WG1 BROCHURE: MOVING FROM OIL-BASED TO BIOBASED PACKAGING – KEY MATERIAL ASPECTS FOR CONSIDERATION

PACKAGING MATERIAL BASED ON BIODEGRADABLE AND RENEWABLE RESOURCES

Over the last few decades, extensive research into and development of biobased packaging materials has been undertaken in Europe within numerous collaborative projects. A great deal of knowledge about biobased polymeric materials and their functional derivatives has been generated. In this overview the definition of 'biobased' takes the most sustainable meaning: *biodegradable materials derived from renewable resources*. Among these materials, *lignocellulose*, *hemicellulose*, *starch*, *chitosan*, *polyhydroxyalkanoates* (PHA) and *polylactic acid* (PLA) are considered to have the highest commercial potential. Unfortunately, very few of the alternative solutions identified have reached the market. Why has there been so little uptake?

This overview gives you a short introduction to the current situation in the field of packaging applications; it identifies the potential renewable packaging alternatives, explores the future possibilities and explains the challenges that still need to be overcome.

DO WE NEED PERFECT PACKAGING OR A PACKAGING THAT IS SUITABLE FOR PURPOSE?

Despite the ready availability of several biobased solutions, most packaging products still heavily rely on petroleum-derived materials, which contribute to enhanced emission of greenhouse gases and generate a lot of waste. The continued development of *biobased alternatives* would offer *real benefits for the planet* and mankind if they captured a greater share of the market. However, biobased packaging is seen to lack a competitive edge as their properties are considered to be worse compared to petroleum-based products. In fact, many of the packages currently in use are 'far too efficient' compared to the actual needs of the product in the package. Manufacturers choose these over-engineered packaging materials simply because of their familiarity, ready availability, the low cost of petroleum-derived products, and because most of the current production systems have been designed, and are tailored for these petroleum-based products. The existing knowledge about biobased alternatives must be communicated to producers of packaging material, retailers and consumers to demonstrate their competitiveness.

Many dry foodstuffs and foods with a short shelf-life do not make very high demands on the packaging material – so for these products, biobased packages can provide the required levels of gas barrier and hygiene protection. The same is true for take-away foods, which only need short contact or storage times. Consumer goods are another potential application area. The main requirement for toothbrushes, toys, household utensils, tools, sports articles, etc. is a transparent package to 'show-off' the content. Biobased materials are able to provide realistic alternatives to petroleum-based plastic products for this purpose.

WHAT DO BIOBASED PACKAGING MATERIALS OFFER?

Biobased materials alone or in combination with each other offer many interesting solutions as they have a number of *useful functional properties* and *provide positive impacts on society:*

- Excellent *oxygen barrier* and excellent *grease barrier* – less material needed for coatings/films;
- Potential introduction of antimicrobial (and active) functionality to packages by using the natural antimicrobial properties of biobased materials (e.g. chitosan or lignocellulose, which also work as carrier of other active molecules);
- Low carbon footprint;
- Less influenced by fluctuations in oil price;
- Biodegradable/compostable packaging materials promote a more thoughtful approach to dealing with (household) waste and offers reductions in waste production and landfill use;
- Low inherent toxicity and less likely to be harmful to humans and the environment;
- Wider supply base than oil based chemicals – potential to use domestic crops, agricultural and forest waste products and recycled packaging material;
- Use of waste products from agriculture/forest and/or food industry for manufacture of barrier materials (e.g. wheat gluten, chitosan and lignin) offers benefits from both environmental and ethical viewpoints;
- Job creation in rural areas in planting, tending and harvesting but mainly in bio-refining;

- Promotes the balance between agricultural area and forests (increased use of land for agriculture helps to maintain open landscapes in the countryside and reduces overgrown areas).

New biobased materials can fulfill the five basic functions of a package: to *contain (*goods, food), to *protect* (products from environment or environment from products; anti-counterfeiting), to *inform* (legal information, product information), to *trade* (sales, differentiation, competitive advantage) and to *express* (as a vehicle to communicate the brand values).

WHAT ADDED VALUE DO BIOBASED MATERIALS OFFER IN TERMS OF SOCIETAL IMPACTS AND BUSINESS OPPORTUNITIES?

- Improve the *'Green profile'* of your company – enhance your *Corporate Social Responsibility* and get *positive feedback from the market;*
- Opens potential *new product areas* – get a more positive perception among your customers;
- Start-up of production lines for *new biobased materials* (bio-refineries) or increased production volumes of existing biobased materials;
- Lead to increased value of wood or agricultural raw materials due to potential exploitation of waste products via *bio-refinery applications*;
- Contribute to *preserving food for a longer time* so that it can be consumed rather than increasing the food waste streams;
- Companies that are pro-active and *prepare their business for stricter legislation on the use of non-renewable* packaging material will be the first on the market with their new products and hence generate advantages over their competitors;
- Potential *reduction of landfill fees* for packaging waste from recyclable/compostable materials – this must also be included in the profitability analysis of alternative packaging solutions.

WHAT IS THE CURRENT SITUATION FOR PACKAGING ALTERNATIVES?

There are many possibilities and a lot of drivers to replace petroleum-based packaging with biobased solutions. The key properties, and current commercial status, of a selection of biobased, biodegradable materials are presented in Table 1.

Table 1
Selected material properties and examples of commercial products made from biobased materials

Biobased material	Water vapour barrier	Oxygen barrier	Grease resistance	Additional functionality	Commercial products (including blends of materials)	Suppliers
Chitosan	Low	High	High	Antimicrobial	ChitoClear®	Primex ehf
Regenerated cellulose	Moderate	High	Excellent	Heat sealable	NatureFlex™	Innovia Films
Hemicellulose	Low	High	High		Skalax	Xylophane
Starch	Low	High	High		Mater-Bi®	Novamont
Polyhydroxyalkanoate	High	High	Excellent	Heat sealable	Mirel™	Metabolix Inc.
Polylactic acid	Moderate	Moderate	Excellent	Heat sealable	Inego™	NatureWorks LLC

WHAT ARE THE TECHNICAL AND SOCIETAL CHALLENGES?

Matching the properties of biobased materials to the packaging requirements needs in many cases further work before market introduction, e.g. large scale production trials and storage testing. Several possibilities already exist for an effective substitution of petroleum-based packaging, as demonstrated by the quantity of reliable data comparing the functionality of biobased materials with the plastic films in use. Unfortunately, this information does not shout out to non-scientists and industrial people, and this limits the direct application of biobased materials.

Interaction between industry and research institutions

Improved interaction between industry and research institutions is essential in order to address the issues that still prevent effective introduction of currently available biobased packaging material:

• Availability of a *continuous, secure supply* of biobased raw materials for industrial use. If the source of the raw material is seasonal (e.g. annual plants), the continuous demand for these raw materials requires harvesting in the two hemispheres (which can be done e.g. for bagasse from sugar cane) with associated transportation. Otherwise, large stocks of raw materials must be prevented from spoilage (biodegradation) during storage.

• Processes able to deal with the *inevitable variety* in the raw material feedstock and/or flexible purification steps in production are needed. The purification steps should preferably be based on 'green' chemistry.

• Improvements in *package functionality*. Barrier, mechanical and antimicrobial properties are continuously achieved on a laboratory scale, but not all modification processes are immediately appropriate for scale-up or for food contact due to issues with process cost and/or potential health risks (use of potentially toxic reagents). These challenges need further attention.

• *Process adjustments* to meet production scale-up of biobased materials may be necessary and may require additional investment in, or development of new machinery.

• Large scale production often requires *additives* like biocides, de-foamers, lubricants, etc. and their compatibility with biobased materials must be assured.

• The steps for *approval* or acceptance can be costly, complicated and usually take a long time.

Biodegradable (compostable) packages may be desired for short- or medium-shelf life foodstuffs.

For products with a long shelf life, premature degradation of the package could lead to food spoilage causing increased waste. Increasing public concern about ocean pollution means that the “accidental” end of life impact of packaging materials and their biodegradation in aqueous environments must also be taken into account. *Re-usable* packages are often the most economic and environmentally friendly solution for many applications, whereas ***material recycling*** *or* ***incineration*** may be favorable in other cases.

The raw materials should comply with each of the hundreds of technical specifications demanded of a useful package. The most relevant criteria for biobased materials are:

• Compliance with direct food contact legislation;
• High barrier levels (to water, oil and grease, oxygen, water vapour, aroma);
• Easily processable at any stage of the package’s life cycle;
• Repulpable, recyclable and biodegradable;
• Compatible with standard papermaking and converting equipment;
• Free of odour and taste.

ARE THERE ANY THREATS?

As with all new technology, a number of potential threats to success can be identified. Social, political and ethical aspects must be considered:

• Conflicting interests regarding the use of agricultural crops (e.g. potato, corn, wheat, rice, sugar cane) for the manufacture of industrial products instead of direct use as food for consumption;

• Increasing production of agricultural crops for industrial use creates demand for land area, which may conflict with the interests of the forest sector;

• The use of agricultural land to grow industrial crops instead of cultivating food for consumption may be controversial in some regions; the use of biomaterials derived from wood or waste products from forestry (e.g. lignocelluloses) does not compete with land for food production;

• Food safety regulation – newly developed materials or combinations of materials can normally be approved if all components, including chemical reagents for the production of biopolymer derivatives, are approved for food contact; however, some substances have not (yet) been approved and some solutions can involve potential health risks (e.g. synthetic nanoparticles, allergens, by-products);

• Costs of new biobased materials and processes are often higher compared to current, established, materials and processes;

• The players involved in the development of materials (material suppliers) are several links upstream from the market players (brand owners, authorities and consumers) in the value chain; a better integration of all the players could greatly improve the adequacy of the material developments upon their launch into the market;

• The intermediary players (converters, printers) are generally small- and medium-size companies, which do not have the resources to invest or alter processes in order to make prototypes, which could demonstrate the potential of new biobased materials.

CLASIC PACKGING SOLUTIONS AND BIOBASED ALTERNATIVES

Table 2 summarises a selection of food products, their barrier requirements, the classic packaging solutions and potential biobased alternatives together with their technology readiness levels.

Table 2
Barrier requirements of selected food products with classic- and biobased packaging solutions

Packed product	Barrier requirements	Classic packaging solution	Biobased packaging solution	Technology readiness level
Meat / fish	High barrier against oxygen and gas (aroma); adaptable to MAP or VSP	Trays (PS, PP, PVC with EVOH + LDPE or PVC as coating) + foil (PVC) or lid, bags, for short term storage; waxed paper (wrapping), paperboard external packaging; transparent films (PP, PE)	Multilayer packaging materials, functional biobased coating (modified starches) + antimicrobial and anti-fogging systems	On the market (as pilot packaging on selected markets); still more expensive than conventional solutions
Fresh cheese	High barrier properties; grease, water, O_2, CO_2 and N_2, aroma and light. MAP (80% N_2, 20% CO_2)	Transparent films/foils; bags (e.g. LDPE/ EVA /PVdC / EVA), trays, wrapping films (PE, laminated), plastic cups (HDPE, PP, PS) + high barrier lid (PA/LDPE)	Eco-paper for short term storage (wrapping); PHA/modified PLA films	On the market, still more expensive than conventional plastics
Dairy products/liquids	High barrier properties; light, water, water vapour, O_2	Glass, PET or HDPE bottles (with LDPE caps); thermoformed HIPS, PP, paperboard cartons/cups (with or w/o aluminum foil layer) PET, PVC, PVdC and PLA cups PE/EVOH/aluminum-laminated paperboard	PLA bottles and cups	On the market
Dried food	High barrier properties; water vapour (scavenging moisture), O_2, light high/moderate for grease and aroma	Waxed paper, LDPE, PVC or aluminum-coated/laminated paper or paperboard, plastic films (BOPP), metal cans	Paper/paperboard coated with biobased materials	Close to market
Salad (flexible packaging)	High oxygen barrier, water resistant, e-MAP (perforation)	Transparent laminated PP films	1) PLA films (perforated) 2) Coated paper with biobased films + transparent window	On the market, still more expensive than conventional plastics
Fruits/ vegetables	Medium barrier properties (water vapour) or adaptable to MAP	Perforated PP, OPP, LDPE; PVC films/bags, trays, pouches, overwraps; PS/PP trays	Molding pulp – trays PLA films (perforated) Edible coatings (polysaccharides: xanthan gum, starch, cellulose, HPC, MC, CMC, proteins:	On the market (molded pulp trays); On the market (PLA as pilot packaging in selected markets, e.g. for tomatoes); still

			chitosan, corn zein, wheat gluten) + low barrier packaging films	more expensive than conventional solutions
Take-away food	Grease, thermal insulation	Polystyrene foam trays	Paperboard with grease barrier coating on the inside	On the market

BOPP=biaxially oriented polypropylene, CMC=carboxymethyl cellulose, EVA=ethylene vinyl acetate, EVOH=ethylene vinyl alcohol, HDPE=high-density polyethylene, HIPS=high-impact polystyrene, HPC=hydroxypropyl cellulose, LDPE=low-density polyethylene, MAP=modified atmosphere packaging, MC=methyl cellulose, OPP=oriented polypropylene, PA=polyamide, PE=polyethylene, PET=polyethylene terephthalate, PHA=polyhydroxyalkanoate, PLA=poly lactic acid, PP=polypropylene, PS=polystyrene, PVC=polyvinyl chloride, PVdC=polyvinylidene chloride, VSP=vacuum skin packaging

BIOBASED MATERIALS HAVE BRIGHT FUTURE PROSPECTS

Bio-refinery products – biobased materials derived from wood – have attracted a lot of attention in recent years and this trend is expected to continue. The same is true for regenerated cellulose obtained from wood or annual plant sources. Multilayers of biobased coatings and combinations of biobased- and inorganic layers and/or synthetic barriers to enhance the overall functionality are anticipated to become important future solutions. Market forecasts and trends are opening new perspectives for biobased materials as alternatives in the packaging industry. Customers are looking for eco-solutions on the market and studies of consumer behavior indicate that consumers are willing to pay more for environmentally friendly products. The costs for biobased alternatives are likely to decrease in the near future due to increased market availability of raw materials and increased production volumes coupled with increased production efficiency.

Some research questions still need to be answered. European scientists are seeking industrial partners to collaborate on joint research projects. The opportunity that is offered by Horizon 2020 must be exploited to develop the new and emerging technologies and continue to refine products based on renewable resources.

JOIN FUTURE RESEARCH PROJECTS AND HELP SCIENTISTS TO HELP YOU TO INCREASE YOUR COMPETITIVENESS!