ENHANCED PERFORMANCE OF BIMODAL LLDPE IN FROZEN FOOD PACKAGING APPLICATION

Hanneli Seppänen
BOREALIS POLYMERS OY
FINLAND

ABSTRACT

In this study several polyethylene grades, used today in frozen food packaging, were evaluated and it was noted that Borstar® bimodal LLDPE products from Borealis will deliver a unique toughness / stiffness balance, high mechanical strength and impact resistance at low temperatures, even down to – 40 °C which is required for packing, transporting, handling and storing of frozen food. The special matt surface with low friction brings benefits to processability as well as filling on the packaging machines and offers potential for differentiated eye-catching appearance and printing for enhanced sales appeal.

DISCUSSION

Frozen food packaging market and requirements for packaging films

General consumer trends are affecting the growth of frozen food packaging market. Smaller families, more single person households and an ageing, affluent population demand smaller portions and convenient easy-to-open-and-use packages. More women work outside the home and so less time is available for making food, increasing the appeal of food with short preparation times. Eating habits are also changing. Snacking and eating out is more popular. Families eat less together. Therefore the demand for frozen ready meals rises continuously.

Frozen food sales growth in 2002 was 2-3 % , with price discounts, buy-one-get-one-free promotions, limited new product development and competion from chilled food sector. However, 1996-2000, frozen food sales grew by 15 %, whereas retail food sales increased only 4,8 %. Biggest growth has been seen in frozen ready meals, pizza and bakery. Food development is a key feature, e.g. rising pizzas, soft ice cream, crossover brands from other sectors, notably from confectionery. Sales are declining in frozen potato products, cakes and desserts. Frozen food packaging market is increasing, due to growth in both frozen food consumption and food development to meet consumer demands for convenience, premium products and easier, quicker food preparation. Main packaging development is in converting, new packaging designs and solutions made possible by enhanced packaging materials.

The frozen food packaging film industry as well as frozen food packaging film market require improved mechanical performance, adequate barrier properties, good advertising function, fast packaging speeds, automation and pro-environmental argumentation. Industry is developing differentiated films for smaller, easily openable, low-temperature resistant and/or microwaveable packages which increasingly need to support a branding philosophy. New design features like matt film surface help in enhancing the branding. Downgauging flexibility with good overall performance will give additional benefits. Food packaging requires economical, innovative solutions with high package integrity and excellent food quality. Package design is increasingly important in new product promotions.

Several types of films are used today. <u>Mono films</u>, mainly blends of e.g. EVA or LDPE with LLDPE, still dominates in volume sold to this market. <u>Co-extruded films</u>, with tailor-made combinations delivering functional properties, downgauging and mechanical flexibility, are increasingly replacing mono films. Coextrusion technology allows the combination of a sealing layer with a strong core layer together with desired optical properties and printability in the surface layer. Laminated film structures particularly yield combinations of polymers with high stiffness and optical properties (BOPP, PET) or also barrier properties (PA) with PE.

New frozen food packaging film solutions with bimodal LLDPE

Borealis have developed a range of LLDPE grades using own bimodal technology, which offers excellent advantages for frozen food film. This has been confirmed through our co-operation with the frozen food packaging value chain.

Bimodal LLDPE products in particular deliver a unique toughness/stiffness balance, high mechanical strength and impact resistance at low temperatures, even down to –40°C which is required for transportation, handling and storage. Film producers and converters also require excellent processability, high output and flexibility in mono/co-extrusion and blending. Bimodal LLDPE products are proven to be very convenient LLDPE products to process in blown film equipment resulting in reduced production problems and improved regularity.

In addition the special matt film surface with low surface friction brings benefits to processability and filling on the packaging machines. The matt surface also offers the potential for differentiated aesthetic appearance and printing. As a result of these properties, end users find bimodal LLDPE bags consistent when carried home from the supermarket and stored in the freezer. The nutritional quality of frozen food remains excellent. Matt surface bags are proven to be very eye-catching and emphasising the product differentiation, like matt surface bags for organically grown frozen food products.

The performance of bimodal film can be evaluated by using a frozen food film (FFF) specification radar, Figure 1. Most important properties (Stiffness, Dart Drop Impact, MD tear resistance, Ball puncture resistance at +23°C as well as –40°C) have been defined at frozen food packaging lines together with food producers and packers, Table 1.

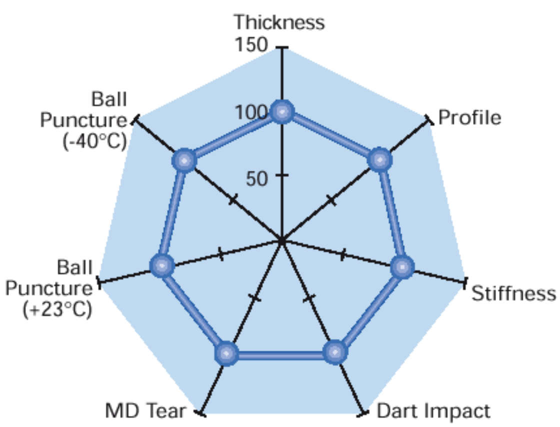


Figure 1. FFF specification radar

Physical property	Description	Specification
Film Thickness (optional)	Should be in accordance with the specified film Thickness.	100 [%]
2-Sigma Film Thickness Variation	Film Thickness profile is important in order to map potential weaknesses in the tubular film/bags.	<6 [%]
Modulus/ Stiffness	1% Secant modulus in Transverse Direction, reflects the rigidity of the film and is important for the packaging operation in FFS as well as transport and handling of the bags.	>200 [MPa]
Film Impact RT (23°C)	Dart Drop Impact test performed on the flat side of the bag/ film in order to map toughness and mechanical strength.	>4.5 [g/µm] [F50%]
MD Tear Resistance	Elmendorf tear strength in the Machine Direction is critical and reflects the general mechanical strength and toughness.	>2.0 [N]
Ball Puncture RT (23°C)	Ball Puncture test performed on flat side of the bag/film in order to map toughness and mechanical strength, based on ASTM D5748-95 (Puncture behaviour of plastic film sheets). This method determines the resistance of a film to the penetration of a probe at room temperatur (RT).	>2 [J]
Ball Puncture at -40°C	Ball Puncture test performed on flat side of the bag/film in order to map toughness and mechanical strength, based on ASTM D5748-95 (Puncture behaviour of plastic film sheets). This method determines the resistance of a film to the penetration of a probe at room temperatur (RT).	<2 [J]

Methods: Thickness & variation - own method
Stiffness - ASTM 882-A
Impact - ISO 7765-1A
Tear resistance - ISO 6383-2
Ball puncture - ASTM D5748 -95

Table 1. FFF specification properties, description and method.

Comparison of bimodal LLDPEs to the FFF specification as well as to commercially used coextruded frozen food packaging film are presented in Figures 2 and 3.

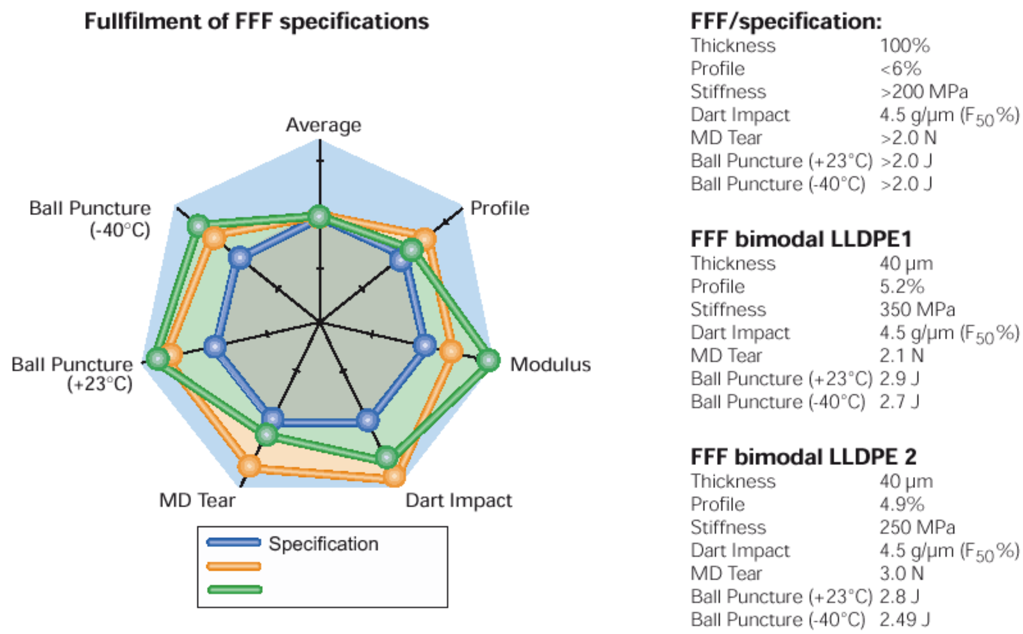


Figure 2. Bimodal LLDPEs compared to FFF specification.

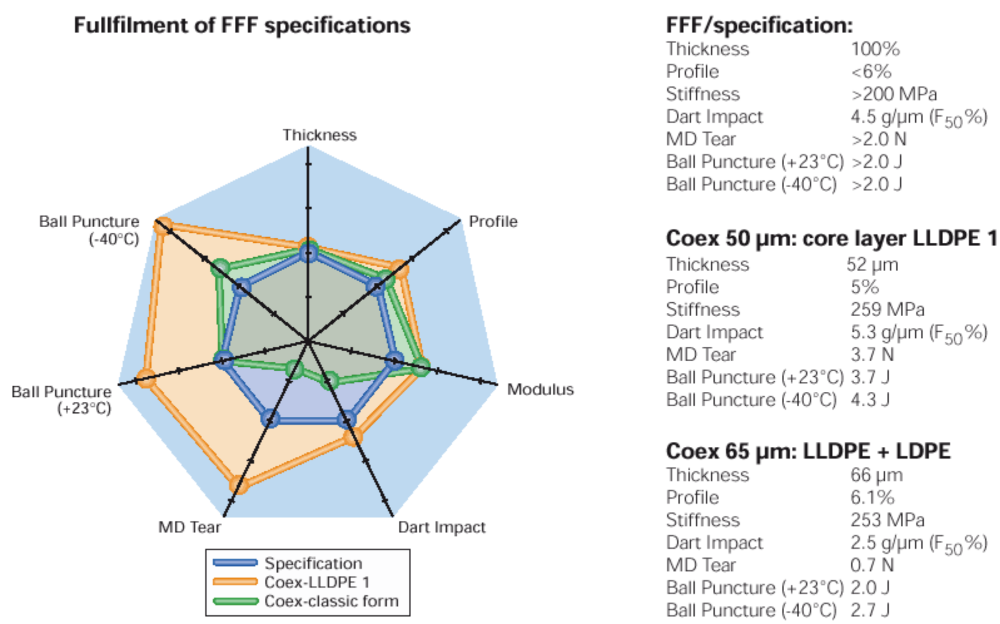


Figure 3. Two coextruded frozen food films compared to FFF specification. In the first film bimodal LLDPE is in the core layer, enhancing impact properties, especially at low temperatures. The other film is a typically used coextruded frozen food packaging film.

Processability problems occurring with conventional and "enhanced" LLDPEs can be overcome with bimodal LLDPEs which offer better bubble stability, less thickness variation and improved output flexibility as well as processing options on various die and screw configurations with high productivity, Figure 4.

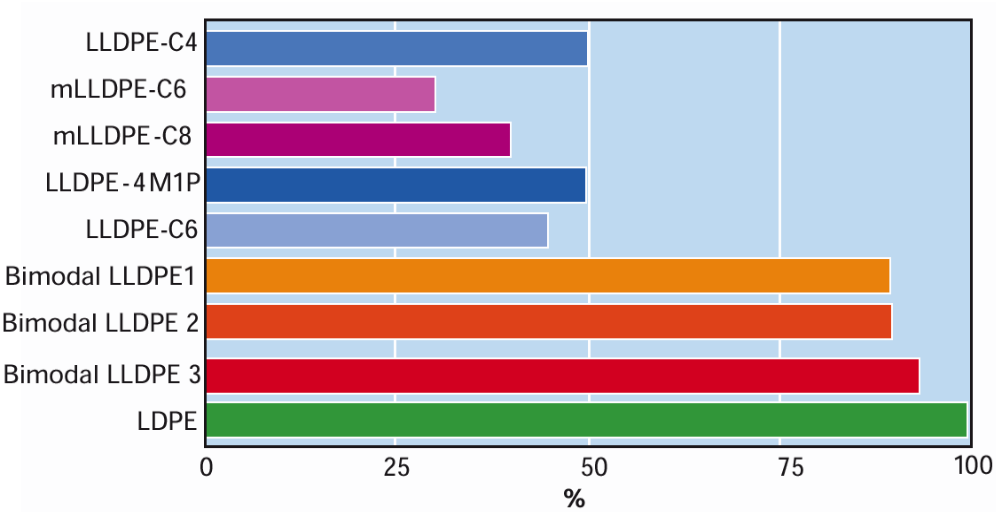


Figure 4. Processability comparison of materials typically used in frozen food packaging films.

CONCLUSIONS

Bimodal LLDPEs from Borealis offer several advantages for frozen food packaging film market. Improved mechanical performance and processability, enhanced economical benefits as well as excellent low temperature resistance are the major advantages.

Benefits to the whole frozen food packaging value chain are significant. For the film producer and converter bimodal LLDPEs offer good processability on conventional dies and screws, both in mono- and co-extrusion processes, improved bubble stability with a more even thickness profile as well as downgauging potential with thickness flexibility. Blending flexibility with bimodal LLDPEs is an additional benefit. For the frozen food packer films made from bimodal LLDPE will offer far better balance between stiffness and toughness than conventional PEs. Impact properties are excellent, especially at low temperatures where the impact resistance is superior. The most important benefit from bimodal LLDPE films for the retailer is improved package integrity with less broken packages in the freezers, as well as enhanced sales appeal due to the inherent bimodal matt surface effect which permits innovative design solutions. Finally the end user will find that frozen food bags made from bimodal LLDPE do not break when carried home from the supermarket and stored in the home freezer. The nutritional quality of the frozen food packed in bimodal film remains excellent.

Enhanced performance of bimodal LLDPE in frozen food packaging application

Hanneli Seppänen
Application manager
Borealis Polymers Oy
Finland

Content

- Frozen food packaging market today
- Frozen food packaging industry and market demands
- Consumer trends in frozen food packaging
- Trends in frozen food packaging concepts
- Today´s packaging solutions
- Frozen food packaging film specification
- Low temperature performance of bimodal LLDPE
- Processability of various PEs used in frozen food packaging films
- Conclusions / Bimodal LLDPEs contribution to frozen food packaging film
- Bimodal LLDPE contributes to the whole frozen food packaging value **chain**

Frozen food packaging market today

- Frozen food sales growth 2002 was 2-3 % , with price discounts, buy-one-get-one-free promotions, limited new product development and competion from chilled food sector
- However, 1996-2000, frozen food sales grew by 15 %, whereas retail food sales increased only 4,8 %
- Biggest growth in frozen ready meals, pizza and bakery
- Sales declining in frozen potato products, cakes and desserts

Frozen food packaging market today (cont.)

- Food development is a key feature, e.g. rising pizzas, soft ice-cream, crossover brands from other sectors, notably from confectionary

- Frozen food packaging market is increasing, due to growth in both frozen food consumption and food development to meet consumer demands for convenience, premium products and easier, quicker food preparation

- **Main packaging development is in converting, new packaging designs and solutions possible with enhanced packaging materials**

Frozen food packaging industry and market demands

- Improved mechanical performance
- Adequate barrier properties
- Good advertising option
- Downgauging with better or equal properties
- Fast packaging speeds
- Automation
- Pro-environmental argumentation
- Cost efficient packaging with benefits for the whole packaging value chain

Consumer trends in frozen food packaging

- More single person households
  - -> **smaller portions**
  - -> **convenience formats**
- Ageing, but affluent population
  - -> **smaller portions**
  - -> **easy to open & re-close, use and through-away**
  - -> **premium lines with good nutritional value**
- More women working outside home
  - -> **less time used for making food**
  - -> **food with little preparation time**
  - -> **wider variety of foods**
  - -> **home deliveries, e-commerce**
- Changing eating habits
  - -> **more eating out, snacking**
  - -> **demise of traditional family meals**
  - -> **frozen & microwaveable meals**

Trends in frozen food packaging concepts

- Increased pack line speeds -> **mechanically improved packaging with seal integrity**
- Automation -> **strong, consistent packaging materials**
- Smaller packs -> **easy-openable packaging**
- Bigger packs or multipacks -> **tougher, reclosable packaging**
- **Multimaterial** structures become dominant over monomaterial ones
- Optimal **downgauging** with focus on
  - acceptable cost
  - source reduction (less grades in formulations)
  - legislation (taxes based on package weight)
  - acceptable performance

Today´s packaging solutions

Flexible Packaging

Plastic / mono films, coex films, laminates, bag-in-box

- ice cream, vegetables, potato products, fruit & berries, meat, poultry, ready meals

Laminated paper / with plastics, aluminium

- ice cream, ready-to-oven bakery products

Rigid Packaging

Paperboard / extrusion coated, barrier, non-barrier

- as primary packaging for ice cream, fish, seafood, meat products, vegetable & potato products
- as secondary packaging for ready meals, desserts, pizzas

Paperboard + PET / CPET

- dual-ovenable ready meals

Plastic / trays, cups, tubs, boxes

- ice cream, desserts

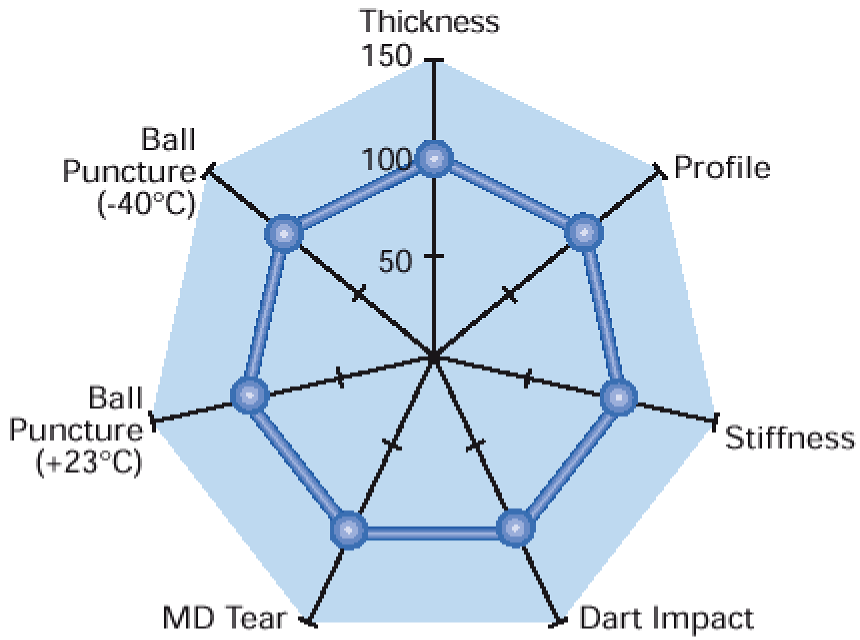
Aluminium

- ovenable ready meals, lidding

Types of frozen products packed

- Potato products
- Vegetables
- Fruit and berries
- Fish products
- Seafood
- Meat products
- Poultry products
- Ready meals
- Pizza
- Bakery products
- Desserts
- Ice cream

Frozen food packaging film (FFF) specification

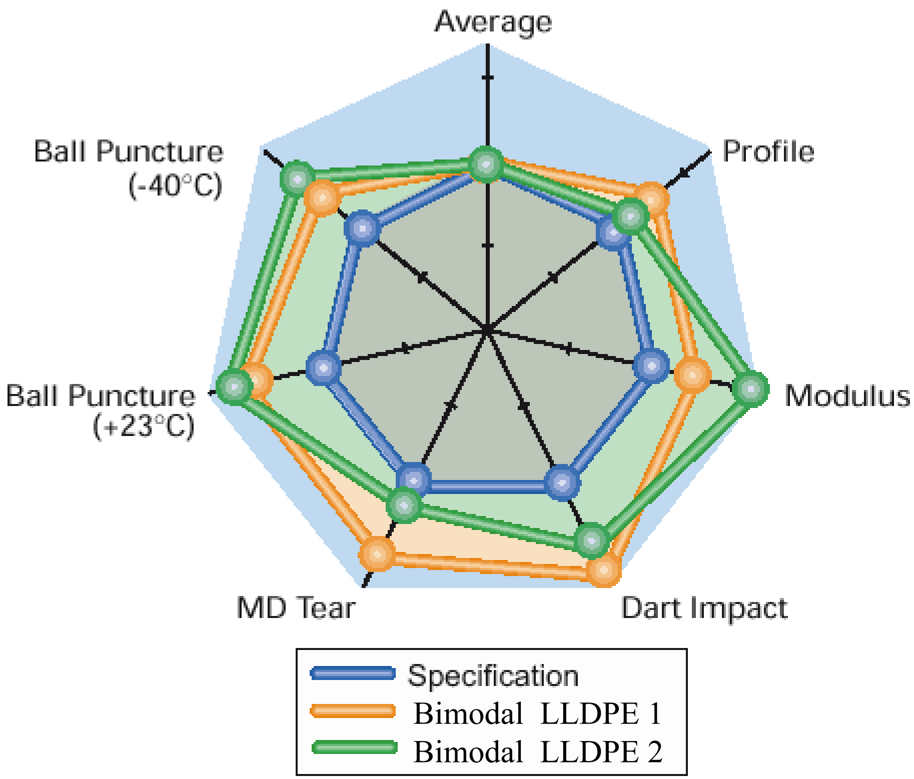


Properties specified for frozen food packaging film (FFF) according to relevant testing at food producer and packer

Physical property	Description	Specification
Film Thickness (optional)	Should be in accordance with the specified film Thickness.	100 [%]
2-Sigma Film Thickness Variation	Film Thickness profile is important in order to map potential weaknesses in the tubular film/bags.	<6 [%]
Modulus/ Stiffness	1% Secant modulus in Transverse Direction, reflects the rigidity of the film and is important for the packaging operation in FFS as well as transport and handling of the bags.	>200 [MPa]
Film Impact RT (23°C)	Dart Drop Impact test performed on the flat side of the bag/ film in order to map toughness and mechanical strength.	>4.5 [g/µm] [F50%]
MD Tear Resistance	Elmendorf tear strength in the Machine Direction is critical and reflects the general mechanical strength and toughness.	>2.0 [N]
Ball Puncture RT (23°C)	Ball Puncture test performed on flat side of the bag/film in order to map toughness and mechanical strength, based on ASTM D5748-95 (Puncture behaviour of plastic film sheets). This method determines the resistance of a film to the penetration of a probe at room temperatur (RT).	>2 [J]
Ball Puncture at -40°C	Ball Puncture test performed on flat side of the bag/film in order to map toughness and mechanical strength, based on ASTM D5748-95 (Puncture behaviour of plastic film sheets). This method determines the resistance of a film to the penetration of a probe at room temperatur (RT).	<2 [J]

Methods: Thickness & variation - own method
Stiffness - ASTM 882-A
Impact - ISO 7765-1A
Tear resistance - ISO 6383-2
Ball puncture - ASTM D5748 -95

Fullfilment of FFF specifications



FFF/specification:

Thickness	100%
Profile	<6%
Stiffness	>200 MPa
Dart Impact	4.5 g/µm (F_{50}%)
MD Tear	>2.0 N
Ball Puncture (+23°C)	>2.0 J
Ball Puncture (-40°C)	>2.0 J

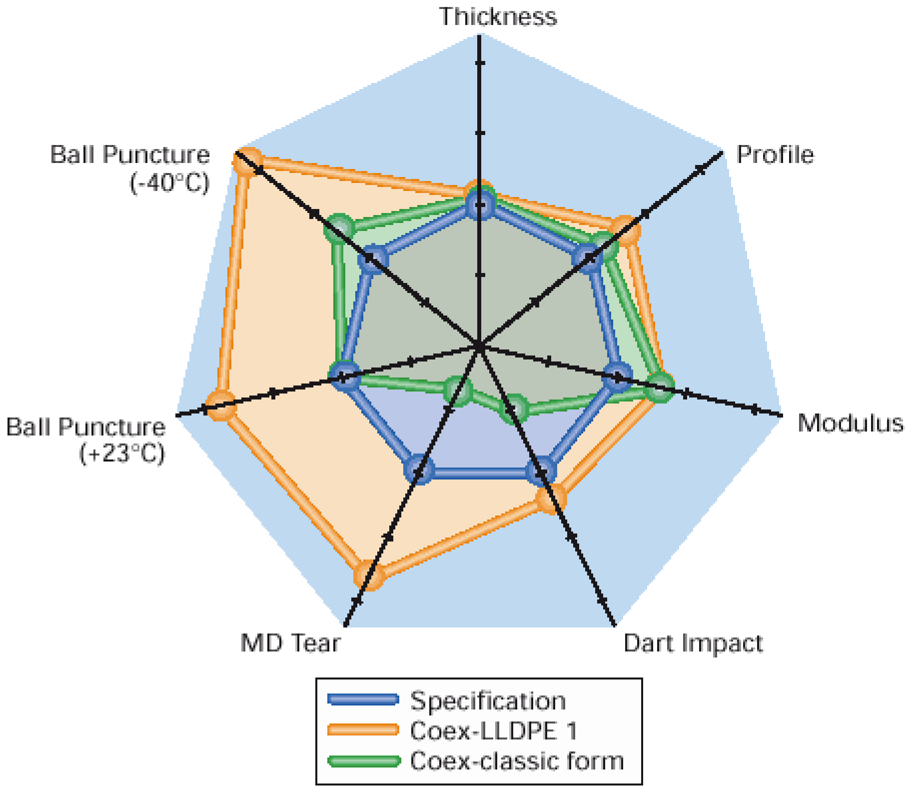
FFF bimodal LLDPE1

Thickness	40 µm
Profile	5.2%
Stiffness	350 MPa
Dart Impact	4.5 g/µm (F_{50}%)
MD Tear	2.1 N
Ball Puncture (+23°C)	2.9 J
Ball Puncture (-40°C)	2.7 J

FFF bimodal LLDPE 2

Thickness	40 µm
Profile	4.9%
Stiffness	250 MPa
Dart Impact	4.5 g/µm (F_{50}%)
MD Tear	3.0 N
Ball Puncture (+23°C)	2.8 J
Ball Puncture (-40°C)	2.49 J

Fullfilment of FFF specifications



FFF/specification:

Thickness	100%
Profile	<6%
Stiffness	>200 MPa
Dart Impact	4.5 g/µm (F_{50}%)
MD Tear	>2.0 N
Ball Puncture (+23°C)	>2.0 J
Ball Puncture (-40°C)	>2.0 J

Coex 50 µm: core layer LLDPE 1

Thickness	52 µm
Profile	5%
Stiffness	259 MPa
Dart Impact	5.3 g/µm (F_{50}%)
MD Tear	3.7 N
Ball Puncture (+23°C)	3.7 J
Ball Puncture (-40°C)	4.3 J

Coex 65 µm: LLDPE + LDPE

Thickness	66 µm
Profile	6.1%
Stiffness	253 MPa
Dart Impact	2.5 g/µm (F_{50}%)
MD Tear	0.7 N
Ball Puncture (+23°C)	2.0 J
Ball Puncture (-40°C)	2.7 J

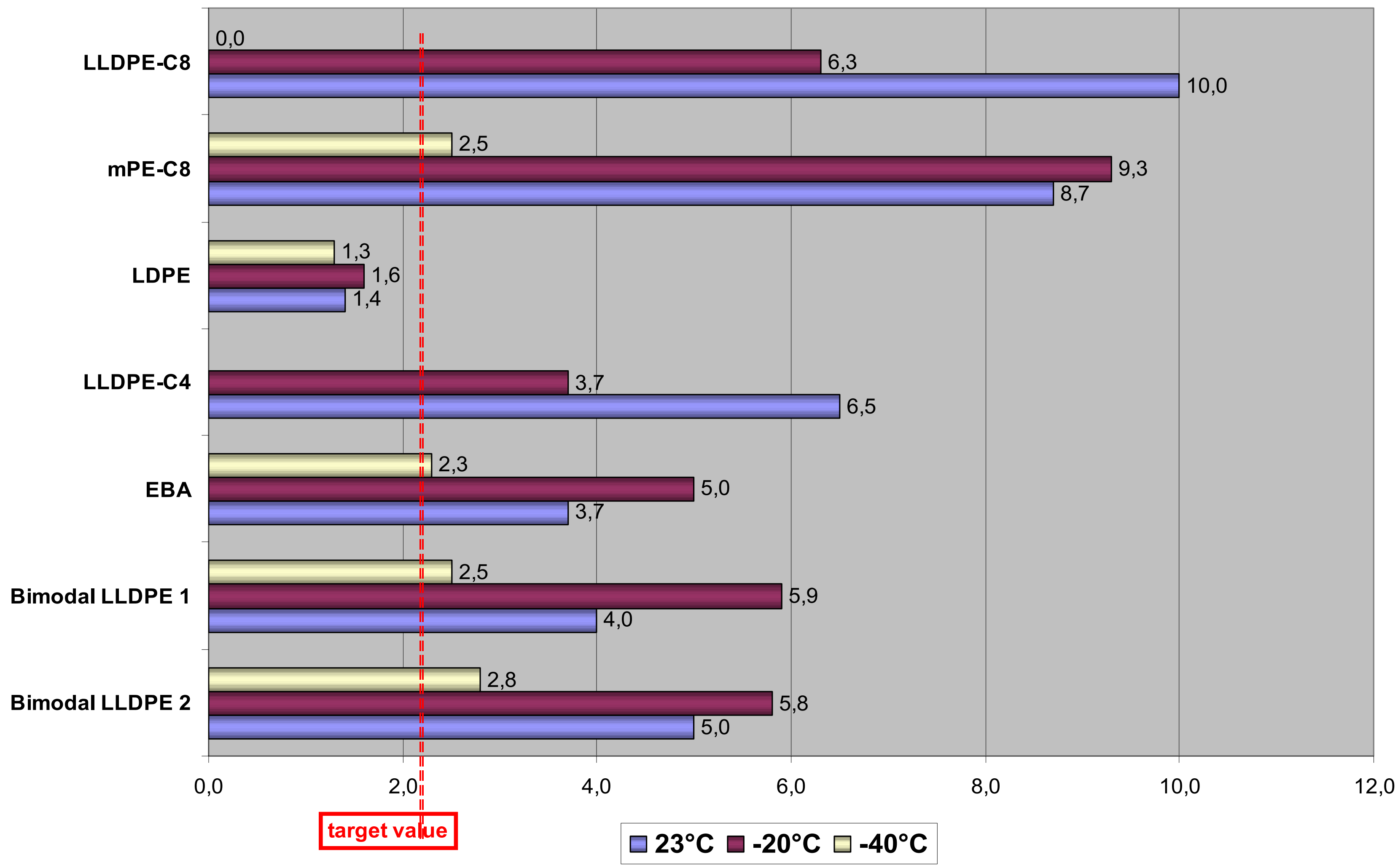
Ball puncture resistance (slow propagation) at low temperatures

The procedure based on ASTM D5748-95 determining the resistance of a film to the penetration of a probe in following conditions:

- Universal testing machine : Zwick 1445/Zwick Z050 (tension and compression, load cell : 10 kN)
- Specimen holder according to ASTM D5748-95, inside diameter = 102 mm
- Probe ball according to ASTM D5748-95, probe diameter = 19 mm
- Test speed 250 mm/min
- Register thickness of sample based on average
- Temperatures : RT (room temperature) and -40°C (temperature chamber)
- Conditioning time : - RT samples min 24 h at room temperature
  - -40°C samples at -40 °C for about 2 h (before testing)
- Results :
  - Max force (N)
  - Displacement at max. force (mm)
  - Energy at break (total energy) (J)
  - Displacement at break (mm)

Ball puncture resistance at low temperatures

Energy at break (J)



Impact Falling Weight (rapid propagation) at low temperatures

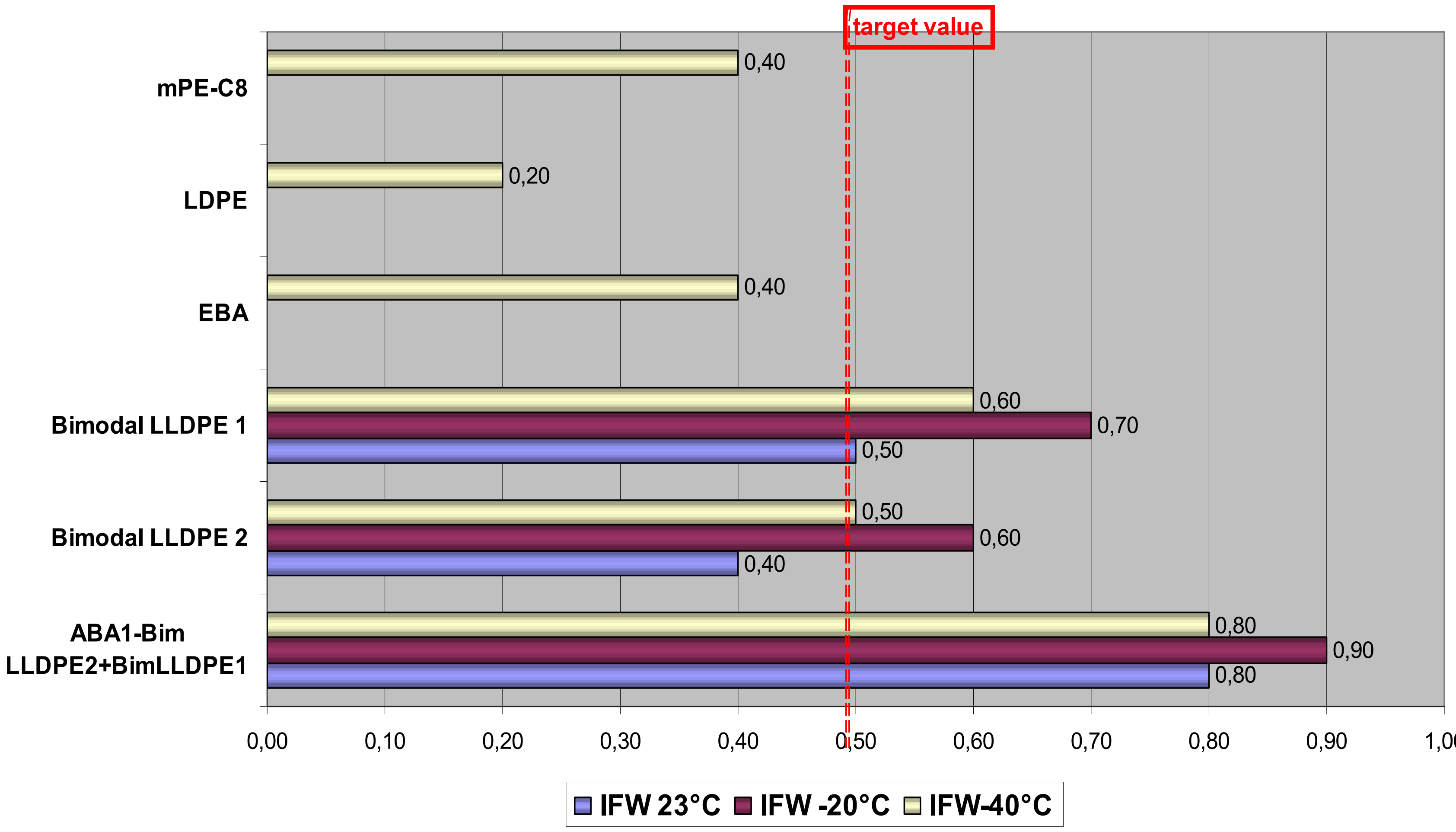
The procedure based on ISO 6603 determining the resistance of a film to the penetration of a probe in following conditions :

- Height of fall : 100 cm
- Weight of probe : 3.22 kg

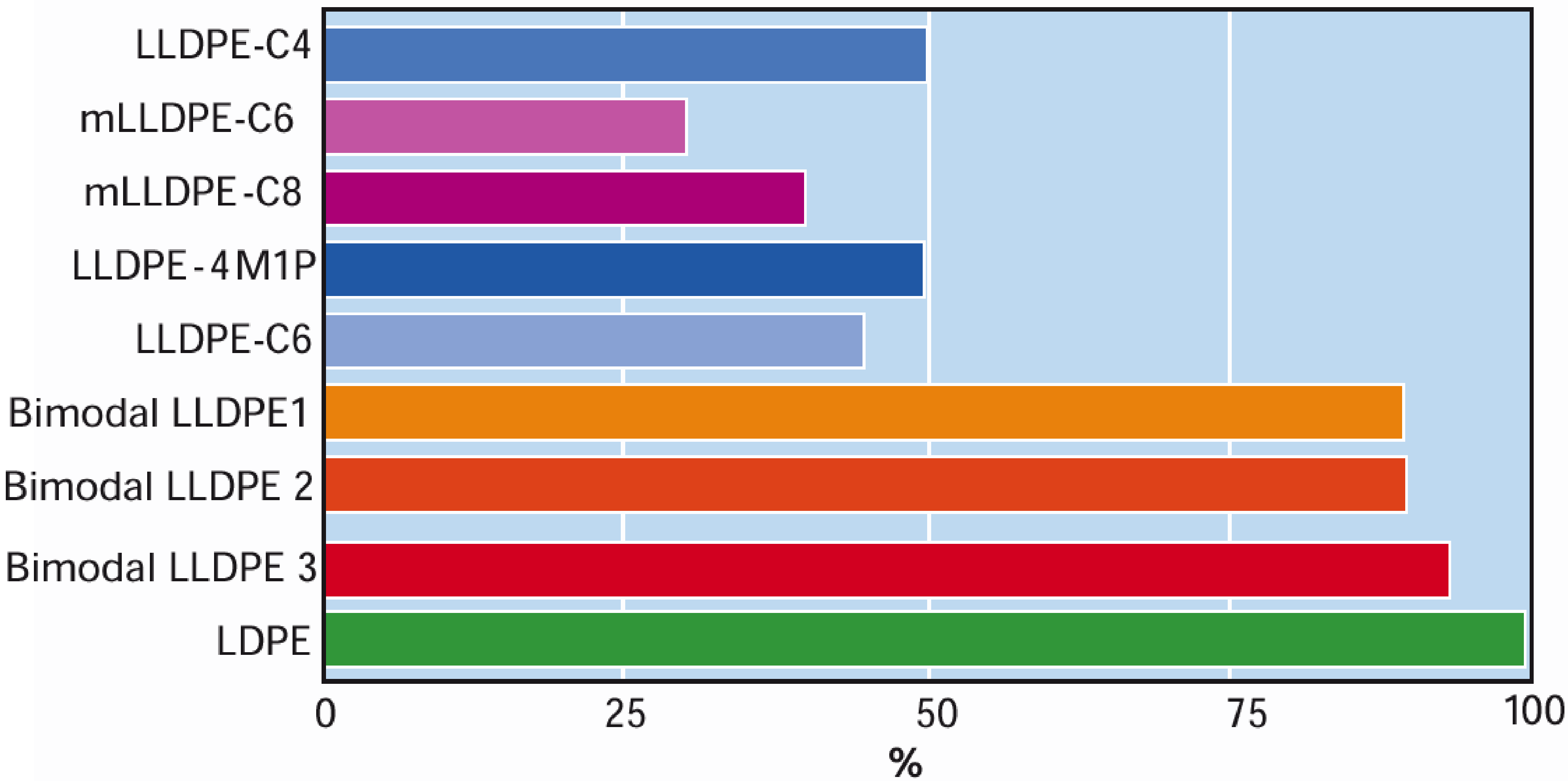
- Results :
  - Max force (N)
  - Displacement at max. force (mm)
  - Energy at break (total energy) (J)
  - Displacement at break (mm)

Impact Falling Weight at low temperatures

Energy at break (J)



Processability of various PEs used in frozen food packaging films



Conclusions
Bimodal LLDPE contribution to frozen food packaging film

Improved mechanical performance

- Excellent mechanical properties at room temperatures
- Excellent impact properties at low temperatures
- Excellent stiffness / impact balance
- Bimodal LLDPE grades are suitable for both coex and mono extrusion
- Lower extrusion temperature requirements vs conventional LLDPEs
- Good bubble stability
- Downgauging potential

Conclusions
Bimodal LLDPE contribution to frozen food packaging film

Improved processability

- Processability and bubble stability close to LDPE
- Flexible film extrusion on various die and screw systems with high productivity
- Excellent processability compared to other “enhanced PEs”
- Small thickness variation
- Processing on conventional dies and screws
- Output flexibility
- Blending flexibility

Conclusions
Bimodal LLDPE contribution to frozen food packaging film

Enhanced economical performance

- Film production regularity
- Improved production efficiency
- No special dies, die gaps or screws needed
- Downgauging flexibility due to excellent stiffness / toughness balance
- Suitable for both mono and co-extrusion
- Bimodal LLDPE in the outside layers will give less blocking problems
- Optimal printing surface
- Blending flexibility
- Less (white) masterbatch needed in certain applications

Conclusions
Bimodal LLDPE contribution to frozen food packaging film

Excellent low temperature performance

- Excellent impact resistance at room temperature
- Very good low temperature (-40ºC) impact performance
- Improved stiffness /impact balance through the packaging cycle from +23 ºC to -40 ºC

The package integrity remains very good in frozen food bags produced from bimodal LLDPE film through the total freezing-packaging-storing-selling-using-cycle

Borstar® bimodal LLDPE contributes to the whole frozen food packaging value chain

- **Film producer and converter**
  - processability
  - bubble stability
  - downgauging potential
  - blending flexibility
  - good printability
- **Frozen food packer**
  - stiffness/toughness balance
  - low temperature impact properties
- **Retailer**
  - package integrity
  - sales appeal
  - innovative design solutions.
- **End user**
  - frozen food bags do not break
  - food nutritional quality remains excellent.