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Natural-based coatings for food paper packaging

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Commonly employed in food packaging, paper-based materials require barrier properties to guarantee food safety. If used in direct contact with food, packaging is usually produced with materials and processes that could compromise its recyclability. In order to search for more sustainable solutions, the researchers of CIPACK (Interdepartmental Centre for Packaging) developed some natural-based coatings as barrier to oil and grease. The experiments conducted in the laboratories of Politecnico di Milano confirmed the good fatty repellence of the biopolymers-based treatments. After the tests, possible applications of the treatments have been investigated: compostable food containers represent a sustainable alternative to common packaging used for ready-to-eat meals or fast food. Based on scientific method and design process, this study is connected to Expo Milano 2015: the main themes of the exposition will be food safety, food security, and the quality for sustainable developments.

Keywords: *food packaging; paperboard; bio-based materials; coating; barrier properties*

1 Introduction

Packaging is one of the most important actor in the food supply chain. Food packaging is designed to contain and protect, prevent contamination, provide information, manipulate, transport and store products. Moreover, packaging extends shelf life and maintains the quality and safety of goods [18]. The history of food packaging is strictly connected with eating habits, and evolved as man’s lifestyle has changed. Developed in the prehistoric times, when people moved from nomadic to settled life, food packaging was the response to the need of containing and storing food. Until the Industrial Revolution, that brought the development of new materials and manufacturing processes, the most used materials in packaging were the natural-based ones: leaves, wood, gourds, shells, etc. [6]. Later, containers were shaped from natural materials to chemical compounds (as pottery and glass jars), or fibre-based materials (e.g. paper, fabric and cloth).

At the end of the 19th century, paper-based materials emerged for wrapping and packaging food. In the field of food industry, paper and paperboard became essential especially after the development of the process for deriving cellulose fibres from wood pulp. As wood was a cheap and plentiful raw material, cellulose fibres replaced rapidly cloth fibres as the primary source of paper material. In the 1850s, cardboard made of corrugated paper started to be used to manufacture folding boxes. The cheapness, lightness and strength of the material, made cardboard useful for shipping and storing: these characteristics made corrugated cardboard the most used material for transportation, even today. The importance of paper-based materials in food packaging grew up in the 1880s: paper and paperboard were made suitable for fluids and greasy foods packaging, by coating them with a paraffin film [8]. By 1952, glass and tin containers for beverage were substituted with Tetra Pak, a paperboard container coated with a polyethylene film. The popularity of paperboard food containers increased also because it solved some problems of wood or metal boxes:

cardboard pack can integrate the printed graphic and, thanks to the two-dimensional shape, the support allowed a more rational transport. Moreover, cardboard packaging is easily and quickly re-designable, in order to respond to the specific needs of different contents and media [36]. From the 1950s, the history of food packaging was influenced by the affirmation of marketing and communication strategies. Packages became “silent sellers”: they reflect the contained product, and guide customers in their choices. Paper and paperboard packaging increased in popularity throughout much of the 20th century. On the other hand, paper-based materials lost their importance with the introduction of plastics in food packaging (late 1970s and early 1980s), which replaced them in many uses. Recently, the attention on environmentally friendly solutions, prompted designers research on finding more sustainable solutions both for cellulose materials, and for polymeric ones [6].

Since the Seventies, the impact of urbanization on family structure addressed to a new cultural dimension, characterized by the fragmentation of food styles: together with traditional models, started to coexist novel models (exotic, macrobiotics, natural, etc.), and new styles of food consumption (frozen food, fast food, snacks, ready-to-eat meals, etc.). Alongside these trends, since the early Nineties, the compulsive consumerism has given way to a more conscious model: through a critical consumption, consumers increase awareness on environmental impact produced by themselves [10]. The growing need of “wasting no time” evolved, in recent decades, into a new consumption phenomenon: the food nomadism. Nowadays, it is easy to find gastronomic experiences based on local food, mobility and sustainability. The habit of “eating everywhere” enhances the responsibility for designing new packages, which must be able to respond as container, handling tool, and support for a new way of sustainable consumption [21].

From the nineties, the importance of preserving and maintaining food quality and safety grew up as the need of uprising packaging sustainability. The model of sustainable development, in fact, begins to arise to the entire market field. From the Report of the World Commission on Environment and Development - Our Common Future: “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [38]. Europe Commission welcomed the initiatives based on the principles of prevention and responsibility, promoting programs with the objective of raising community awareness about environmental issues. In this context, in 1994, it was introduced the “Packaging Directive”, which aim is to standardize the European Member States in the management of packaging waste. European Parliament and Council Directive edited ‘94/62/EC’, one of the first acts which introduced the concept of prevention and adoption of sustainable approach in the industrial production. The directive contains provisions related to packaging reuse, recovery and recycling. It establishes also programs for the collection of packaging waste, sets recycling and recovery targets, and founds requirements for the admission of all kind of packaging on the European food market [14].

Teaching behaviour change on material consumption, and food packaging waste, introduce to a wide range of design issues, including performance and aesthetic properties, issues of expressiveness and character, critical points beyond sustainability, and problems of compatibility with food [16]. The food packaging industry prompted the research on sustainable food packaging solutions able to ensure the safety and quality of food, reducing both food waste, and the environmental impact of food packaging [13]. During the last twenty years, food packaging demonstrated signs of improvement from a sustainable point of view, although there is still a long way to go. Food packaging industry “faces the challenge in developing new packaging materials that protect food all through the supply chain while being recyclable, compostable, produced with renewable energy or even edible” [35].

The aim of this paper is to suggest a new starting point for the design process: the analysis of the interaction between packaging materials, in particular paper-based ones, food-packaging context and the quality of products contained. Materials design, indeed, integrates engineering culture (materials, surfaces and processing skills) with the design method through a deeper and more aware understanding of the relationship between structure and properties, whether physical-mechanical and functional ones. This study allow understanding how the role of a designer, with competences on material and technology, could contribute in proposing innovative solutions for a specific problem. Along this paper, guidelines related to a sustainable development, as recyclability and compostability, have been proposed as well as possible applications on the food packaging market.

1.1 Research question: Designer's call for sustainability

In recent years, sustainability has become a critical matter for designers and manufacturers. Design for sustainability is a complex and dynamical issue, related to social, cultural, ecological and economical aspects. "Designing for sustainability not only requires the redesign of our habits, lifestyles, and practices, but also the way we think about design" [41]. The conversion towards a more sustainable production needs a collaborative and systemic approach, open to contributions from diverse disciplines and perspectives. The collaboration with different experts, professionals and stakeholder networks would emphasize the central role of design: in manufacturing sector, designers' aim is also to promote, facilitate and set condition for product innovation. The role of designers in facilitating such collaborative approach would help the merging of new trans-disciplinary knowledge. As consequence, a designer has the potential to start closing the gap between scientific and academic research, and product development, merging strategy, research, concept, design and production into one cohesive workflow and effective process. Moreover, integrating design method with engineering skills, a designer is able to provide a complete project dossier comprising product choice of materials, concept, and the selection of technological aspects of the production. As facilitators of the connection between manufacturers and scientific researchers, designers can help to change dominant worldviews and value systems, integrating the specialist knowledge of diverse disciplines in the search for more meaningful and sustainable solutions [27]. This paper proposes a trans-disciplinary design dialogue, guided by the underlying intention to develop more sustainable solutions as a powerful tool for innovation in food packaging market.

1.2 Focus on materials: Designer's analysis and contribution

The increase of innovative and sustainable materials in the market demonstrates that materials research represents one of the most concrete and promising ways to achieve a more sustainable production. This research is an example of how a designer with knowledge of materials science and an understanding of the role materials play in design development, could facilitate the collaboration between chemical researchers and paper-based packaging producers. The work of the designer, in this case, is also to direct the academic research in practical solutions. Starting from a real need of the market (increasing oil barrier properties of paper-based packaging and uprising packaging sustainability), the designer has taken advantage of the experience of CIPACK researchers on bio-based materials to imagine sustainable scenarios for food packaging market. The main steps of the designer research have focused on:

- Food packaging market
- Advantages and disadvantages of paper-based packaging
- Application of paper-based food packaging

- Food sectors that require oil repellence (ready-to-eat meals and fast food packaging)
- Traditional oil barrier solutions and coating methods
- Alternative and sustainable oil barrier coatings (from literature and CIPACK researchers' experience)
- Selection of most used paper materials in ready-to-eat meals and fast food packs (support of producers)
- Choice of natural-based coatings to test (together with CIPACK researchers)
- Choice of experiments to verify the barrier of the coatings[1]
- Benefits and advantages of implementing natural-based coatings on the market

2 Background analysis: Paper-based food packaging

Food packaging market, according to the diversity of products, shows several packing solutions. The selection of a specific food packaging material mainly depends on foodstuff contained, expected shelf life, distribution systems, climatic conditions and consumer habits. To eliminate the differences among the use of products and materials in the diverse Member States, European Commission, through the Regulation (EC) n. 1935/2004, established general principles for the design of food packaging. The directive underlines that: "any material or article intended to come into contact directly or indirectly with food must be sufficiently inert to preclude substances from being transferred to food in quantities large enough to endanger human health or to bring about an unacceptable change in the composition of the food or a deterioration in its organoleptic properties" [33]. Food packaging industry faces everyday with the choice of the most appropriate material for the storage of specific food products. Most commonly used food packaging materials are glass, wood, metal (e.g. aluminium, steel), plastic-based and cellulose-based materials. Each one offers distinctive properties, connected to advantages and disadvantages, which have to be critically considered in order to make the right choice.

Among all food-packaging materials, paper, paperboard and cardboard play a central role. Accounting for around 65% of all recycled packaging, cellulose-based materials have the highest recycling rates worldwide, and represent, together with plastic, the packaging material most used to contain liquid, dry or greasy foods [37]. Cellulose materials are particularly appropriate in food packaging field for some features such as disposability, recyclability, but also low cost, versatility and easy workability. The last two properties allow paper-based materials to acquire the three-dimensional shape with a simple gesture. Indeed, through bending, paper gains function, strength, and expressiveness. Furthermore, working with paper, paperboard and cardboard, stimulates a sustainable design thinking: the development of a two-dimensional design allows focus on material optimization and processing waste reduction [9]. Cellulose-based materials have a wide range of applications: as transport packaging, corrugated cardboard is the main material used to realize boxes, paperboard clusters for products as pasta, frozen food, bakery products, and beverage packs, while paper sheets are employed as wrapping paper or to produce bags and sacks [32].

2.1 Raw materials

All cellulose materials have in common the presence of cellulose fibres in their structure. Consisting of cellulose and hemicellulose, and mainly obtained from wood pulp, cellulose fibres are characterized by a biodegradable nature. Coming from renewable resources, paper-based materials can be evaluated as recyclable and biodegradable products. The level of biodegradability of cellulose-based materials depends on other substances used in the transformation process. Adhesives, sizing materials (e.g. chalk, clay and

[1] support of CIPACK researchers and the Department of Chemistry, Materials and Chemical Engineering "Giulio Natta" at Politecnico di Milano

other mineral fillers), additives (substances that polymerize in the paper) and other agents (e.g. pigment and optical brightening agents), could compromise the cellulose material recycling process and the compostability of the whole packaging [25]. Paper-based packaging is made from a combination of fibre inputs: virgin fibres, the ones that come directly from the wood pulp, and recycled fibres, that can be either recovered from factory trimmings (PIW, post-industrial waste), or all fibrous wastes that are collected from municipal solid waste (PCW, post-consumer waste) [23].

Manufacturers consider virgin fibre as the best warranty for a safe contact with food. Paper-based materials for food packaging application, mostly derived from virgin fibres and, if compared to a recycled product, they have superior mechanical properties and a better machinability. Over the years, however, the production of virgin fibre-based packaging has been drastically reduced, mainly because of the high economic and environmental cost of the material. For example, in order to produce a ton of paper from virgin pulp are required:

- 15 trees
- 440,000 litres of water
- 7,600 kWh of electricity

The environmental impact of a virgin fibre-based product is superior to the one processed from recycled paper, but it is necessary to underline that, at the end of its lifecycle, virgin paper product could be better reprocessed [7].

Recycled fibres-based products are generally characterized by lower mechanical properties, if compared to virgin fibre-based ones. In spite of this, recycled materials are easily employed as secondary and tertiary packaging. The main advantage of using materials made from recycled fibres is the low economic and environmental cost. To produce one ton of waste paper, for example, are necessary:

- 0 trees
- less than 1% of the water used to produce 1 ton of virgin paper
- less than 30% of the energy used to produce 1 ton of virgin paper

The European Commission published a regulation on recycled plastic materials intended to come into contact with foods, but it has not a harmonized legislation governing the use of food contact paper and board materials yet. Recycled paper materials must comply with the appropriate laws of each EU Member State, that only in some cases have specific legislations or recommendations. The debate over a harmonization in that field is open, since recycled fibres could be source of potential migration of substances into food. On one hand, if the strong interest about environmental issues is forcing manufacturers to employ more recycled materials in food packaging, the demand for the redaction of specific jurisdictions addressing the safety of recycling processes and materials becomes more pressing year-over-year. Because of that, in order to ensure the safety of consumers against food contamination, paper-packaging industry concentrates its studies and researches on increasing barrier properties [28].

2.2 Food packaging properties and requirements

Food packaging aim is to protect products against physical, microbiological and chemical deterioration, and at the same time to preserve food from organoleptic changes (flavour, odour, texture, colour or taste). Some of the factors that could compromise the quality of food and its shelf life are temperature, time, light, gas and moisture. Barrier properties, controlling the permeation of substances through the packaging material, are the main element in effort to optimise protection, odour control and extension of food shelf life [2]. Paper-based materials offer both physical and mechanical strength, together with flexibility of process, property that makes them the first materials used in the production of packages. As explained above, cellulose materials show many advantages if compared to synthetic polymers: recyclability, biodegradability, and compostability. However, paper-based materials are characterized by poor barrier properties, because of the high porosity of fibre network [43].

One of the most requested property of the food packaging market is the resistance to grease permeation. Greaseproof properties have relevance both to functionalize greasy and fatty foods packaging, guarantying the integrity of the structure of the material, and to ensure the safety of consumer from any phenomenon of migration of contaminants (from the material to food). Trends in food packaging show how the development of new sustainable alternatives to traditional greaseproof papers is important. In this segment, in fact, packaging consumption is growing rapidly because of some factors [20]:

- The growing demand of mono portions, connected to the diffusion of single-person families. The reduction in capacity leads to a greater average weight of packaging: common examples are replacing a 550 g capacity pack with two 250 g packs
- The increase in pre-packaged products (e.g. salami and cheese, biscuits, snacks, etc.)
- The greater raise in portioned and packaged products (cut, washed and ready-to-eat products)

The good permeation of oil and grease through paper-based products could represent a serious obstacle to the use of those materials in food packaging applications. Because of their lipophilic nature, fatty substances could damage the print, and generate the separation of laminated materials. These problems are common in flexible packaging, both as cellulose-based and polymeric-based materials. Lipophilicity is the property that allows some chemical substances to dissolve in fats, oils, lipids. The chemical structure of a molecule determines the lipophilicity of a material: substances such as oil, are substantially formed by non-polar molecules joined together by Van Der Waals forces. The lipophilic substances can dissolve in other lipophilic substances: oil is able to mix with the gasoline, since it is a solvent characterized by non-polar molecules. On the contrary, a hydrophilic substance tends to dissolve in water or in another hydrophilic substance, but not in a lipophilic one. Often lipophilic substances are hydrophobic; for that reason the term "lipophilic" is used as a synonym for non-polar or hydrophobic, even if there are cases of hydrophobic but not lipophilic substances (e.g. silicones and fluorocarbons).

Figure 1 Oil drop on treated paperboard with CIPACK's coating

The resistance to oil and grease permeation is strongly linked to the absence of pores on the paper-based material, and is determined by their size and shape. The greater is the size and the presence of pores, the weaker is the barrier to oil and grease [24]. For that reason, only a small percentage of packaging intended to be in contact with food is made of uncoated and untreated paper (3.5%). When used as primary packaging, cellulose materials are usually treated, coated, laminated, or impregnated with materials such as waxes, resins, or lacquers [12].

2.3 Traditional grease barriers

Used to pack liquid products, greasy food (e.g. fast food packaging) or to realize baking papers, paper plates and cups, filters, and cheese wrappings, greaseproof paper can be produced by different techniques.

The most common method to fabricate oil resistant paper is beating of pulp. Beating and refining consist of mechanical actions, which, through a compression and a rub, “scratch” the surfaces of the fibres that protrude outwards (fibrillation). Structural changes undergone by cellulose pulp affect both the external and the internal surface of the fibre, and greatly influence the barrier properties of the final cellulose products. Moreover, refining process facilitates the formation of inter-fibre connections: as a result, the pulp density increases and confers to the paper a higher mechanical resistance. At the end of a long pulping process, the pores drastically reduce in size and number, the substrate becomes a closed surface structure, and, in some cases, paper-based products express greaseproof properties. However, beating and refining are not enough to guarantee the repellence to all fatty substances: in many cases, they tend to penetrate paper surface even through very small pores. A possible solution to increase the fat and oil resistance can be achieved through longer pulp refining processes, but that implies an increase in energy costs [4].

Figure 2 Non-coated paperboard (up) and oil-repellent CIPACK’s coated paperboard (down)

Some polymer emulsions, such as perfluorocarbons (PFCs), outline a low surface energy, and have optimal properties for paper coating. Fluorinated coatings, indeed, exhibit water and fat repellency: water or oil drops, in contact with a surface treated with fluorinated compounds, tend to assume a spherical shape. The fluorinated compounds may be added in the slurry (pulp) or applied on the surface of the paper-based material. They are widely used as oil-repellent paper for fast food application or as packaging for butter.

Multi-layered materials, consisting of laminated paper with polymer (PE, EVOH, PVC, etc.) or aluminium film, are widespread in the food and beverage market. Since these packages cannot be separated, except by special technology or by pyrolysis, it would be better to define them composite packaging materials. The lining process, designed to make the cellulose material impermeable to water and fats, is commonly obtained by two techniques. The first method is the extrusion of the polymeric film, with subsequent lamination onto the cellulosic substrate. The second one is heat lamination, which consists in applying the film lining to the substrate already lined with an extruded material that acts as an adhesive layer. In both cases, the layers are pressed through hot drums. One of the most common polymeric film used in lining paper is low-density polyethylene (LDPE), characterized by low thickness and weight, high toughness and excellent printing with water-based inks. For this reason, it is suitable for food contact, and it shows a total barrier to oil and grease. Food containers made from paperboard lined with synthetic polymers are common in single-use applications, such as cups for drinks, ice cream cups and containers for fast food (e.g. popcorn, chips, sandwiches, etc.) [30].

Surface coatings constitute a physical barrier to the penetration of fatty substances in paper. Superficial coating flaws, such as small holes or cracks, affect barrier properties. They could be due to a non-homogeneous distribution, or caused by abrasion during the product manipulation. There are several approaches to surface coating technology: from cellulosic material coating with polymeric solutions or wax emulsions, to treatments derived from natural substances. Polyvinylidene chloride (PVdC) is one of the polymers widely used in food packaging treatments. Characterized by excellent barrier properties to fats, acids, gases and vapours, PVdC shows a high degree of transparency, which guarantees an excellent presentation of the products packaged. The material has also good heat-sealing properties, which allow agile and rapid sealing operations. PVdC coating is usually employed for fatty products characterized by strong flavours or aromas, as confectionery, milk products, cured meats, smoked fish and dried products [24].

Traditional surface treatments, based on the application of waxes, polymeric coatings or aluminium films, present disadvantages in terms of sustainability: they cause environmental problems due to materials recycling and recovering process.

2.4 Recycling, biodegradability, compostability

Until a few years ago, the need of packaging sustainability has not represented a priority in food packaging market. Moving towards efficient and advanced solutions, biodegradable packaging is nowadays becoming an essential part of the global market, supporting the increasing consumer awareness and the development of more sustainable alternatives. Currently, the demand for biodegradable packing products is growing up: the companies employ packaging as a medium to preserve and promote the quality and safety of the environment along with their products.

Derived from cellulose, the most abundant natural polymer on Earth, cellulose-based packaging are recognized as eco-friendly and renewable materials, also because they can be easily recycled. Indeed, today paper-based materials are the most recycled materials in the world: paper and paperboard recycling rates ranging from 70-80% in North America and even 90% in Central Europe. “One of the fastest growing markets for recycled paper is the food-service market. Although it represents a small percentage of the overall market for recycled paper (<1% of the total recycled paper market), it is expected to grow faster than the overall demand for recycled paper packaging” [37].

At the end of its use, another way that a paper packaging can take up is degradation (biodegradation, compost). A cellulose-based pack can be declared “biodegradable” if it is made of organic substances, as cellulose, or synthetic compounds that are capable of being readily attacked, decomposed, and assimilated, by the action of natural agents such as bacteria and fungi. The biodegradability level of cellulose-based food packaging depends on the substances used in the production process, and on the materials applied as surface treatments. Biodegradable food packaging does not include cellulose-based items that have a synthetic or plastic coating in more than five percent of the total volume of the item. According to the European Standard EN 13432:2002, a biodegradable material should degrade at least of the 90% in 6 months, in an environment rich of carbon dioxide (UNI EN 13432:2002). On the other hand, according to the UNI EN 14995:2006, a material is “compostable” if it degrades at least of the 90%, in biodegradable fragments of the dimension of 2 mm, in contact with organic materials in a period of 3 months (UNI EN 14995:2006).

Unfortunately, not all paper-based food packaging can be recycled or easily degraded. On one side, indeed, cellulose materials that contain organic residues, as food wastes, cannot be recycled. If the dirty recycled material remains for a long time in storage, the food residues activate a process of organic degradation, which also involves the rest of the collected cellulose-based material, compromising the whole quality of the recycled product. Otherwise, synthetic and polymeric coatings, which assure a barrier to oil and grease, do not permit to destine paper-based packaging to the compost [31]. The problem of recyclability and compostability of paper-based food packaging is particularly urgent in the applications intended to be in contact with greasy food. In this research, possible solutions to the problem will be discussed, in particular focusing on some biopolymers that show barrier properties to oil and grease.

2.5 Natural-based grease barriers

As anticipated in the previous paragraphs, barrier to oil and grease represents a particularly interesting property in food paper packaging. It has relevance both to the chemical structure integrity of the material, both to ensure product safety and quality. The research in this field is appealing because it involves critical issues beyond sustainability. The use of oil repellent bio-based coatings in food packaging industry, would contribute both to increase the value of the raw material employed (virgin paper) and to reduce safety risks related to the use of recycled raw materials in paper packaging [17]. Bio-based polymers can be directly extracted from biomass products (as polysaccharides, proteins, and lipids), synthesized from bio-derived monomers, extracted from microorganisms (e.g. bacterial cellulose), or synthesized from synthetic monomers (petrochemical products). Natural biopolymers from polysaccharides (chitosan, alginate, pectin, carrageenan, etc.), proteins (soy protein, corn zein, wheat gluten, casein, etc.), and lipids (bio-resins), show promising development in the future of paper food packaging. These substances exhibit good barrier properties: that makes them suitable as coatings to replace synthetic treatments (made of polyethylene, polyvinyl alcohol, rubber latex, and fluorocarbon) currently used in food packaging applications [5].

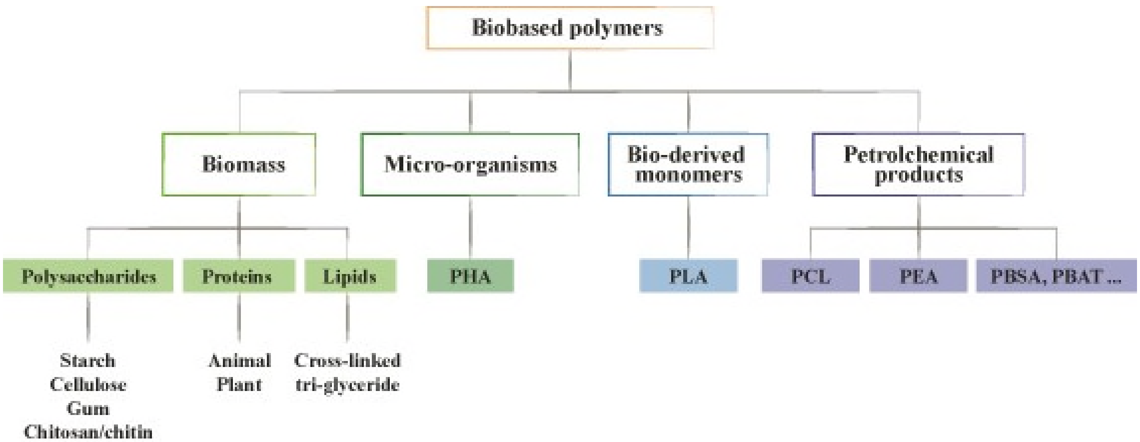

Figure 3 Classification of the biodegradable polymers [5]

CIPACK researchers, from the Interdepartmental Centre for Packaging (Parma, Italy), formulated some natural-based coatings derived from polysaccharides. Recognized as the first biopolymers formed on Earth, polysaccharides are made of polymeric carbohydrate structures (chains), formed by repeating units (mono- or di-saccharides) joined by glycosidic bonds. Polysaccharides structures are quite often linear and heterogeneous, containing slight modifications of the repeating unit. Depending on their structure, these macromolecules can have distinct properties from their monosaccharide building blocks. Polysaccharide-based films are quite stiff but, because of their strong hydrophilic nature, they exhibit poor water vapour barrier properties, if compared with synthetic packaging films. Besides, polysaccharide-based coatings show excellent gas, aroma, and lipid barrier properties [22]. Moreover, bio-based films combined with paper or paperboard allow packaging materials to be biodegraded or composted.

3 Experiments

CIPACK is studying the interesting properties shown by some natural substances, applied as coating to paperboard. From their research, it became apparent as some biopolymers can enhance the product shelf life, and provide barrier properties to gas, water and oil, without compromising the biodegradability of the functionalized cellulose substrate [22]. In the laboratories of the Department of Chemistry, Materials and Chemical Engineering "Giulio Natta" at Politecnico di Milano, some experiments have been carried out in order to evaluate the barrier properties to oil and grease of these coatings. After the choice of the cellulose support to be treated, two different techniques of coating deposition were analysed: the brushing and the spray coating. The experiments consisted in the Kit Test (TAPPI 559 cm-12) [42], which evaluates the level of greasy repellence, and the "Oil Drop Test", that measures the diffusion of fatty substances at critical temperatures.

3.1 Paperboard samples

A market research has been conducted to assess the most used paperboard support in contact with fatty foods (e.g. fast food). Some companies, which manufacture and distribute cellulosic-based materials for food packaging, supported the selection of a specific type of paperboard to be tested. The samples used for tests included untreated and treated (with fluorinated emulsions) paperboard.

Table 1 Type of paperboard samples used in the experiments

	Acronym	Type	Grammage	Composition
1	MMK VER 230 - TQ	Excellent Top (n. 12100)	230 g/m^2	90% virgin fibre + 10% coating
2	MMK VER 230 - TF	Excellent Top (n. 12100) **Treated with fluorinated emulsions*	230 g/m^2	90% virgin fibre + 10% coating
3	MMK RIC 250 - TQ	Top colour TC/GT1 (n. 31115)	250 g/m^2	15% virgin fibre + 72% recycled fibres (PIW) + 13% coating
4	MMK RIC 280 - TF	Top colour TC/GT1 (n. 31115) **Treated with fluorinated emulsions*	280 g/m^2	15% virgin fibre + 72% recycled fibre (PIW) + 13% coating
5	MRD RIC 320 - TQ	*Snacks secondary pack*	320 g/m^2	Recycled fibre
6	BAR VER 375 – T?	*Egg pasta primary pack*	375 g/m^2	Virgin fibre

An acronym identifies each sample. It underlines the paper-based material's manufacturer or importer, the composition of the material (VER, virgin fibre, or RIC, recycled), the weight of the paperboard and the presence or not of surface treatments (TQ, untreated, TF, treated with fluorinated emulsions, "A5 + BOR", treated with CIPACK's coatings). The final letter in the acronym identifies the method used for coating deposition (P, by brushing, and S, by spray coating). The abbreviation "MMK RIC 250 - T (P3 + BOR) P", for example, identifies a paperboard sample composed of recycled fibre, characterized by a grammage of 250 g/m^2 and treated with CIPACK coatings by brushing.

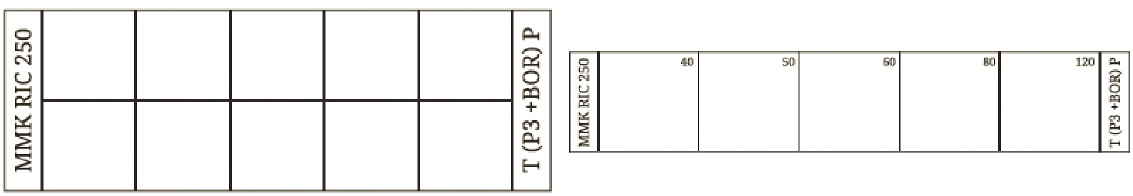

Figure 4 Kit Test sample (sx) and "Oil Drop Test" sample (dx)

For each test, specific specimens have been prepared. The Kit Test sample has dimension 50x145 mm, and it consists of 10 boxes, required to order the drop deposition on the surface. The "Oil Drop Test" specimen has different dimensions (35x120 mm), and less boxes: the 5 squares identify respectively the conditioning temperature of the oil drop in oven (40, 50, 60, 80, 120 °C).

3.2 Natural-based formulations

During the tests, carried out at "Giulio Natta" Department (Politecnico di Milano, Italy), three coatings formulations, based on natural substances were analysed. In order to improve the strength and compactness of the coating, other natural substances (their presence is indicated by letters BOR) have been added into the natural-based formulation. These substances did not alter the "green" characteristics of the treatments.

The three tested coatings were impermeable to solvents, oil and grease, but not to water, because of the hydrophilic nature of the bio-based substances used in the formulations. The use of such solutions in packaging applications is particularly interesting also because it increases the printability level of the paper product [40]. The cost of a natural-based coating competes with the current grease repellent treatments applied in food packaging [34]. Figure 6 shows the three bio-based formulations tested. The first and second coating in figure (Figure 6), showed the defect of darkening the treated surfaces. Even if brightness may not add much value to the functional properties of the paper, it is still the most important selling feature. Considering the equal terms of oil and grease resistance, the use of the third coating in figure is preferable. All the treatments confer to the paper a shiny and smoothie surface appearance, similar to plasticized paper materials.

Figure 5 CIPACK's natural-based coatings tested at Politecnico

Figure 6 Brushing and spray coating deposition

3.3 Coating methods

Coating methods, used to treat the surface of cellulose materials, can be chosen according to the substance to be applied (e.g. powder, liquid solution, etc.), to the time machine, the drying process, etc. Because of the availability of small size samples, the coating techniques used in the experimental stage consisted of brushing, simulating the industrial process of size coating, and spray coating. Each sample has been weighed, before and after the treatment, in order to determine the amount of the coating deposited on the surface. The average amount of solution deposited by brushing was about 50 g/m^2; it is much higher than the quantity spread by size coating process (approx. 20 g/m^2). On the other hand, by spray coating, the quantity of solution deposited in laboratory was similar to the one commonly placed by the industrial method (approx. 20 g/m^2) [29]. After the surface treatment, the samples have been dried at ambient temperature for one night.

3.4 Tests

The primary function of a fatty food packaging is to prevent the absorption by the cellulose material of the greasy substances, protecting the user from contact with lipids, and preventing possible migration of substances from the material to the food. The experimental phase was conducted in two stages. In the first stage, the greaseproof performance of the natural-based coatings has been investigated through the TAPPI 559 cm-12 oil kit test. In the second stage, the resistance to oil and grease absorption in critical conditions (e.g. high temperature) has been analysed by an empirical test: the “Oil Drop Test”.

Kit Test (TAPPI 559 cm-12)

Commonly known as the “Kit Test”, the standard TAPPI 559 cm-12 describes a procedure for analysing the repellence degree of paper and paperboard coated with fluorochemicals or other film-like barriers (as biopolymers). The kit reagents, formulated by mixing toluene, heptane, and castor oil in varying proportions, are numbered 1 to 12 in ascending order according to their chemistry “aggressiveness”. The most aggressive solution (highest numbered) that remained on the surface of the paperboard without causing failure, reported as the “kit rating”, indicates the material’s index of resistance to grease [42]. Failure is indicated by darkening of the substrate caused by penetration. After the preparation of the samples and the kit solutions, the experiment follow these steps:

- Starting from an intermediate kit number test solution (n.6), a drop (0.035-0.05 mL) has been released onto the surface of the tested specimen
- After 15 seconds, the excess of tested solution has been removed, and the tested area examined
- If the specimen failed the first test, the experiment would be repeated choosing the next lower numbered kit solution
- The test will end when the highest numbered kit solution that does not cause failure would be identified. The number of this kit solution represents the rating for the specimen

The steps would be repeated three times in order to verify the coating homogeneity. After testing all the samples for each type of paperboard, the arithmetic average of the four kit ratings has been calculated. The average value of approximation is 0.5 units. For example, if the values measured for the four samples of a virgin fibre paperboard are 5, 7, 7, 6, the average degree of resistance to oil and grease, representative of the type of paperboard, is 6 (arithmetic average= 6.25).

Oil Drop Test

The “Oil Drop Test” is an empirical test used to measure the resistance of a paper-based material to the absorption of fatty substances in variable conditions of temperature. The test evaluates the time absorption of a castor oil drop on a sample conditioned in oven at 40-50-60-80-120 °C. After deposing an oil drop (0.035-0.05 mL) on the specimen, it will be transferred into oven. The absorption time of the oil droplets will be registered and monitored at regular time intervals (15, 30, 45, 60, 90, 120 minutes). The main characteristics for the comparison of different samples are the drop diameter, the presence of spots in the back of the support (that puts in evidence the drop absorption), the dilation or the conservation of the drop spherical shape, etc. [1].

4 Results and Discussion

The results of the two tests conducted at Politecnico di Milano were very encouraging: polysaccharide-based coatings exhibited good barrier properties to oil and grease, even in critical conditions (e.g. high temperature). The paragraphs below show the better results obtained.

Table 2 Kit Test results on “MMK VER 230 – T (A5 + BOR) S” samples

	Samples	**Kit Test value TQ**	**Kit Test value TF**	**Kit Test value T - S**
1	MMK VER 230 – T (A5 + BOR) S	6	7	**12**
2	MMK VER 230 – T (A5 + BOR) S	6	7	**12**
3	MMK VER 230 – T (A5 + BOR) S	5	8	**12**
4	MMK VER 230 – T (A5 + BOR) S	4	9	**12**
	Kit Test average value	5	8	**12**

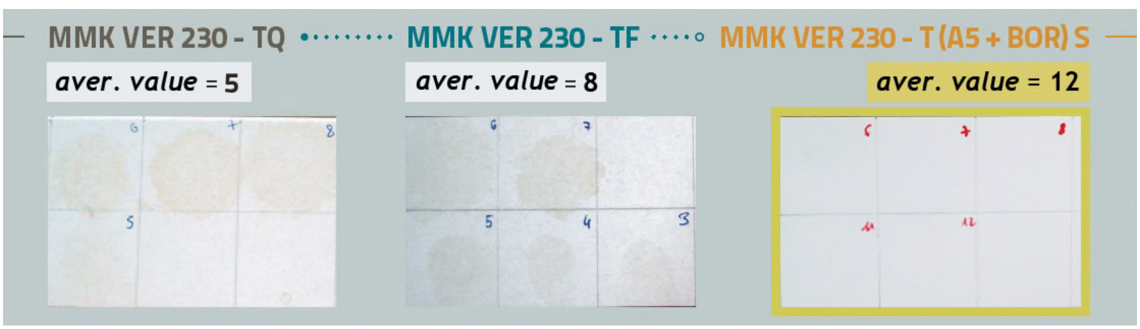

Figure 7 Comparison between the level of oil absorption (Kit Test - TAPPI 559) of uncoated paperboard (sx), fluorinated paperboard (c) and natural-based coatings (dx) on virgin fibre based materials

Kit Test (TAPPI 559 cm-12)

The Kit Test revealed how much uncoated paperboard absorbs greasy substances: virgin fibre based materials showed an intermediate Kit rating (n. 5), while recycled fibre based ones exhibited even a lower barrier (n. 4). In both cases, spots caused by grease penetration were quite evident. Testing the samples treated with fluorinated emulsions, the results demonstrated good greaseproof performance: the Kit value referred to virgin fibre-based paperboard was 8, although the Kit rating for the recycled material was 6. From the comparison between the results obtained with uncoated samples, treated with fluorochemicals specimens, and the samples coated with biopolymers, it has emerged as CIPACK coatings offer the best greaseproof performances. Analysing the two techniques of deposition, the best results obtained were the one of natural-based treatments deposited by spray coating. Amongst all tests, the most promising results emerged with the spray coating on virgin paperboard: the samples Kit rating was 12.

From the image below, it is easy to see that the grease resistant paperboard realized from an environmentally friendly approach demonstrated a higher level of performance in comparison to traditional products. Positive results were obtained, indeed even in the case of recycled-base paperboard: the Kit rating exceeded value 11.

Table 3 Kit Test results on "MMK RIC 250 – T (A5 + BOR) S" samples

	Samples	Kit Test value TQ	Kit Test value TF	Kit Test value T - S
1	MMK VER 230 – T (A5 + BOR) S	3	7	**12**
2	MMK VER 230 – T (A5 + BOR) S	4	6	**12**
3	MMK VER 230 – T (A5 + BOR) S	5	6	**11**
4	MMK VER 230 – T (A5 + BOR) S	5	5	**12**
	Kit Test average value	4	6	**12**

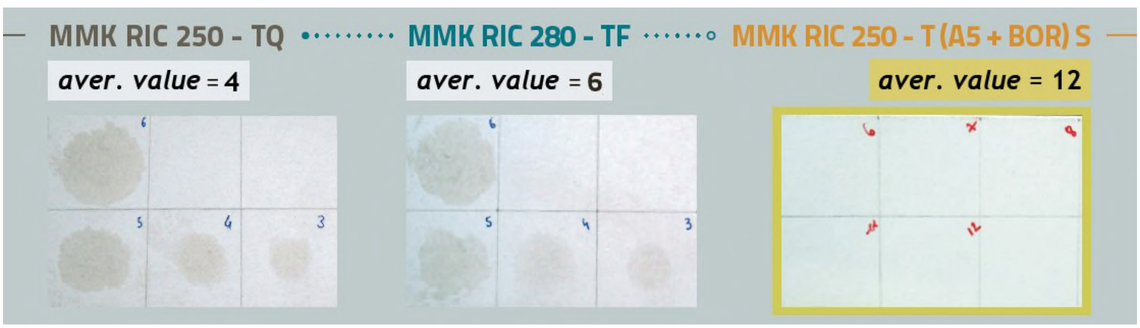

Figure 8 Comparison between the level of oil absorption (Kit Test - TAPPI 559) of uncoated paperboard (sx), fluorinated paperboard (c) and natural-based coatings (dx) on recycled fibre based materials

Oil Drop Test

The "Oil Drop Test" highlights the differences in the absorption of an oil drop by treated or untreated substrates at different temperatures. This test is particularly important because the contact with hot fatty foods increases the absorption of greasy substances by the paperboard packaging. The experiment showed that untreated or fluorinated specimens, when put in the oven, exhibited an absorption phenomenon directly proportional to the temperature of the oven. After few minutes in oven, the oil drop started expanding, losing its spherical conformation. After thirty minutes, the cellulose support began to absorb the drop. All the samples, both virgin and recycled fibre based ones, untreated or treated with fluorinated emulsions, showed clear absorption phenomenon after two hours. The oily spots were present both on the surface of the specimen, and on its back.

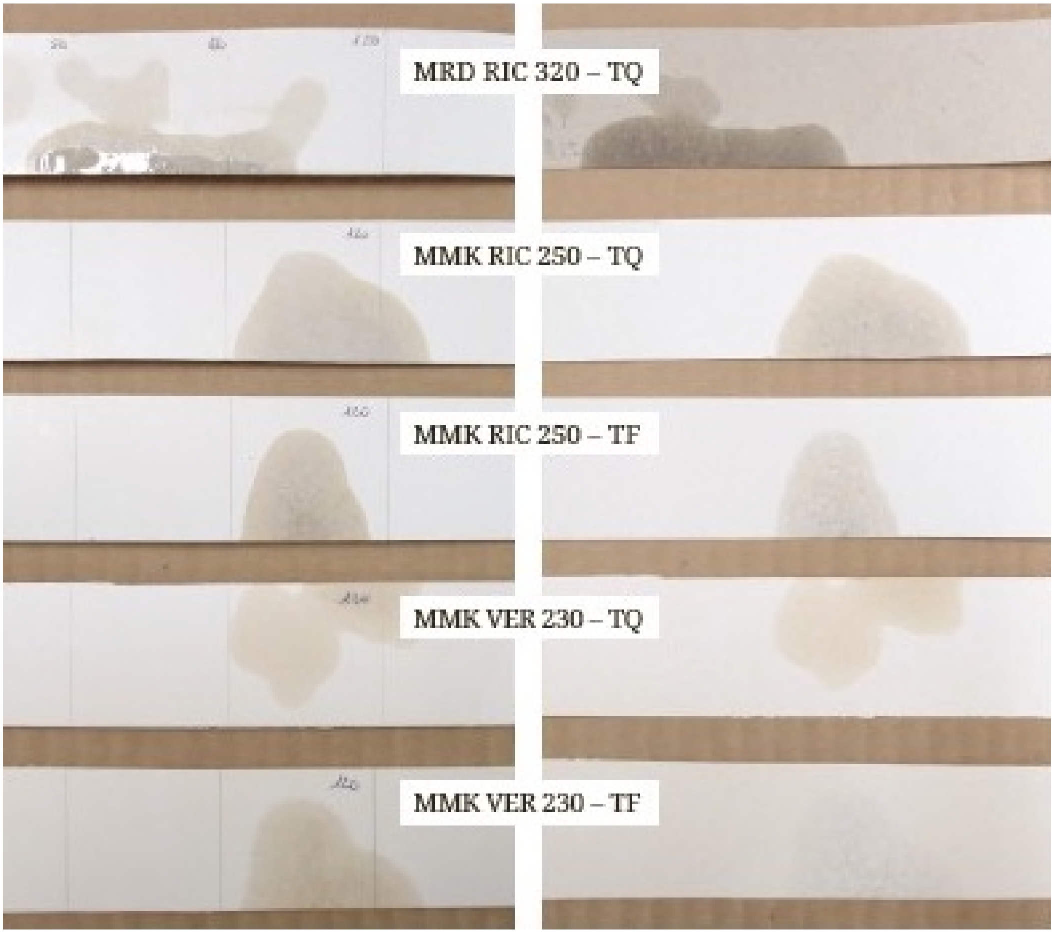

Figure 9 Level of oil absorption in critical temperature conditions (120°C) after 120 minutes. Comparison between uncoated (TQ) and fluorinated paperboard (TF)

On the other hand, natural-based coated samples did not show any absorption phenomenon. Even after two hours, the drops on the surface of the specimen were characterized by a spherical appearance, and they remained confined to the surface at the same point where they were released. To analyse the greaseproof performances of the coating developed by CIPACK researchers, the samples have been taken out from the oven and the excess of oil removed from the surface. On almost all the specimens treated with biopolymers, no stains or spots were noticed at the end of the experiment. No oily spots were visible on the back of the coated samples. Only in few cases, some little dark dots evidenced that superficial absorption occurred. In these cases, anyway, it is important to underline that, probably, the oil penetration occurrence could be attributed to the faulty brushing coating deposition.

Figure 10 Level of oil absorption in critical temperature conditions (120°C) after 120 minutes. Comparison between uncoated paperboard (sx), fluorinated paperboard (c) and natural-based coatings (dx) on virgin (VER) or recycled (RIC) fibre based materials

5 Conclusions

The positive results obtained from the experiments open the way to a new idea of food packaging. A system where packaging meets market criteria in terms of performance, is designed to be functional and safe, is produced from renewable resources, and at the end of its life cycle, can be recycled or degraded without leaving contaminants or toxic residues into the environment. The aim of this research is to provide guidelines for designers, engineers, producers to support the development of sustainable, innovative, and functional packaging materials destined to the direct contact with food.

5.1 Implications

The potentials offered by this research are numerous. First, the opportunity to work directly in contact with different materials and technologies made possible imagine sustainable scenarios of application: compostable food containers represent an innovative and environmentally friendly alternative to common packaging used for ready-to-eat meals or fast food.

Ready-to-eat meals

Over the years, the time devoted to food preparation has been drastically reduced. People have changed their eating habits with others: eating outside, buying pre-cooked and ready-to-eat meals, for example. Along this way, in food market some needs greatly increased: conserving and portioning meals, demanding for containers and solutions which allow consumers to quickly heat and cook food, holding out against the freezer-microwave passage. Moreover, the orientation of consumer towards eco-friendly and sustainable packaging and products is growing up. For these reasons, food packaging industry is constantly searching for innovative and more sustainable solutions in ready-to-eat food products [26]. Street food, as take-away products, and fast food meals, require a functionalized packing, in particular repellent to oil and grease substances. Natural-based coatings would be a possible sustainable solution to be applied on paper-based packaging for ready meals.

Ready-to-eat meals are food products that can be eaten as sold; they are characterized by a high degree of readiness, completion, and convenience. Ready meals are classified as traditional, continental, ethnic, vegetarian, and low calorie. Preparation methods, preservation techniques, and added culinary skills are all characteristics that contribute to the convenience of food products. However, also packaging can be considered as a time saving solution, able to added convenience for consumers [19].

In ready meals, the main evidence trend is the growing diversification of the products, with the introduction of new recipes and tastes: this fact puts into effect the constant design of new packaging solutions. Ready meals are offered in different packaging formats that require specific properties depending on the food contained. Commonly, ready meals shelf life is short; for this reason, their packaging needs a low permeation of oxygen and water vapour, a high oil and grease barrier, and the suitability and the thermal resistance for heating in microwave or oven. The most common formats used to pack meals that do not require Modified Atmosphere Packaging (MAP), are boxes, pots and trays in polymeric materials (PP, PE, PET, PPO), and treated paperboard. The presence of aluminium trays on the market is decreasing, leaving great opportunities for the development of innovative solutions as biopolymer coating on paper or paperboard packaging materials.

Fast food

The industry of Quick Service Restaurants (QSR), better known as fast food, is generally a system of franchising that focuses on low cost, high volume, and high speed of food production. Commonly, fast food products are pre-heated or pre-cooked and served on the go: as a result, this kind of food is supplied in a packaging whose aim is to facilitate the eating on-the-road. Most used pack in fast food industry are, for example, disposable tableware, boxes or trays, cups, lids and wrappers for hot dogs, hamburgers, nuggets, sandwiches, noodles, etc. All these packs are generally waterproof and greaseproof.

In recent years, even the fast food industry is under pressure to reduce the environmental impact of its packaging products. In the late 1980s, there was growing public concern over the huge quantity of non-recyclable packaging produced by the fast food industry (e.g. polystyrene clamshells). Nowadays, the challenge is placed upon recycling or composting one of the principal materials used in fast food packaging: paper. Cellulose-based packaging are employed in the food industry mostly for their characteristics of low cost and ease of use. However, the 85% of paper-based packaging used is treated with low-density polyethylene (LDPE) [3].

Even in the fast food sector is increasing a strong eco-friendly orientation. Some of the greatest business companies in the industry of Quick Service Restaurants, as McDonald's and Starbucks, have emerged as leaders in the green fast food movement. The two companies have been working on improving their sustainability by reducing the use of polymeric materials on their packaging, replacing polystyrene cups with paper products, increasing the amount of recycled fibres, allowed in fast food packaging, and promoting reusable trends. In order to improve packaging sustainability in fast food sector, a possible way to practice is the substitution of the synthetic coatings with the biopolymers-based ones.

5.2 Limits

Currently, research limitations turn around technical and economic aspects. First, as most of bio-based materials, CIPACK's treatments have some limitation in processability. The weak mechanical and thermal properties should be improved by using additives and functionalization agents, and by optimizing process conditions. As for bio-based plastics, such as PLA or PHA, the rapid technological development of new natural-based coatings has yet to be translated into significant market impact. This aspect primarily due to high production cost of raw natural-based materials employed to realize the oil-repellent coatings. Even if bio-based treatments could not compete with the common oil-repellent coatings yet, they offer the possibility to decrease environmental costs for packaging manufacturers. In the market sections in which grease barrier properties are most requested, in fact, actually solutions employed are not environmental sustainable. Greaseproof paper packaging, destined to the direct contact with food, are usually made of virgin fibre materials. This raw material represents the highest guarantee on hygiene and safety of the food products, but is characterized by significant energy costs and environmental impacts. In spite of this, virgin fibre quality is almost never valorised, especially at the end of its life cycle. Indeed, greaseproof paper packaging neither can be collected and recycled with paper-based products, because of the presence of food residues, nor be composted, as generally coated with non-biodegradable films. Designing and producing a cellulose packaging without imaging a re-use of the raw material employed, is no longer possible. It is therefore necessary to start a truly sustainable cycle, able to enhance and valorise the use of natural resources as virgin fibre. On that way, to compost greaseproof paper packaging could be an interesting solution. In order to verify the compostability of CIPACK coating, future test could also include an analysis of the environmental impact assessment (LCA) in paper packaging production, based on virgin and recycled fibres as raw materials.

5.3 Future research

This research represents the beginning of a design process that tries to find sustainable packaging solutions that achieve a commercial outcome. After the exploration of advantages and shortcomings of the tested coatings application, will be identified new opportunities that could be used to start a dialogue within the supply chain about the complex interactions between packaging and food.

Sustainable practices at Expo 2015

The study perfectly fits on Expo 2015 Milan theme: "Feeding the planet, Energy for life". The theme explores the world of food and nutrition as a complex process of interaction and transformation between humankind and nature. Food is a very complex theme, being much more than mere feeding: it has influenced history, environment, industrial, economic and social development as much as tastes and art. The theme of packaging, as packaging industry is one of the four links in the food chain, will be part of the discussion about technology and innovation for food safety. As Expo 2015 Milan is expected to attract over 20 million visitors, it would be a great occasion to communicate sustainable principles, which could be applied in the packaging system. The presence of national and international schools, universities and research institutes, creative professionals, but also packaging industry professionals and consumers at Expo 2015 Milan, could contribute to diffuse latest developments in the field of food packaging. The adoption of an environmental action strategy for sustainable development in packaging, handling and storage of goods sectors, would also facilitate the design of a "target vision" for companies to strive toward continuous improvement on materials and technologies. The pursuit of sustainable innovation by business leaders companies in food packaging sector will drive production for better packaging that helps to provide for a better tomorrow. As direct consequence, Expo 2015 theme highlights the sustainability issue as a guide to perceive the industrial innovation. Packaging industry companies can take the lead as ambassadors for good design, to let consumers understand the value of packaging, preserving at the same time the embedded resources in the products they buy. Designers, constrained by consumer perceptions, indeed, could directly contribute to communicate the important role of food packaging in assessing sustainable development, preserving the natural environment and reducing food waste [15].

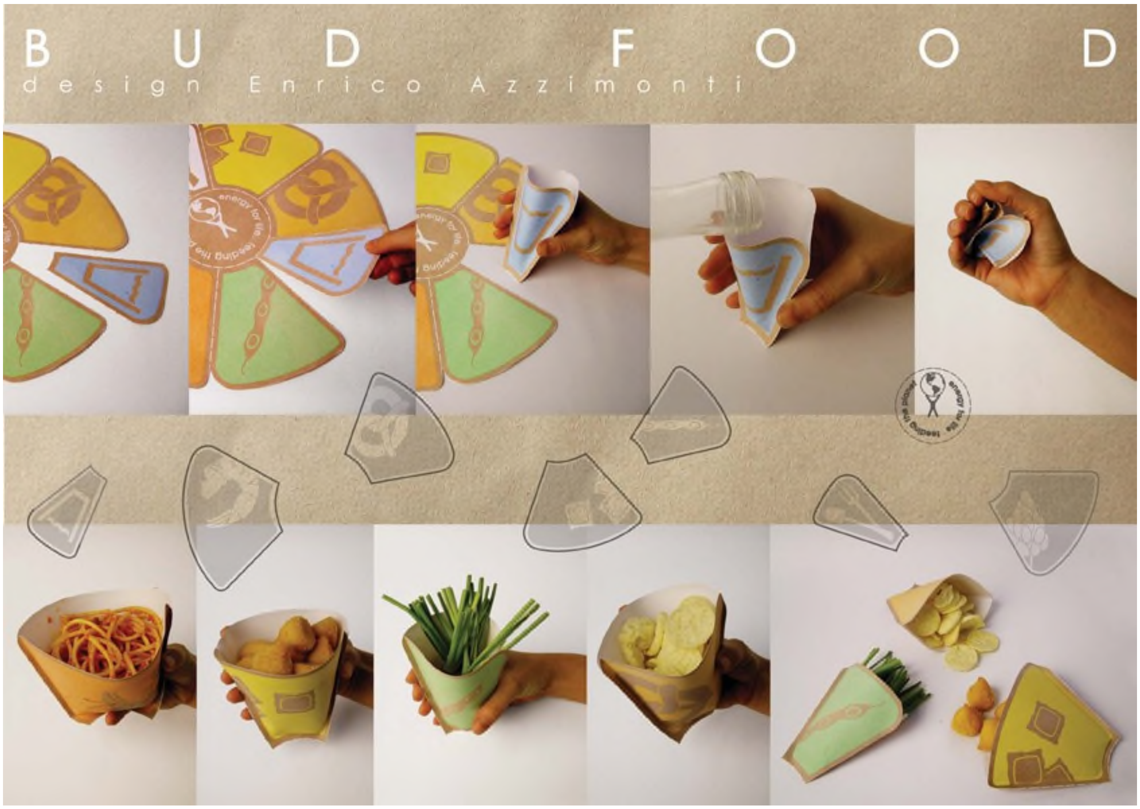

Figure 11 Bud Food, design Enrico Azzimonti (2010) [www.expopack.org]

Packaging opportunities to reduce food waste

As outlined on the previous paragraphs, packaging plays a central role in protecting, transporting, selling, storing, and in consuming food. In doing so, it helps to deliver a wide range of functions while reducing food waste. However, despite the fact that manufacturers, retailers, government agencies and food recovery organisations are implementing strategies to reduce food waste in the supply chain, there has been little attention paid to the potential contribution of packaging [39]. There are significant opportunities to reduce food waste in the supply chain through improvements and innovation in packaging. Reusable packaging could increase efficiencies or extend the shelf life of products; packaging systems can be developed to recover surplus and redirect it to charitable agencies. Moreover, packaging opportunities at the processing stage could implicate the elimination or light-weighting of packaging components; the design of containers that could ensure that a product can be completely consumed; the development of packaging materials and technologies that extend food shelf life; the production of different packs sizes that accommodates consumers' needs.

In particular, this research focus on sustainable packaging systems developed to reduce food waste, imaging a possible application of the tested oil-repellent coatings in a packaging for leftovers.

A large amount of food is wasted in the hospitality sector. According to WRAP - Waste & Resources Action Programme, an independent not-for-profit English company, each restaurant annually throws away 21 tonnes of food, 30% of which comes from the leftovers on diners' plates. In order to reduce the volume of this kind of food waste, many associations all over Europe launched campaign to promote the use of doggy boxes. An example is "Too Good To Waste", "a website that allows diners to submit their favourite leftover recipes as well as suggest restaurants they would like to see provide doggy boxes [11]. The design of a "doggy bag" integrated with the meal pack or with the restaurant devices, could help encouraging customers to take leftovers home.

Figure 12 D&AD ASDA Lunchboxes, design Emma Smart (2006) [www.smartemma.co.uk]

The implementation of this study could be supported through further steps:

- The research into the potential for packaging to be improved to reduce food waste, combining the action of packaging industries, scientific organizations, universities and creative professionals
- The analysis of the reasons for waste in different food services (e.g., restaurant, take away, café), in order to identify new opportunities for packaging innovation to "capture" waste
- The development of design concepts and models of possible packaging solutions to be employed as leftovers boxes

Figure 13 KOT, design Agnese Piselli (2014)

Overall, this research shows that small changes in behaviour around packaging, and continued innovation in food packaging industry, could deliver the benefits society is looking for, in particular: preserving food quality, ensuring food safety, uprising packaging sustainability, and reducing the food waste.

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Design Sciences, Advanced Technologies and Design Innovations

Towards a better, stronger and sustainable built environment

Aims and scope

Today's design strongly seeks ways to change itself into a more competitive and innovative discipline taking advantage of the emerging advanced technologies as well as evolution of design research disciplines with their profound effects on emerging design theories, methods and techniques. A number of reform programmes have been initiated by national governments, research institutes, universities and design practices. Although the objectives of different reform programmes show many more differences than commonalities, they all agree that the adoption of advanced information, communication and knowledge technologies is a key enabler for achieving the long-term objectives of these programmes and thus providing the basis for a better, stronger and sustainable future for all design disciplines. The term sustainability - in its environmental usage - refers to the conservation of the natural environment and resources for future generations. The application of sustainability refers to approaches such as Green Design, Sustainable Architecture etc. The concept of sustainability in design has evolved over many years. In the early years, the focus was mainly on how to deal with the issue of increasingly scarce resources and on how to reduce the design impact on the natural environment. It is now recognized that "sustainable" or "green" approaches should take into account the so-called triple bottom line of economic viability, social responsibility and environmental impact. In other words: the sustainable solutions need to be socially equitable, economically viable and environmentally sound.

IJDST promotes the advancement of information and communication technology and effective application of advanced technologies for all design disciplines related to the built environment including but not limited to architecture, building design, civil engineering, urban planning and industrial design. Based on these objectives the journal challenges design researchers and design professionals from all over the world to submit papers on how the application of advanced technologies (theories, methods, experiments and techniques) can address the long-term ambitions of the design disciplines in order to enhance its competitive qualities and to provide solutions for the increasing demand from society for more sustainable design products. In addition, IJDST challenges authors to submit research papers on the subject of green design. In this context "green design" is regarded as the application of sustainability in design by means of the advanced technologies (theories, methods, experiments and techniques), which focuses on the research, education and practice of design which is capable of using resources efficiently and effectively. The main objective of this approach is to develop new products and services for corporations and their clients in order to reduce their energy consumption.

The main goal of the *International Journal of Design Sciences and Technology* (IJDST) is to disseminate design knowledge. The design of new products drives to solve problems that their solutions are still partial and their tools and methods are rudimentary. Design is applied in extremely various fields and implies numerous agents during the entire process of elaboration and realisation. The International Journal of Design Sciences and Technology is a multidisciplinary forum dealing with all facets and fields of design. It endeavours to provide a framework with which to support debates on different social, economic, political, historical, pedagogical, philosophical, scientific and technological issues surrounding design and their implications for both professional and educational design environments. The focus is on both general as well as specific design issues, at the level of design ideas, experiments and applications. Besides examining the concepts and the questions raised by academic and professional communities, IJDST also addresses the concerns and approaches of different academic, industrial and professional design disciplines. IJDST seeks to follow the growth of the universe of design theories, methods and techniques in order to observe, to interpret and to contribute to design's dynamic and expanding sciences and technology. IJDST will examine design in its broadest context. Papers are expected to clearly address design research, applications and methods. Conclusions need to be sufficiently supported by both evidence from existing research (reference to existing design research knowledge) as well as strong case-studies from any design discipline. A paper must contain at least one chapter on research questions, methodology of research and methods of analysis (the minimum length is 1500 words). The concluding chapter (the minimum length is 1000 words) will summarise the paper and its results. The concluding chapter also examines and discuss applications, advantage, shortcomings and implications of the investigation for both professional and educational design communities as well as for the people and the society. Also authors are also encouraged to include in this chapter a discussion of the possible future research that is required or is possible in order to enhance the research findings.

The papers considered for IJDST cover a wide range of research areas including but not limited to the following topics: Design research, design science, design thinking, design knowledge, design history, design taxonomy, design technology, design praxeology, design modelling, design metrology, design axiology, design philosophy, design epistemology, design pedagogy, design management, design policy, design politics, design sociology, design economics, design aesthetics, design semantics, design decision-making, design decisions, design evaluation, design sustainability, design logic, design ontology, design logistics, design syntaxis, design ethics, design objective, design responsibility, design environment, design awareness, design informatics, design organization, design communication, design intelligence, design evaluation, design education, design theories, design techniques, design methods, design operations, design processes, design products, design users, design participation, design innovation, design inspired by nature, design case studies, design experiments, etc.

The *International Journal of Design Sciences and Technology* is devoted to further exploration of all themes and issues that are directly or indirectly relevant to the exploration, introduction, discussion of design sciences and technology, cross referencing domains and any other themes emerging in the future.

Instructions for Authors and Review Process

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[2] **Blackman, DA** (2001) Does a Learning Organisation Facilitate Knowledge Acquisition and Transfer? Electronic Journal of Radical Organization Theory, 7:2 [www.mngt.waikato.ac.nz/Research/ejrot/Vol7_1/Vol7_1articles/blackman.asp]

[3] **Buxton, W** (1997) Living in Augmented Reality: Ubiquitous Media and Reflective Environments. In: Finne K, Sellen A and Wilber S eds, Video Mediated Communication, Erlbaum, Hillsdale NJ, 363-384

[4] **Dixon, NM** (2000) Common Knowledge: How companies thrive by sharing what they know, Harvard Business School Press, Boston, MA

[5] **Djenidi H**, **Ramdane-Cherif A**, **Tadj C** and **Levy N** (2004). Generic Pipelined Multi-Agents Architecture for Multimedia Multimodal Software Environment, Journal of Object Technology, 3:8, 147-169

[6] **Gorard, S** and **Selwynn, N** (1999) Switching on to the learning society? Questioning the role of technology in widening participation in lifelong learning, Journal of Education Policy, 14:5, 523-534

[7] **World Bank** (2002) Social assessment as a method for social analysis, World Bank Group [www.worldbank.org/gender/resources/assessment/samethod.htm]

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