***Development of a cost-efficient strategy for testing and evaluating the migration of UV printing inks and UV lacquers from packaging into foods (project IGF* 17095N)**

Summary

Migration of components from printing inks into foods needs to be considered for evaluating the food regulatory compliance of printed packaging materials. Two migration mechanisms are feasible for printing ink on the outside of packaging. Firstly, the printing inks can migrate (permeate) through the packaging into the food. Secondly, the storage of the packaging material on rolls or in stacks means that the printed side is in direct contact with the food contact side of, for example, the next layer, sheet or hollow article. Thus printing ink components can transfer directly to the food contact side and later, after the packaging process, into the food. This migration mechanism is called set-off. These transfer processes are determined by the partition coefficients (between the layers) and the diffusion coefficients (in the layers).

The project work studied the set-off of UV printing ink components (photoinitiators and acrylates) from a printed polypropylene film to various acceptor films at 40°C and 60°C. The acceptor films represent the food contact layers. Polyethylene, polypropylene, polyethylene terephthalate, and aluminum foil with three different heat-sealing lacquers were used as acceptor materials. The printing was undertaken with three ink systems, namely a conventional non-food ink with low molecular weight photoinitiators and acrylate monomers, a low-migration food ink with exclusively "polymeric" photoinitiators and acrylates, and a further low-migration food ink consisting mainly of non-polymeric photoinitiators. In addition, the protective effect of a top lacquer layer was investigated. In total, twelve different photoinitiators and eight different acrylates were studied in the three systems. The transfer of the printing ink components to the acceptor materials was measured as a function of time. From this the partition coefficients (between the layers) and the diffusion coefficients (in the layers) were calculated.

The low molecular weight printing ink components established partitioning equilibrium within a short time in contact with the polyolefin films. In contact with the heat-sealing lacquers, equilibrium was not established even after 10 days at 40°C and but after 15 to 20 days at 60°C. Indeed, a temperature of 60°C led to the onset of softening of the heat-sealing lacquers and some visible set-off was observed, meaning that accelerated testing at 60°C was not suitable. Overall, the acrylate-based heat-sealing lacquers showed high affinity for the printing ink components, as demonstrated by the partitioning equilibria on the heat-sealing lacquer side. The top lacquer layer only gave a protective effect in cases where no partitioning equilibrium was established during the contact time.

By evaluating all the partition coefficients, an upper limit line was derived. This allows the partition coefficients of other printing ink components in similar UV systems in contact with polyolefins to be estimated. The results for the heat-sealing lacquers were too different to be able to make general statements. The set-off scenario was included as an option in the migration modeling software. Users thus have a relatively easy-to-use tool for modeling contact between materials when stored on rolls or in stacks. The results can be used to

evaluate reverse printing and also as a worst-case scenario for set-off when storing hollow articles in stacks.

The project results enabled to estimate the migration theoretically by mathematical modelling under near-real conditions from a further important layer class, namely UV printing inks and lacquers on plastics. This mathematical modeling strategy enables industrial companies to keep the required laboratory work and time, which largely determine the cost of compliance testing, as low as possible. In addition, conclusions were drawn from the studies about the experimental set-off tests. Suitable conditions for set-off simulation were proposed, so allowing realistic transfer for printed materials stored for long periods on rolls or in stacks. These conclusions provide the basis for guidelines for testing the compliance of UV printing ink layers on plastic food contact materials.

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