References
Monsanto Company (Biopol™)
PHB production

Price

The price (1997: 15-60 DKK/kg) is very high compared to other oil-derived polymers.
Prices are thus falling down (1993: 100-140 DKK/kg) and, in a couple of years they could reach a level which would enable mass-production (2-6 DKK/kg).

Environmental notes

Creation: Made from renewable natural sources like sugar.

Use: It is biocompatible and therefore can be implanted in the body without causing inflammations. The producer claims that is not toxic.

Disposal: It biodegrades in microbially active environments in 5-6 weeks.
The action of some enzymes produced by microbs solubilises PHB which is then absorbed through the cell wall and metabolised.

PHB is normally broken down to carbon dioxide and water when degraded in aerobic conditions. In absence of oxygen the degradation is faster, and methane is also produced.
PHB is not degraded in biologically inactive systems such as sanitary landfills.

Photo

Thomas Nissen (Computer graphics)

Material *PLA - Polylactide*

PLA is a biodegradable thermoplastic derived from lactic acid.

It resembles clear polystyrene, provides good aesthetics (gloss and clarity), but it is stiff and brittle and needs modifications for most practical applications (i.e. plasticizers increase its flexibility).

It can be processed like most thermoplastics into fibres, films, thermoformed or injection moulded. Used for compost bags, plant pots, diapers and packaging.

Category	Biopolymers
Products	Compostable bag
Processes	Most conventional plastic processes like: Blow moulding Injection moulding Extrusion Vacuum forming Fibre spinning
References	Neste Corporate Technology Cargill Dow Polymers LLC
Price	Current prices (1997) are between 40 and 70 DKK/kg.

Environmental notes	*Creation:* Lactic acid can be obtained on the basis of renewable starch containing resources (e.g. corn, wheat or sugar beat) by fermentation, or by chemical synthesis of non-renewable resources. *Disposal:* If composted properly it takes 3-4 weeks for complete degradation. The first stage of degradation (two weeks) is a hydrolisis to water soluble oligomers and lactic acid. The latter, as a naturally occurring substance, is a rapid metabolisation into CO2, water and biomass by a variety of micro-organisms.
Additional Info	The future tendency is towards a sharp decrease of the price, thanks to the introduction of plants capable to mass-produce the material. Future prices are expected to fall to few times the price of PP (15-20 DKK/kg).
Photo	Thomas Nissen (Computer graphics)
Copyright	

Material *10 % Starch*

Starch can be used as biodegradable additive or replacement material in traditional oil-based commodity plastics.

If starch is added to petroleum derived polymers (e.g. PE), it allows disintegration of the blend, but not its biodegradability.

Category	Biopolymers
Products	Compostable bags
Environmental notes	*Disposal:* Starch can in theory accelerate the disintegration or fragmentation of the synthetic polymer chains. Microbial action consumes the starch, thereby creating pores in the material, which weaken it and enable it to break apart. Disintegration of starch-plastic blends is not the same as biodegradation. Their breakdown, also under optimal conditions, is quite slow. Starch content needs to exceed 60% before significant material breakdown occurs.
Additional Info	In 1993 LDPE-starch blends were commercialized under the trade name Ecostar®
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Material *50 % Starch*

Also called plastified starch materials. They exhibit mechanical properties similar to conventional plastics such as PP, and are generally resistant to oils and alcohols, however, they degrade when exposed to hot water.

Properties of these materials can be varied as the content of starch and other materials changes.
They are fully biodegradable and compostable, and they can replace traditional plastics in food service, food packaging, personal health care, etc.

Their basic content (40-80%) is corn starch, a renewable natural material. The rest is performance-enhancing additives and other biodegradable materials.

Category	Biopolymers
Products	Pen, biodegradable Golf tees Trash bags
Processes	Most conventional plastic processes like: Blow moulding Injection moulding Extrusion Thermoforming
References	Novamont S.p.A. (Mater-Bi®)

Environmental notes

Creation: Made of renewable natural sources (starch).

Disposal: When disposed in biologically active environments such as composte facilities and wastewater treatments systems, they display degradation characteristics similar to leaves, wood chips and paper.

Photo

Thomas Nissen (Computer graphics)

Material *90 % Starch*

Usually referred to as thermoplastic starch.
They are stable in oils and fats, however, depending on the type, they can vary from stable to unstable in hot/cold water. They can be processed by traditional techniques for plastics.

These materials consist mainly (>90%) of starch obtained from renewable natural sources. Colouring and flame retardant additives are possible.

Category
Biopolymers

Products
Starch-based tube
Degradable compost bags
Agricultural mulch film
Golf tees

Processes
Most conventional plastic processes like:
Blow moulding
Injection moulding
Extrusion
Thermoforming

References
Biotec GmbH (Bioplast®)
NOVON International (NOVON®)

Price
Prices vary from 20 to 40 DKK/kg

Environmental notes
Creation: Made of renewable natural sources.

Disposal: Depending on the grade, thermoplastic starch can degrade completely within five days in aqueous aerobic testing and in 45 days in a controlled compost, or can even decompose in water.

Photo
Thomas Nissen (Computer graphics)

Material *Foamed starch*

Starch can be environmentally friendly blown into a foamed material using water steam.

Foamed starch is antistatic, insulating and shock absorbing, therefore a good replacement for polystyrene foam.

It can be used as packaging material or can be pressed into starch-based sheet for thin-walled products, such as trays, disposable dishes etc.

Category
Biopolymers

Products
Loose-fill
Disposable cup

Processes
Water steam foaming
Extrusion
Cutting
Moulding

Similar materials
Foamed PS

References
Biotec GmbH (Biopur®)
National Starch & Chemical (Eco-Foam®)
Norel (Envirofill™)

Environmental notes
Creation: Foamed starch is 99% starch, which is a renewable resource found in corn, wheat, rice, potatoes, etc.
Foaming is performed using water steam instead of hydrocarbon-based blowing agents used for blowing PS.

Disposal: It dissolves when soaked with water leaving just a dilute corn starch solution. The solution is not toxic and is consumed by microbial life in about ten days, leaving only carbon dioxide and water.

It can also be re-used, recycled, incinerated, or composted along with other organic materials, since it decomposes very quickly.

Photo Thomas Nissen (Computer graphics)

Material *Casein formaldehyde*

Casein formaldehyde is a plastic of natural protein origin, made from organic substances such as milk, horn or vegetable products such as soy beans, wheat, etc.

It can be made to look like celluloid, ivory, or artificial horn.
It is odourless, insoluble in water, and only with difficulty inflammable.

In the first decades of this century, casein formaldehyde was used to make buttons, pins, cigarette-cases, fountain pens, umbrella handles and radio cabinets.

Category	Biopolymers
Products	Button for clothes Gramophone box
References	Plastic museum
Environmental notes	*Creation:* Made from chemical modification of casein, which is a natural renewable resource.
Additional Info	Casein formaldehyde was commercialised under the trade names Galalith and Erinoid.
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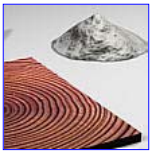
Material *CA - cellulose acetate*



Cellulose acetate (CA) is used for transparent, translucent and opaque objects (e.g. typewriter keys, calculators, switches, car wheel coverings).

Furthermore, it is especially suitable for coatings applications requiring high melting-point, toughness, clarity, and good resistance to ultraviolet light, chemicals, oils, and greases.

Cellulose acetate is an amorphous thermoplastic material belonging to the cellulosic resin family. It is obtained by introducing the acetyl radical of acetic acid into cellulose (as cotton or wood fibres) to produce a tough plastic material.

Danish Name CA - celluloseacetat

Category Biopolymers

Products
Knife-handle
Shoe-heel
Lamp shade
Pen
Umbrella handle

References Plast og gummi ståbi

Environmental notes

Creation: Made from chemical modification of cellulose, which is one of the most diffuse organic substances in nature.

Use: Cellulose acetate is inflammable and burns with a yellowish flame producing a smelling smoke. Additive are often used to decrease its inflammability and to give the material self-estinguishing properties.

Additional Info	First plastic to be injection moulded. Cellulose acetate becomes brittle at temperature under the freezing point. It is an insulator material and shows only a little tendency to electrostatic charging.
Photo	Thomas Nissen (Computer graphics)
Copyright	

Material ***Horn***

It is an organic material containing 80% keratin. It is thermoplastic and can be worked after dry heating or immersion in boiling water or alkaline solutions.

After softening it can be pressed obtaining objects and various laminas, such as tobacco containers, boxes, buttons, pens and combs. It was successfully applied, especially in England, before the advent of plastics.

Danish Name	Horn
Category	Biopolymers
Environmental notes	*Creation:* Horn is natural organic material.
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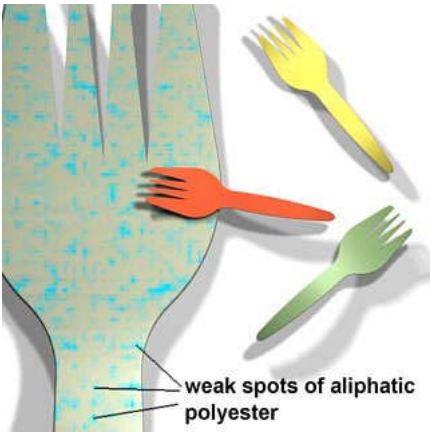
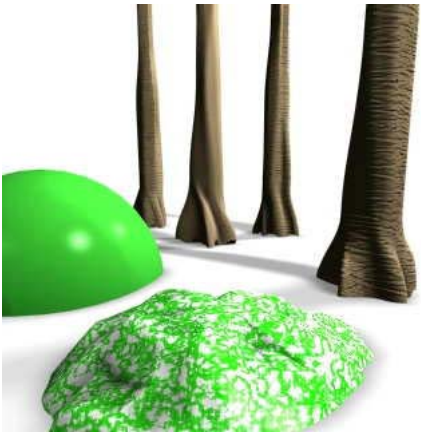


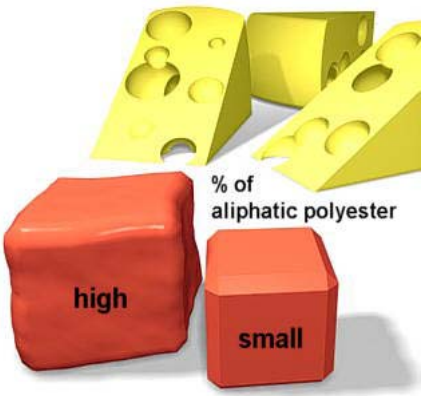
Aliphatic-aromatic copolyr

Return to
materials description



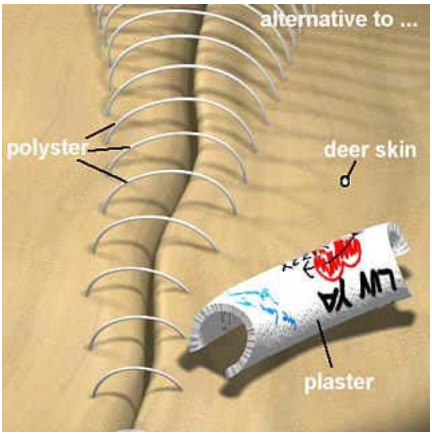
Aliphatic polyesters

Return to
materials description



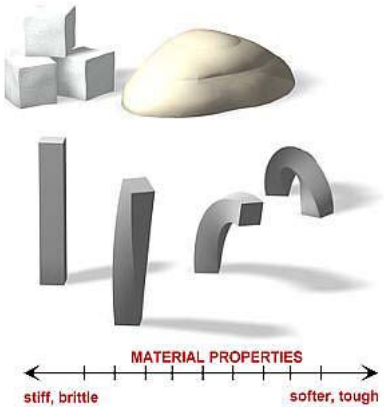
CPLA - Polylactide aliphat
copolymer

Return to
materials description



PCL - Polycaprolactone

Return to
materials description



PHAs - Polyhydroxyalkanc

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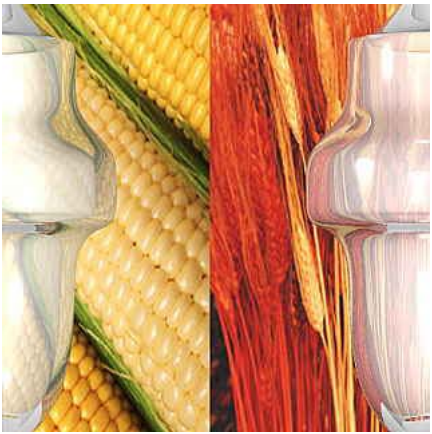
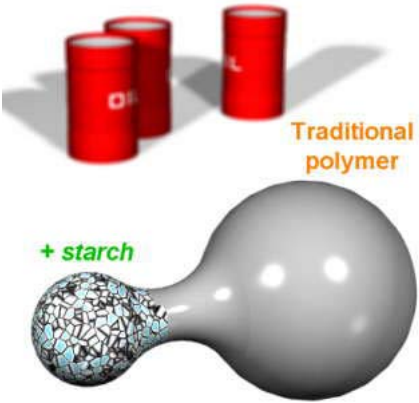
materials description



PLA - Polylactide

Return to
materials description

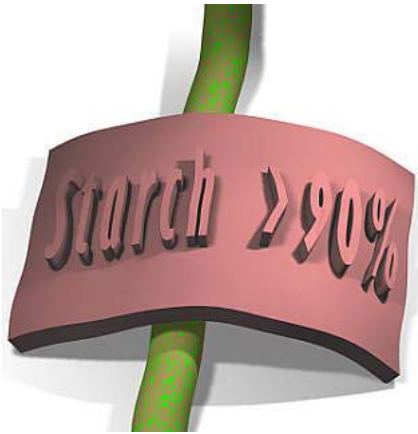


Starch-based biopolymers (
% starch)

Return to
materials description

Starch-based biopolymers
(40-80 % starch)

Return to
materials description



Starch-based biopolymers (
% starch)

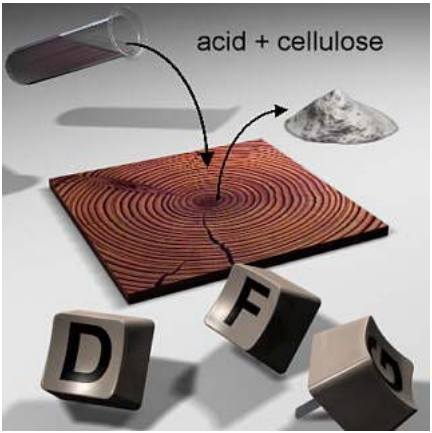
Return to
materials description

Foamed starch

Return to
materials description

Casein formaldehyde

Return to
materials description



CA - cellulose acetate

Return to
materials description

Biopolymers are usually produced from plants and a often biodegradable.

Back

Products *Compostable bag*

This compostable lawn and leaf bag is made of PLA.
It is designed expressly for collecting yard waste as part of municipal composting programmes, and offers an alternative to kraft paper collection bags.

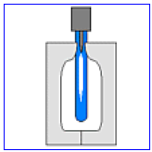
Like kraft paper lawn and leafs bags, the biopolymer bags eliminate the need to separate bags from their contents at compost sites. Both degrade and are easy to print on.

Compared to paper bags advantages are: improved wet strength, better puncture resistance, visibility of content, ease of handling and closing, as well as compactness which minimises storage requirements.

Category	Outdoor equipment
Materials	PLA
Processes	Blow moulding
References	Cargill Dow Polymers LLC
Keywords	Biopolymer Biodegradable Composting Transparent
Price	Competitive with the price of paper bags.
Environmental notes	*Use:* Bags designed only for degradation through composting, and only for carrying leaves, grass etc. They should not be used for waste such as ashes etc. *Disposal:* The bag biodegrades along with the leaves, grass and wood chips inside it to create a rich, organic humus that can be used as a soil nutrient.

Similar products Pot for plants

Process ***Blow moulding***



Used for hollow parts of all sizes. A tube of molten plastics is extruded into an open mould.The mould closes and thereby the bottom of the part welds.

Hot air is blown into the tube and it is blown up until it fills out the mould cavity.

Parts can be produced in small and large quantities, since setup cost is low and tools/moulds are often made of aluminium and cheap.

Danish Name	Blæsestøbning
Category	Mass conserving processes, Plastic moulding
Materials	PS ABS SAN PVC PC PE PP
Typical products	Bottle for motor oil Bottle for organic solvents Tubing for a car
Competing processes	Injection blow moulding
References	Dudek Plast A/S Gravenhorst Plast A/S Kornerup Plast Trading ApS Rosti A/S
Price notes	Moulds can be produced at a relative low price. Setup times are low.
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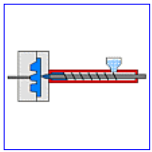
Process *Injection moulding*



For parts of all sizes which require accurate and complex geometry.
Granular plastic or pellets are melted by friction with a rotating screw and actual heating, and then injected into the mould.

Normally, the process is reserved to thermoplastics, but it can be used for shaping fibre reinforced thermoplastics or thermosettings.

When shaping composites, parts with good mechanical properties cannot be produced as the content of fibres must be limited.
Production volumes are medium to large, and the cycle time per part is very short.

Danish Name
Sprøjtestøbning

Category
Mass conserving processes, Plastic injection moulding

Materials
Plastics
Composites

Typical products
Disposable drinking glass
Hedge cutter
Milestone
Razor, biodegradable
Razor, ordinary
Shaver, rechargeable
Spoon, clasp type
Satellite box
Washing machine drum
Gear
Hinge for gramophone lid
Video front-panel

Competing processes
Extrusion
Gas assisted injection moulding

References	A. Johnsen Industri A/S Helarco Jotun Danmark A/S Molytex A/S
Price notes	The injection machine and the shaping mould are very expensive.
Additional info	Possible to achieve good dimensional accuracy and surface finish.
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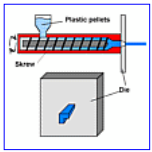
Process *Extrusion*



Profiles of all shapes can be produced. In an extruder the material is heated and continuosly pushed by a rotating screw through a die with the shape of the profile. After the die, the profile is cooled by air or water and cut into desired lengths.

Production volumes are normally high.

Danish Name	Ekstrudering
Category	Mass conserving processes, 2d plastic processes
Materials	Most plastics
Typical products	Garden hose Tubes Metal sheet edge protection Railings Ice cube plastic bag Potholder
Competing processes	Injection moulding Blow moulding Pultrusion Calandering
References	DKI Plast A/S Vestfos Plast A/S Glim Plastic Industri ApS
Photo	Thomas Nissen (Computer graphics)
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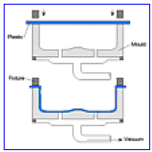
Products *Pot for plants*

This pot for plants is made of aliphatic polyesters (Bionolle®)

Its biodegradability allows the plant to be planted in soil with no need to extract it from its pot.

Category	Outdoor equipment
Materials	Aliphatic polyesters
References	Showa Highpolymer Co. Ltd.
Keywords	Biopolymer Biodegradable Outdoor Renewable resources
Environmental notes	See aliphatic polyesters
Similar products	Compostable bag
Photo	Showa Highpolymer Co. Ltd.
Copyright	

Process *Vacuum forming*



Well suited for larger plastic parts since tools investments are low. Also used for high volume production of e.g. disposable cups and chocolate packaging. The surface facing the mould has the best quality. Material thickness is difficult to control.

A sheet of thermoplastic material is heated to the softening point. The sheet is positioned over a mould with small air canals, and a vacuum pulls the sheet into the mould.

Vacuum is normally sufficient due to the low strength in the material being formed, but for a more complex geometry, additional air or mechanical pressure can be applied.

Danish Name	Vacuum formning
Category	Mass conserving processes, Plastic shaping
Materials	Most thermoplastics e.g. ABS PC PP PS PE
Typical products	Dolphin, bicycle trailer base part KimBox suitcase Appliance housing Disposable cups Commercial sign Shaped packaging Refrigerator inside panels
Competing processes	Rotation moulding Blow moulding Injection moulding
References	Bramstoft & Wassmann ApS Cretex A/S Helge Buch's Eftf. ApS
Price notes	Low tooling costs

Additional info	Difficult to produce small details
Photo	Thomas Nissen (Computer graphics)
Copyright	

Products *Razor, biodegradable*

A double-bladed razor with replaceable head. Handle and razor heads are made of biodegradable plastic.

Danish Name	Barberhøvl, bionedbrydelig
Category	Personal items, Personal care
Materials	PHA (handle and razor head) Stainless steel (blades) PS and paper (packaging)
Processes	Injection moulding (handle) Insert moulding (razor head) Packaging: Extrusion Vacuum forming
References	Kay Razor
Keywords	Personal accessories Cutting function Shave Biodegradable Plastic
Price	Retail price, for 1 handle with 5 razor heads (9/95) DKK 30,-.
Environmental notes	Materials / Production: The plastic is made frm renewable resources. Use / Transport: The razor it self does not use energy, but use require water, soap and energy for heating water. Disposal: putrification or inceneration.
Similar products	Razor, ordinary Shaver, rechargeable
Copyright	

Products ***Shampoo bottle, biodegradable***

This shampoo bottle is manufactured from biodegradable PHBV plastic (commercially named Biopol™).

The biodegradable shampoo bottle is the first major product to be produced using this material.

The closure is injection moulded and the bottle is blow moulded.

Category	Personal items, Personal care
Materials	PHBV
Processes	Injection moulding (closure) Blow moulding (bottle)
References	Monsanto Company Wella
Keywords	Bottle Biodegradable Biopolymer PHBV Biopol™
Price	Approximately 4 DKK/bottle (retail, 1995)
Environmental notes	*Creation:* The plastic is made from renewable resources using traditional production methods. *Disposal:* The bottle will degrade through composting.
Similar products	Razor, biodegradable
Photo	Monsanto Company
Copyright	

Products ***Pen, biodegradable***

This "green pen", with the exception of the ink refill, is made from the corn starch based material Mater-Bi®.

It is very similar to an ordinary plastic pen, but degrades when disposed in a composting site or in natural environment.

Category	Dwelling & office appliances, office equipment
Materials	Starch-based biopolymer (Mater-Bi®)
Processes	Injection moulding
References	Novamont S.p.A. Enpac
Keywords	Biopolymer Biodegradable Pen Office equipment
Price	Approximately 11 DKK (retail, 1997)
Environmental notes	*Creation:* The pen is made from renewable resources using traditional production methods. *Disposal:* The pen will disintegrate in about 12 months after being disposed.
Copyright	

Products *Starch-based tube*

This tube is made of corn starch, is environment-friendly and is designed to decompose in water.

The tube is a direct alternative to conventional spiral-wound tube packaging, including flexible plastics and corrugated paper.
The product can also be made in a variety of vibrant colours.

Category	Dwelling & office appliances, office equipment
Materials	Thermoplastic starch
References	American Excelsior Company
Keywords	Biopolymer Biodegradable Starch Packaging Water-soluble
Environmental notes	*Creation:* The tube is made from renewable resources using traditional production methods. *Disposal:* The tube is designed to dissolve in water after use.
Copyright	

Products ***Loose-fill***

This loose-fill for packaging industry is made of foamed starch.

It offers numerous disposal alternatives and can be a good substitute of CFCs-blown PS.

Category	Packaging
Materials	Foamed starch
Processes	Water steam foaming
References	National Starch & Chemical American Excelsior Company
Keywords	Biopolymer Biodegradable Starch Packaging Water-soluble
Environmental notes	*Creation:* Made from renewable materials. Environment-friendly foaming process. *Disposal:* See foamed starch.
Copyright	

Products *Disposable cup*

The cup shown appears very similar to normal PS disaposable cups, and diaplays similar characteristics as far as thermal insulation and resistance to fluids are concerned.

Category	Food, Food equipment
Materials	Foamed starch
Processes	Water steam foaming Pressing
References	Biotec GbmH
Keywords	Biopolymer Biodegradable Starch Packaging
Environmental notes	*Creation:* Made from renewable materials. Environment-friendly foaming process. *Disposal:* Once disregarded, the cup will completely decompose into useful compost.
Copyright	

Products	***Button for clothes***
	This buttons are made of casein formaldehyde. They show the different decoration possibilities that this material can give.
Category	Personal items, Clothes
Materials	Casein formaldehyde
References	Bottonificio Ontano
Keywords	Biopolymer Decoration 3D decoration Clothes
Environmental notes	*Creation:* See casein formaldehyde.
Copyright	

Products *Gramophone box*

The box housing this gramophone is coated with a layer of casein formaldehyde.

The antique gramophone from 1950 shows how casein formaldehyde can give a beautiful surface appearance.

Category	Dwelling & office appliances, Home electronics
Materials	Casein formaldehyde
References	Plastic museum
Keywords	Biopolymer Decoration Home electroniocs
Environmental notes	*Creation:* See casein formaldehyde.
Copyright	