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PP	Restricted to other programme participants (including the Commission Services)	
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PUBLISHABLE EXECUTIVE SUMMARY

The overseeing, development and optimisation of injection moulding, blow moulding extrusion and film extrusion technology, involved in the technical processing of the pure biodegradable polymers and biopolymers reinforced with nano additives require an extensive testing for the optimal results. The preliminary testing of pure biopolymer, which includes spiral flow test, shrinkage test, wrapage test, rheology test, tensile test, preliminary SCF test etc., are of great importance for the identification of the most influential parameters for specific process technology. Since the definition of the technological window and processing parameters with extensive testing and virtual simulations are based on preliminary testing, wherein a complete testing with all of the combinations of all of the parameters is not essential, but to reduce time and costs, statistical methods will be implemented in order to evaluate the influence of each parameter individually.

Critical parameters for blow extrusion moulding process technology can be summarized as those, which cannot produce a good melt flow at the exit. By understanding a not good melt flow we have to consider on non-uniform temperature, with un-melted particles, with gases or with material degradation. In addition temperature in the cylinder, the manner in which heating is applied (not uniform distribution, warmed areas, exterior vs. internal heating) and also barrel cooling system has to be taking into account (exterior fans or water lines). Residence time in the cylinder (while the polymeric melt is inside the barrel), shear rate and shear stress along the process, which is a consequence of a pressure in the barrel and periphery speed in the screw (Ø, rpm) are also of great relevance for optimised blow extrusion process technology. Further on, the pressure in the barrel, which can be affected by screw compression rate and the pressure by which the polymer melt must reach to the exit through the die (given by flow sections and pressure at the gate) must be also considered. In injection machines interior pressure is controlled by the “Back Pressure” during the plasticizing phase. In blow moulding it is not always controlled, depending if it is a continuous process or with accumulator and depending on the type of machine. The critical parameters are therefore the screw geometry and internal flow sections which are not set up parameters. Die section is a set-up parameter, but conditioned by part geometry (part profile). Periphery speed is given by screw diameter and programmed rpm. The rpm can be reduced but always fulfilling process requirements (cycle time, enough output), affect residence time. All these parameters can be divided into controlled (set-up) or uncontrolled (machine characteristics) by the operator. Thinking in controlled parameters a Design of Experiment (DOE) can be performed in order to see the influence of every one.

Injection moulding is a cyclic process during which molten thermoplastic material is forced into a mould or cavity. After the plastic material cools down, the mould opens and the plastic part is ejected. Nowadays, injection moulding process is widely used for mass production as well as for production of individual test specimens. The cycle time of injection moulding process depends on part's thickness and size, on the material injected, on material the mould is made from, and on injection moulding parameters. There are many parameters that influence the final parts properties, most important of them being injection rate, melt flow temperature, mould

temperature, switchover point, injection as well as holding pressure (its magnitude vs. time profile), time of cooling, drying time, and fibre mass ratio in case of the polymer composite injection moulding process. Each of these parameters plays an important role in ends product quality, whether in respect of parts mechanical properties or its dimension stability and visual appearance. Because the impact of large number of different parameters will be measured for injection moulding process optimisation, it is impossible to test every possible combination. Taguchi method for determining the impact of single factors is the most suitable for this case. For each series of tests Taguchi method specifies which of the three levels of each parameter has to be used. There are many thousands of combinations of parameters, but the Taguchi method picks those combinations that after analysis can show us the influence of specific parameters. The most influential parameters on the mechanical properties must be found together with their optimum.

Due to the complexity of film extrusion process, a kit needs to be developed, which allows imitating the process on a smaller scale. The process can therefore be divided into Part 1 and Part 2, wherein the major advantage is that it requires significantly less material (approx. 3Kg for core testing and 750g for skins) to produce small lab samples. The first being production of the cast tube (i.e. the top of the bubble), and is basically self-explanatory (taking polymer chips, melt extruding them and then forming a crystalline tube or plaque of known dimensions). Industrially, low levels of moisture are needed in film extrusion process and testing of samples has shown that 300 ppm seems to work for all samples. Drying times are thus adapted to give samples with levels of moisture under this. Once dried, the material can be injected or extruded into a correctly shaped die, or can be run through a multilayer extruder, before being cut to the correct dimensions and stored. The second part of the process involves bi-axially orienting the plaque to produce a film and heat setting the material to form a stabilised film. Samples of the material plaques can be used to generate multilayer film structures. Conversion of the plaque to a film is done on a laboratory scale stretcher. These frames allow preheating of a sample with high crystalline characteristics and then draw/stretch bi-axially to dimensions up to 8 x 8, before heat setting and cooling the film to stabilise it. Due to the uniqueness of film extrusion process, a quick trials are needed to determine which biopolymer/blend appears to be the most advantageous to use. The variables involved in film extrusion processing can be divided into a factors affecting material (rheology, melt strength, heat/shear stability, crystalline melting point and range, crystallisation rate and transitions during heating/cooling, draw stress vs. strain temperatures, strain hardening properties during draw) and into a process control factors (extrusion, casting and orientation temperature, area draw ratio, rate of cooling, annealing temperature and relaxation during annealing). Due to the number of variables on film extrusion process the blends of two material were created and characterised for their rheological, gloss, haze, optical, density, colour (LAB values), thickness and shrinkage properties before the experimental trials. Further factors, such as drying efficiency (water content vs. time at 60 and 85 oC), extrusion temperature (190, 210 and 240 oC maximum temperatures), annealing/heat setting temperatures (None, 80 and 110 oC), preheat time vs. plaque thickness (proportional to sample thickness) should also be considered, at once the number of the material variables are reduced.