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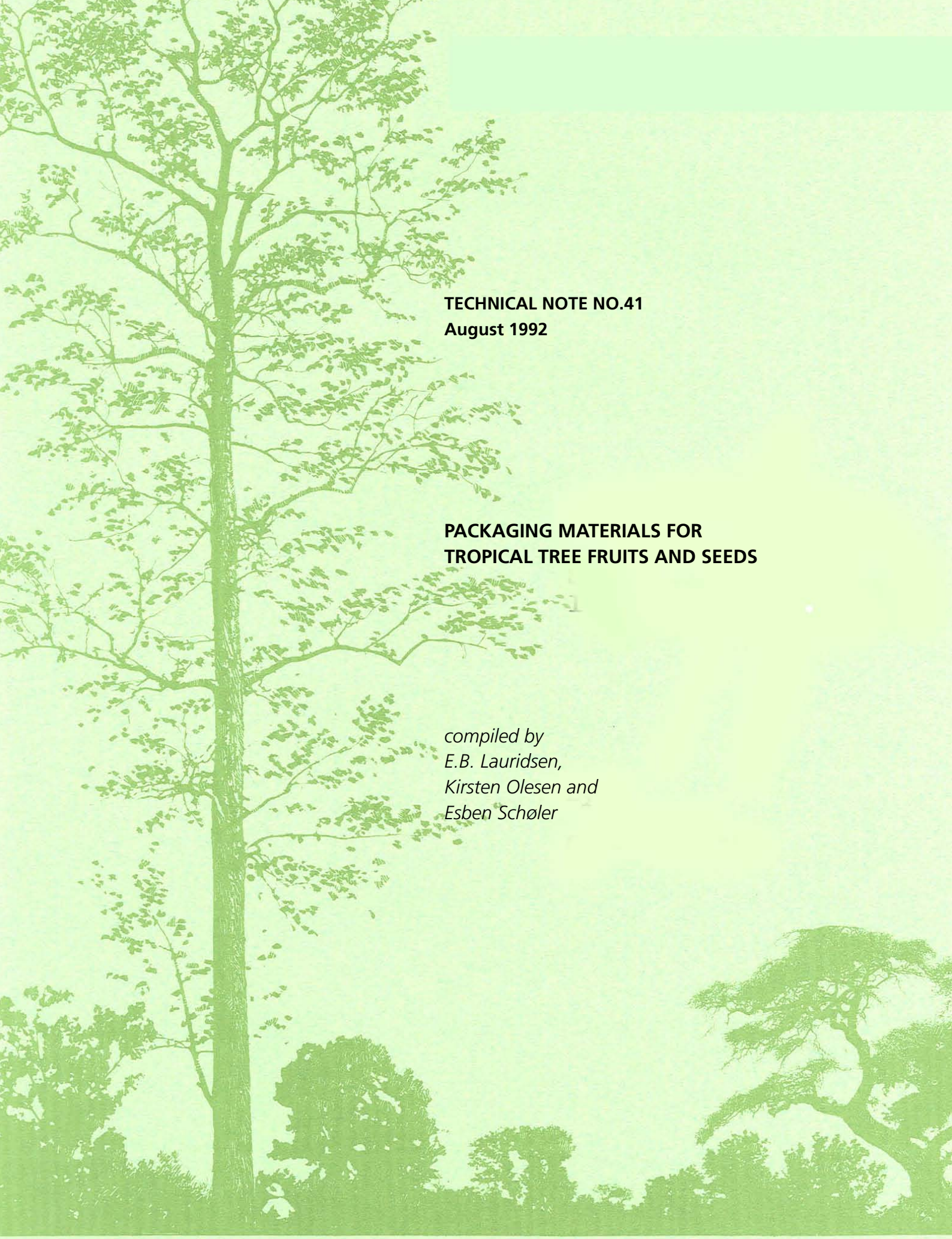

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PACKAGING MATERIALS FOR TROPICAL TREE FRUITS AND SEEDS

compiled by
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DANIDA FOREST SEED CENTRE

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1. INTRODUCTION

Throughout this Technical Note the term 'seed' is used in the functional sense and means a 'unit of dissemination'. This term includes true seeds as well as fruits.

When seed procurement - including all stages from collection, field handling, transport, storage until final distribution - is being planned, choice of packaging material for the different processes should not be forgotten or ignored, as wrong packaging may well damage an otherwise successful operation.

The aim of providing the proper wrapping material for fruit and seed in transport or storage is to ensure against loss of seed and to ensure seed survival.

This Technical Note describes factors causing loss of seed and decrease in seed survival in relation to characteristics of packaging materials, and how to select the best suited materials for particular seeds.

2. FRUIT/SEED CHARACTERISTICS AND ENVIRONMENTAL CONDITIONS

Like all other living organisms seeds can only remain viable within certain intricate environmental limits. Seed moisture content and temperature are the most vital factors to consider; but other physical and biotic factors, including pests and diseases, must also be taken into consideration.

Figure 1 shows the compound effect of seed moisture content and ambient temperature on deteriorative factors and on the activity of insects, fungi, and bacteria.

Micro-organisms cause damage either directly on seed structures, through the effect of toxic substances produced, or by causing heat in the fruit or seed bulk. Insects are directly damaging essential structures. For moisture contents above 10-12% and temperatures above 0-5°C, oxidization of fat seems to be contributing to the loss of viability in certain species. Certain gases may also cause damage. Ethylene, for example, promotes the ripening of green fruits, so that they become more exposed to heat because of fermentation.

By manipulating seed moisture and temperature we can exert control on some of the above factors and thereby on seed viability.

The picture is complicated because much transport and storage concerns fruits as well as true seeds.

For true seeds the effects are dependent upon the kind of seed: so-called recalcitrant seeds cannot be dried as much as so-called orthodox seeds, and many tropical seeds cannot be kept at as low a temperature as temperate seeds.

Some fruits are dry at maturity and will present few problems regarding packing. Fruits with juicy pulp have high levels of moisture content and are therefore much more difficult to handle.

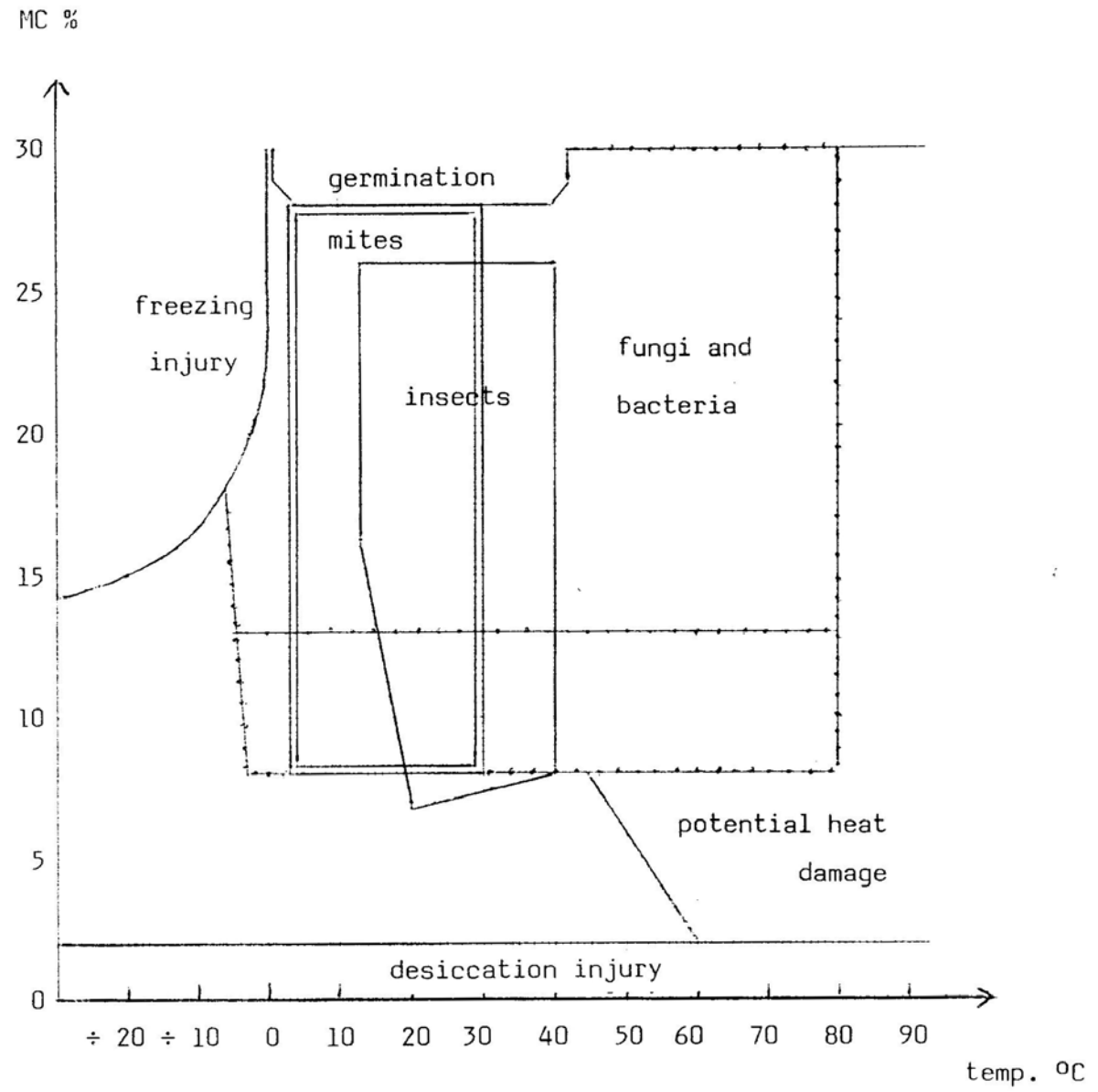

Figure 1. Approximate limits of moisture content (MC %) and temperature (OC) for potentially damaging factors.
The lower MC-limit for attacks by fungi is 13-14% for starchy seeds and 8-9% for oil-containing seeds. (Partly after Roberts, 1972).

Figure 2 shows the approximate limits of optimal conditions for tropical orthodox and recalcitrant seeds. It is evident that orthodox seeds (and dry fruits) can be dried to low moisture levels where micro-organisms and insects are inactive, and where freezing injury does not occur. At such low moisture levels, orthodox seeds can be kept for quite a long time in ambient temperature. This is an important aspect of transport and storage! By also lowering the temperature, the longevity of orthodox seeds may be further increased.

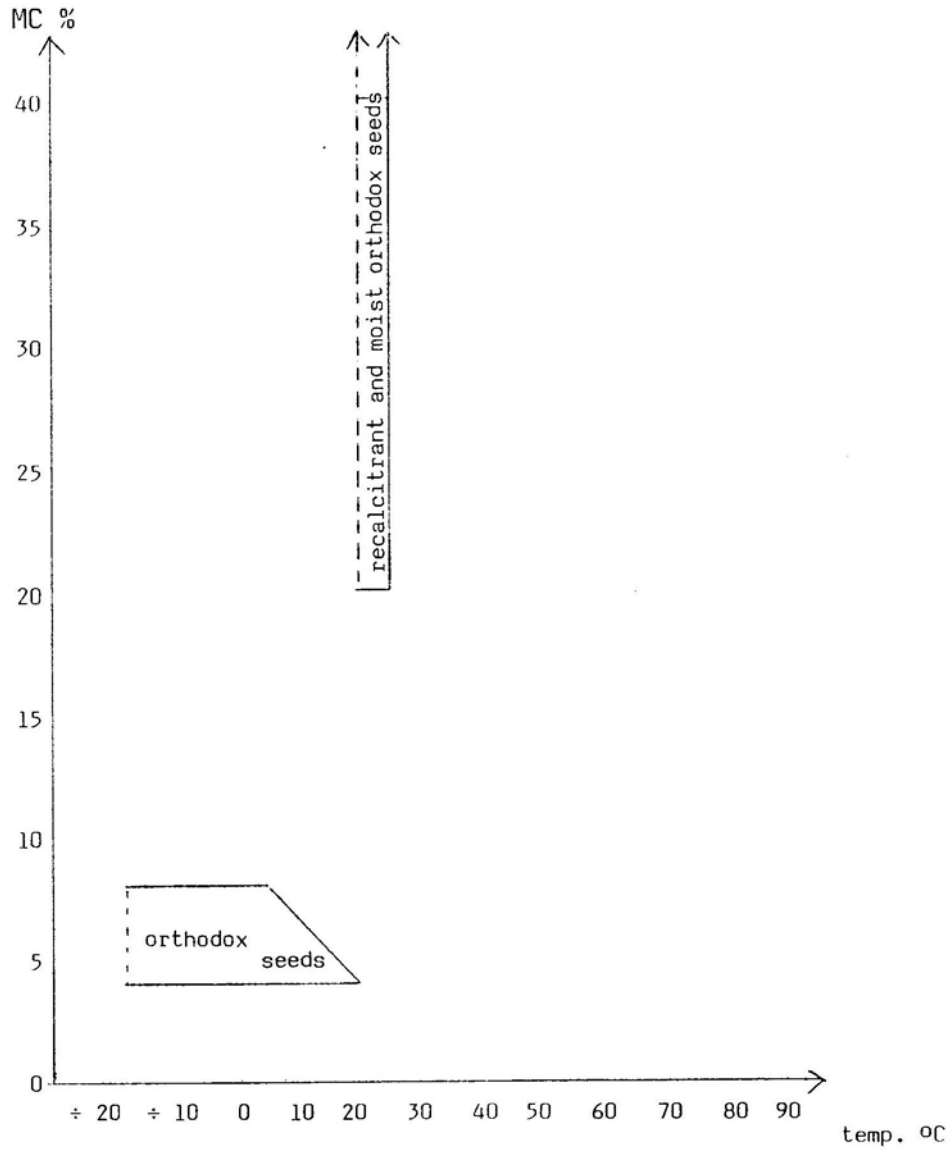

Figure 2. Approximate limits for optimal conditions for tropical orthodox seeds and tropical recalcitrant seeds.
For recalcitrant seeds, the lower limit of critical moisture content lies between 20 and 40% for most species. Some recalcitrant species tolerate lower temperatures and store well at around 10°C. (Partly after Roberts, 1972).

Recalcitrant seeds and many moist, unprocessed fruits must be kept at high humidity (moisture) and relatively high temperature levels. At such levels micro-organisms and insects are very active, the seeds may start the germination process, and chemical processes as well as seed respiration take place. Because of the respiration, there is a need to maintain a certain minimum level of oxygen, otherwise the fruits / seeds may suffocate. If the temperature is lowered, there is a risk of cold or freezing injury.

The environments in which seeds are kept may not be constant. Temperature and air humidity may change. The moisture content of fruits and seeds freely exposed to the atmosphere will gradually change and equilibrate to the relative humidity of the atmosphere.

Furthermore, some of the effects of the environment depend upon the time the fruits or seeds are exposed. Generally, the further we move towards the lower left hand corner of figure 1, the longer time we have at our disposal for transport or storage.

Besides the factors shown in figure 1, fruits and seeds may be exposed to many other factors, viz.:

Atmosphere:	other gases, e.g. ethylene which promotes fruit and seed ripening; quarantine treatment with poisonous gases may kill seed; lack of oxygen may kill some seeds.
Biological agents:	rodents.
Mechanical hazards:	shock, compression, vibrations.

Fruits and seeds are exposed to such conditions, to a varying degree, during the various procurement operations:

- collection
- temporary storage before processing
- transport of non-processed matter
- extraction and processing
- transport of processed matter
- storage at seed bank
- transport to nursery
- possible temporary storage before sowing.

It is important to estimate the conditions and hazards that are likely to prevail in each of these stages, **and** how long each stage will last, hence exposure time for fruits or seed.

Before deciding upon the correct way of packaging fruits or seeds, we thus need to know which kind of fruit or seed we are dealing with (orthodox, recalcitrant, moist or dry fruits) and which condition they are in when they are about to be packed (moisture content, state of ripening). We need also to know the environmental conditions during transport and storage, how they vary, and how long each stage is likely to last.

3. PROPERTIES REQUIRED OF PACKAGING MATERIALS

3.1. General Properties Required of Packaging Materials

The correct packaging material must ensure the maintenance of certain levels of temperature and moisture, and it must provide protection against other hazards as listed below.

Climatic hazards associated with:
humidity
temperature
exchange of gases

Biological hazards associated with:
rodents
insects
micro-organisms

Mechanical hazards associated with:
impact during handling
compression during transit and storage
vibrations particularly during transport
punctures from other packages. sharp protrusions on vehicles, pallets, conveyors,
or by the contents of the package itself.

In addition the packaging material must ensure against direct loss of seed in case of breakage or accidental opening of containers, and it must provide a convenient unit of handling, transport and storage.

Containers must also be adequate to meet any change in conditions likely to occur, e.g. during transport.

When not in use, the material should occupy as little storage space as possible. It must be convenient to open and close packages in order to facilitate customs and quarantine inspection and for drawing samples for seed testing. The material must also be easy to label safely, and finally the cost must be considered.

3.2. Specific Properties of Different Packaging Materials The properties of packaging materials should be evaluated with regard to the following factors:

PERMEABILITY

Ability to hold the required level of moisture and gases.

INSULATION

Ability to maintain a certain level of temperature.

MAXIMUM MESH SIZE

Protection against rodents and insects, i.e. ability to prevent rodents and insects from entering through openings.
Protection against entering of micro-organisms (gonidea, spores, mycelia, etc.)
Protection against impurities (e.g. dust, other seed), Protection against loss of seeds.

MECHANICAL PROPERTIES

Ability to withstand attack by animals, particularly protection against rodents and insects.
Ability to withstand biological deterioration (rot).
Ability to withstand ultraviolet light (sunlight),
Ability to withstand tension,
Ability to withstand tear,
Ability to withstand breakage,
Ability to maintain dimension (rigidity),
Ability to be resilient (elasticity).

EASE IN HANDLING

Convenient size of bag, box, or other container.
Easy to hold (not slipping while handling or stacking).
Easy to stack.
Easy to open, close, and seal.
Easy to clean after use.
Ease with which labels can be attached (and kept in place), or information can be written (and maintained) on material.
Minimum storage space for empty packaging materials.

COST

The cost of the material in relation to value of seed.

Possibly the most important property of a packaging material is its ability to either maintain a certain level of humidity and moisture, or to allow some or full transmission of moisture and gases. We will therefore look primarily at these aspects, and in connection with these discuss the other important properties outlined above.

A low temperature can normally only be maintained if the ambient temperature is low, or in cooled containers. If the ambient temperature is high, the temperature of packed seeds cannot be kept low for long, and it is more important to prevent the build-up of heat.

It will often be feasible to combine materials so that highest protection is achieved in all respects at the lowest possible cost. Commercially there is an inner package (the sales packaging) and an outer package (transport packaging). The inner package normally provides optimal conditions of moisture, protection against insects, fungi, impurities, and direct loss of seeds, while the outer package provides the extra strength during handling and transport.

As the aspect of permeability to moisture and gases is so important, materials are classified as follows:

(1) Materials freely permeable to moisture and gases,
(2) Materials completely impermeable to moisture and gases when sealed, and
(3) Materials partially impermeable to moisture and gases.

3.2.1. Materials freely permeable to moisture and gases

These include hessian or burlap sacks; cotton bags; nylon net sacks; kraft paper bags; baskets of plant materials, plastics or metal; boxes of wood; and containers made of paper, cardboard and fibreboard which have not been coated with wax or similar substances. The materials are used where good air circulation is required.

For orthodox seeds in ambient conditions these materials are suitable only for rather short storage periods; these can be extended in the case of hardcoated seeds or under dry ambient conditions. If a seed store has facilities for controlling both temperature and relative humidity, then permeable containers can be safely used for orthodox seeds for several years, provided that pests can be excluded.

Mesh size

Mesh size depends on the fruits or seeds to be packed.

In the case of eucalypt capsules and fruits of other species with very small seeds, close-weave cotton bags should be used if there is any chance of the fruit opening during transport.

Woven sacks or baskets give no, or only partial, protection against contamination from outside.

Mechanical properties

The tensile strength of jute fibres is high, but it is easily damaged by hooking or snagging. It may also be damaged by compression in stacking and by impact when dropped.

In some cases special chemical treatment is applied to protect it from rot, insects, rodents or fire. Sensitivity to sunlight makes the fibres brittle.

All containers made of natural fibres may harbour undesirable agents like dirt, insect eggs, or mould spores, and will rot under conditions favourable to biodeterioration.

Cotton seed bags are made of printcloth, drill and Osnaburg fabrics. Osnaburg is a stout, coarse, seamless fabric with the greatest tensile strength and tear resistance of cotton materials. Cotton bags are often protected by an outer package made of a more robust material.

The wet-strength of kraft paper, which is used for bags and multiwall sacks, is relatively poor.

Hessian sacks and baskets give no protection against mechanical or physical impact from the invironment. Other measures must therefore be taken to keep sacks and baskets out of reach of mice and rats or protected against dirt or rain.

Woven plastic sacks will not absorb water, alter their dimensions or diminish in strength when subjected to damp conditions, likely to affect hessian sacks.

Ease of handling

Sacks and baskets are readily available in many sizes.

Small nylon net bags are ideal containers for small lots which need to be kept separate. Many of the stages of seed handling (transport, sun or kiln drying, manual dewinging) can be carried out without having to remove the cones or seeds from the bag.

Labels can easily be tied to sacks and baskets.

Hessian and cotton have the advantage that seed triers can be inserted through the cloth to withdraw samples for testing. The resilience of the cloth will close the hole and avoid subsequent loss of seed. For paper bags, the holes made by seed triers can easily be sealed with adhesive tape.

Empty sacks do not take up much storage room, while stacked baskets require some storage space

Cost
Most of these materials are available locally, not too expensive, and can be used more than once.

3.2.2. Materials completely impermeable to moisture and gases when sealed

These containers include metal cans and drums (iron, tin or aluminium), glass jars, and laminated foil packages.

(Plastic bags or containers may be completely or partially impermeable depending on the thickness of the material. These will be dealt with in section 3.2.3. under partially impermeable materials.)

Only metal cans and glass bottles with tight-sealing threaded caps, and good quality laminated aluminium foil can be recommended for long-term storage. However, containers are only as moisture-proof as their sealing. It is essential always to examine the lid, seal, and the rim of cans or jars. There will often be burrs or groves on cans and jars. The seal may not be of the right material, or it may not remain firmly in position.

As faultless and sealed containers of these materials have no openings, they provide full protection against loss of seed and against contamination from outside.

Mechanical properties
Rigid and unbreakable metal cans provide maximum protection against mechanical damage to the seeds when they are completely filled. They provide good protection against rodents and are equally suitable for storage and subsequent shipment.

Aluminium foil alone is not good for packing seed as its strength is low, but it can be combined with other materials with desirable characteristics. Lamination with regenerated cellulose, polyester, polyamide and polypropylene films protects the foil against mechanical damage, improves the barrier properties by blocking minute perforations, and reduces the necessary thickness of foil. Typical laminations are:

1. aluminium foil/glassine paper/aluminium foil/heat-sealing lacquer.
2. aluminium foil/tissue paper /polythene.
3. paper/polythene/aluminium foil/polythene.

With proper selection of materials, aluminium foil laminations can resist water-vapour transmission; e.g. even the thinnest foil combined with polythene film shows no measurable water-vapour transmission.

Well-sealed glass containers provide good protection against mechanical damage and rodents and are excellent for long term storage. The fragility of glass is a disadvantage.

In some areas, dry fruit/seed may be stored in eathernware jars, produced locally. They offer good pro-

tection against loss and contamination from outside, but are usually fragile and are only moisture proof if they are glazed and have sealed lids.

Ease of handling
Containers are available in many sizes.

Screw-top or clamp-down lids are very convenient if periodic opening and subsequent resealing is anticipated.

Aluminium foil is easily heat-sealed. But further experience of the lasting qualities of laminated foil packets is needed before they can be recommended for general use in long term storage (several decades).

Containers differ much in their ease to be handled, depending on their shape. Glass containers usually give a feeling of insecurity, and they can usually not be stacked.

The ease of labelling depends on the facilities available on a particular container. Proper labelling may not always be easy, e.g. on containers without handles.

Eathernware jars are usually less handy.

Empty tins and glasses take up storage space.

Cost
These containers are among the most costly of the materials, but they may often be found at the market place and second-hand stores at relatively cheap rates.

3.2.3. Materials partially impermeable to moisture and gases

This group includes primarily plastics:

Polyethylene = Polythene (PE)
Polypropylene
Polyester (PET)
Polyamide (nylon) (PA)
Polyvinylidene chloride (PVC)

PE, in its low density form, has a relatively low water-vapour transmission rate but the permeability to gases is high.

High density PE is more resistent to water penetration than regular PE of the same thickness.

The permeability of PE changes with the temperature; thus the lower the temperature, the better the resistance to water vapour; and the higher the relative humidity of the surroundings the faster is the moisture transmission into the bag.

Soft PVC (i.e. PVC with a certain amount of plasticiser) has high permeability.

The permeability to moisture and gases of plastic and polythene containers will depend on the type of material together with the thickness of the material, cf. table 1.

Table 1. Water-vapour transmission rates for different packaging materials.
Temperature 25°C, relative humidity differential 75%-2% (From: Warham, 1986b).

Materials	WVTR g/m²/day
Jute	3300
Kraft 1 ply 80 g/m²	1950
Kraft 2 ply 80 g/m²	1440
Kraft 4 ply	880
Kraft 6 ply	740
Woven polypropylene	1120
PVC	51
Low-density PE	4
PE-coated kraft 10 g/m²	10
PE-coated kraft 23 g/m²	4
PE-coated kraft 34 g/m²	3
Woven PE/PE/kraft liminate	1

The thickness of plastic foils are given in different units, i.e.

1 micron		= 0.001 mm	= 1 µ
1 mil	= 0.001 inch	= 0.025 mm	= 25 µ
1 thou	= 0.001 inch	= 0.025 mm	= 25 µ
1 gauge	= 0.00001 inch	= 0.00025 mm	= 0.25 µ

Polythene bags have been used with good results for up to 5 years' storage of *Pinus caribaea* in Honduras. A thickness of 100-125 µ is recommended, as thinner polythene can permit a significant passage of water vapour in time and is also subject to mechanical damage in handling (Robbins 1983). Harrington (1973) considered 75 µ high density or 125 µ regular density for temperate conditions, and 175 µ high density or 250 µ regular as adequate for even severe tropical conditions, cf. Table 2, p.14.

The property of these materials in respect of permeability may be improved by either adding resins, by combining different plastics, or by combining one or more plastics with other materials:

Polyvinylidene chloride resin
Polyvinyl alcohol resin
Aluminium foil/polythene laminates (cf. 3.2.2.)
Polythene-coated kraft paper.

In addition to these modern plastic materials we have:

Moisture-proof cellophane.

Figures 3 and 4 show the water uptake of wheat seed stored in different packaging materials.

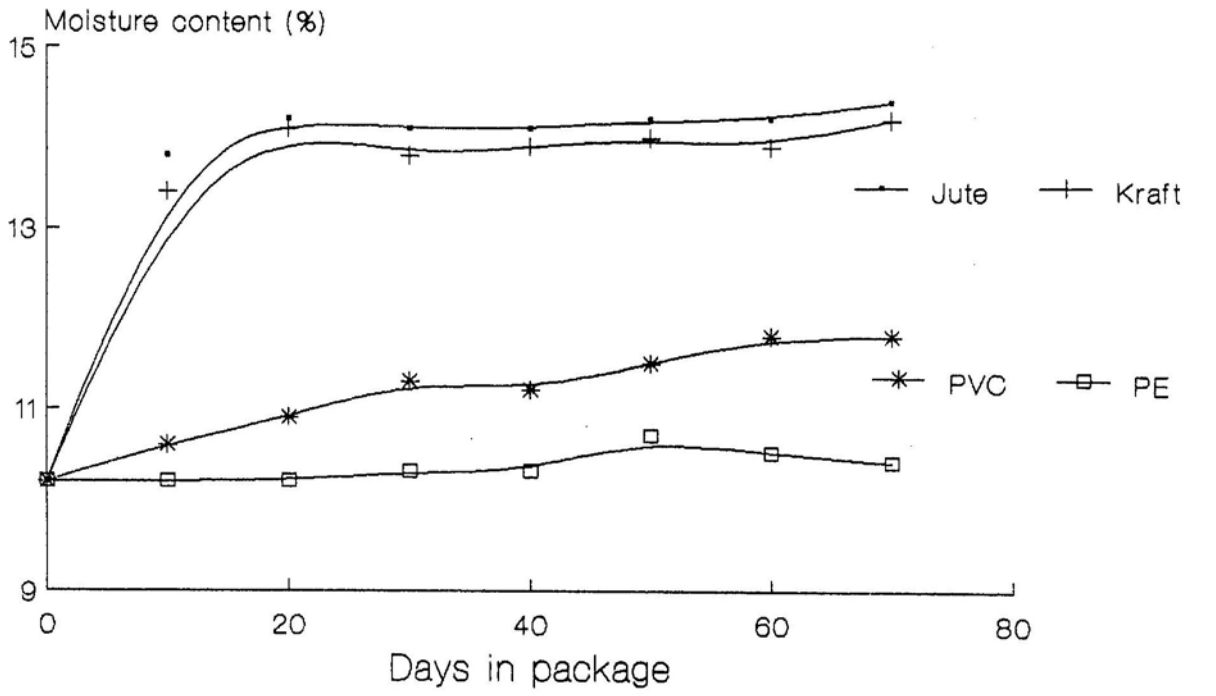

Figure 3. Increase in moisture content ot wheat seed in 4 different packaging materials up to 70 days. Relative humidity was 75 % and temperature 30°C. (After Warham, 1986 a)

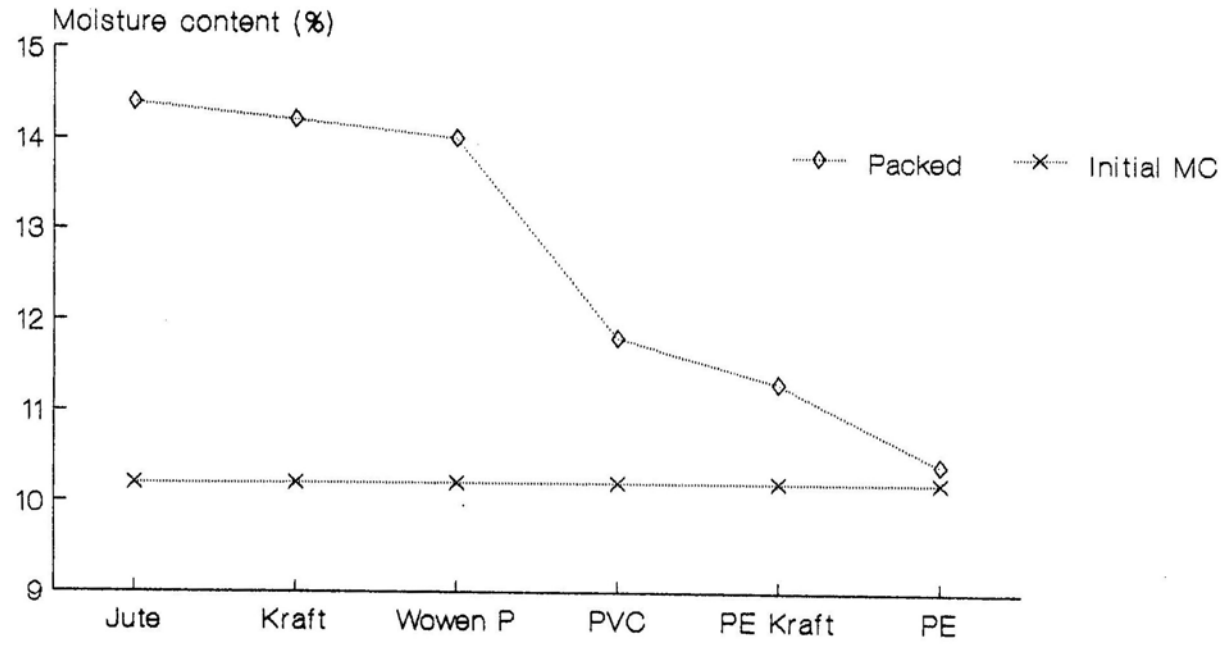

Figure 4. Moisture content of wheat seed after 70 days in 6 different packaging materials. Relative humidity was 75 % and temperature 30°C.

The partially impermeable packaging material can thus be ranked from poorest to best in respect of water-vapour transmission:

polyvinyl chloride (PVC)
polythene-coated kraft paper
low-density polythene.

Note that the figures concern the outer layer of the seed lots, whereas increase is slower and less in the middle.

Essentially, for seed in bulk the outer layer of seeds protects the inner bulk, thus larger bulks are better protected. The smaller the bulk or sample, and the longer time the seeds need to be transported or stored, the greater is the requirement for a packaging material and for the quality of the material.

As faultless and sealed containers of these materials have no openings, they provide full protection against loss of seed and against contamination from outside.

Mechanical properties
PE can be laminated to other films, foil, paper, fabrics, and fibreboard to combine desirable characteristics and improve physical properties.

Plastic bags thinner than 100-150 µ (approx. 0.1 mm) are not sufficiently resistant to puncturing during handling.

Polyamide or nylon has good strength and moulding properties, and relatively low permeability. It is used in many laminates, e.g. for vacuum packing.

The use of PVC is declining as it degrades very slowly in nature, and chloride is liberated when PVC is burnt.

Ease of handling
Bags may be bought according to size or made from a roll of PE using a heatsealing machine.

The heat-sealability of low-density PE is excellent. It is frequently used as the inner layer in laminates. High-density PE is more difficult to heat-seal.

The outer container should normally be rigid and of a handy size, fitting the weights of the seed lots; i.e. plastic or metal boxes, plastic or metal cans from 1 to 30 litres, and for large seed lots, plastic drums of 60 to 150 litres.

For temporary storage, the bags should be sufficiently large so that an adequate amount of loose plastic is available for twisting together and tying, excluding as much as possible of the enclosed air. For longer storage, the bags must be heat-sealed.

Cost
PE and PVC are comparatively inexpensive. Polyester and laminated materials are rather expensive.

Carbon dioxide

Sometimes there is a need to maintain a certain atmosphere around the seed, and the choice of packaging material is then very important, e.g. to maintain an atmosphere of carbon dioxide or to prevent entrance of ethylene or oxygen. However, there is little information available in this respect.

The carbon-dioxide exchange method: The seeds are packed with an appropriate volume of carbon-dioxide gas in a bag of plastic film of low gas permeability and then sealed. At this stage the gas surrounds the seeds and expands the bag. But the volume of the bag gradually decreases because of the carbon-dioxide adsorption by the seeds and finally the bag adheres to the seeds.

Note that some materials having a high resistance to carbon-dioxide and other gases may not necessarily have adequate resistance to water vapour; e.g. the bags ('Riloten/X', manufactured for the food industry) previously used by Danida Forest Seed Centre for this method had an unsatisfactorily high water vapour transmission rate.

The following materials are listed in descending order of carbon dioxide permeability:

MATERIAL	PERMEABILITY (gr/25 μ x m^2 x 1 atm.)
Polyethylene	75
Polypropylene	30
Moisture-proof cellophane	0.3
Polyester	0.2
Polyamide	0.1
Polyvinylidene chloride resin	0.1
Polyvinyl alcohol resin	0.02

3.3. How to Buy Plastic Materials

Plastic materials have evidently quite different properties in respect of protection of seed. Therefore, it is important to be able to distinguish the different types.

First, materials differ in their smell when burnt. PVC will have a pungent, acid smell; it will turn dark, become soft and decompose, while PE will smell and look like paraffin wax. It will melt and drip. The lower part of the flame of PE will be blue, the top yellow and the smoke white, whereas PVC's flame will be yellow-orange. See further in Appendix 1.

Regarding the density of materials, it is possible to buy according to weight in relation to area, g/m^2 , see Table 2.

Table 2. Weight in grammes per m^2 of some plastic materials.

Film thickness	PE low density	PE high density	transparent PVC
75 µ	69	71	94
100 µ	92	95	125
125 µ	115	119	156
150 µ	138	143	188
175 µ	162	167	218
200 µ	184	190	250
225 µ	207	214	281
250 µ	230	238	313

4. CHOICE OF PACKAGING MATERIAL

As is understood from the above, a large number of factors and their interaction need to be considered when selecting packing material for seeds to be transported or stored.

WE MAY INITIALLY CONSIDER

Are seeds moist or dry?
Are seeds recalcitrant or orthodox?
Which minimum or maximum moisture content and
temperature are needed?

FOR THE DEFINED CATEGORY, THE FOLLOWING NEEDS TO BE ASKED

Are seeds healthy (free of insects and diseases)?
Can they be further processed to improve storability?
Small sample or bulk?
Conditions and their possible variation
during transit or storage?
Length of time in transit or storage?

THEN THE PROPERTIES OF PACKAGING MATERIALS MUST BE EVALUATED

in respect of:

Permeability
Insulation
Maximum mesh size
Mechanical properties
Ease of handling
Cost

Each situation must be described as fully as possible in order to provide the ultimate basis for determining the best suited packaging material. It will always be a matter of the 'critical situation' that should determine the choice.

Some Cases

4.1. Mature, indehiscent, dry fruits with orthodox seeds During collection, transport and temporary storage

During collection, the fruits are most often placed in bags or sacks of jute (hessian).
For dry cones or fruit, polyethylene heavy duty sacks may be used.
During transport and temporary storage, large open-mesh baskets are ideal.
Small nylon net bags are ideal containers for small lots which need to be kept separate.
Woven plastic sacks may also be used.

Storage
For orthodox seeds in ambient conditions the following containers are suitable only for rather short storage periods: hessian or burlap sacks, cotton bags and containers of paper, cardboard and fibreboard.

In the case of hardcoated seeds or in dry ambient conditions, the storage period can be extended. If a seed store has facilities for controlling both temperature and relative humidity, then permeable containers can be safely used for orthodox seeds for several years, provided that pests can be excluded.

Plastic bags may be used, but type and thickness of the material must be adequate for the length of storage period and the ambient conditions.

Only metal cans and glass bottles with tight-sealing threaded caps, and good quality laminated aluminium foil can be recommended for long term storage.

4.2. Mature, dehiscent, dry fruits with orthodox seeds

The types of bags are essentially the same as for indehiscent fruits. However, the weave of the bag will depend on the size of the seed.

In the case of eucalypt capsules and fruits of other species with very small seeds, close-weave cotton bags should be used if there is any chance of the fruit opening during handling, storage and transport.

4.3. Mature, indehiscent fruits (with orthodox seeds) with juicy pulp During collection, transport and temporary storage

The same kind of containers as for recalcitrant seeds, see below.

Storage
This kind of fruit cannot be stored. They should be processed as soon as possible.

4.4. Recalcitrant seeds During collection, transport and temporary storage

Recalcitrant seeds must be treated with great care, baskets or cloth bags usually being suitable containers. If plastic bags are used, their tops should be left open and small holes made in the sides.

The size and number of holes in the containers should be reduced during transportation in open vehicles. Open containers should be covered with newspaper or cloth to reduce the desiccating effect of air movement.

If seeds begin to germinate, the germinants may be saved if they are placed in rigid containers lined with newspaper or other absorbent material and kept moist.

For temporary storage of recalcitrant seeds, open or freely permeable containers such as hessian sacks or baskets should be used and desiccation avoided.

Storage

Actual storage of recalcitrant seed is usually not realistic if the seed is sensitive to low temperatures. 'Storage' of such seeds amounts to keeping them alive until they are sown.

---

indehiscent seeds remain in the fruit, viz. teak.
dehiscent seeds are discarded from the other fruit parts, viz. eucalypts.

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6. APPENDICES

Appendix 1

1. Identification of some plastic-materials by flame test

Material	smell	flame colour	reaction
Polyethylene PE incl. EVA *)	burnt wax	blue with yellow top, white smoke	burns; melts and drips
Polypropylene PP like polyethylene			
Polyvinyl chloride PVC	pungent acid	yellow/ orange with green centre	self extinguishing **) turns black and soft; . decom-poses
Polyvinyl i denechloride PVDC	pungent acid	yellow with green edges	self extinguishing; turns black and hard
Ichloride PVDC			
Polyamide PA (nylon)	burnt hair or feathers	blue with yellow top	self extinguishing; melts; hard drops; pulled out in fibres; foamy
Polyester PETP	sweet	yellow with blue centre; yellow-black smoke	develops a lot of soot; burns with steady flame, no drops

*) Ethylene vinyl acetat, consists largely of PE
**) may burn because of plasticizers

(a sample of the material is held in a flame for not more than 10 seconds).

Appendix 2

2. The permeability of some plastic materials

The figures give an impression of the order of magnitude.

Material	water vapour $g/m^2/24\ h$	oxygen	carbon dioxide $m^l/m^2/24h/atm.$
PE			
low density	10-20	6000-8500	35000
high density	5-10	1600-2100	7000
EVA	25-45	7000-14000	20000
PP			
un-oriented	4-12	1300-6400	8500
biax orient.	4-8	2000-2500	8000
PETP	10-30	40-100	200-500
PA			
PA 6 and 66	200-350	30-200	150-400
PA 11	5-15	90-500	2300
PVC soft	200-600	500-7500	500-12000
PVDC	0.5-5	5-26	40-50

Permeability to water vapour was measured at 38°C and 90 % relative humidity. For the gases the temp. was 20° C and relative humidity 0 %. All materials were 0.025 mm (25 μ) thick.

Permeability depends on the thickness of the material; at double thickness permeability is halved.

Permeability to gases changes with temperature and is halved when temperature drops 10°C.

Different modifications of the materials greatly change their permeability.

3. Properties of some plastic materials

Summary

Polyethylene PE is found in low density form and high density form (weights, see page 14). Ethylene vinyl acetate EVA consists largely of PE. The permeability to water vapour is low, but high to gases. Both high and low density PE can be used for sub-zero temperatures. Low density PE and EVA have good heat-sealing properties. Low price. Good mechanical properties. Widely used.

Polypropylene PP is found in un-oriented and in oriented form, of which the former may resemble high density PE; very strong, but gets brittle below 0 °C. Cannot be heat-sealed by normal sealing methods.

Polyvinyl chloride PVC is found in many types, from soft and elastic to very rigid types. Plasticizers are added to thin films. They have high permeability to water vapour and gases. Mechanical properties are good. Sealing properties are not too good. Soft PVC may be sealed by high-frequency methods.

Polyvinylidene chloride PVDC has low permeability to water vapour and gases. Mostly used in combination with other packaging materials. Common sales name is Saran.

Polyamide PA (nylon) is found in different types. They can all be used below 0 °C. The permeability to water vapour is medium, low to gases. Good mechanical properties.

Polyester PETP has good mechanical properties and can be used below 0 °C. Mostly used in combination with other materials. Permeability is medium, but is often improved by PVDC. Difficult to heat seal.