Project Summary: Recycled Packaging: Definitions, Descriptions, Challenges and Solutions

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New Zealand FOOD SAFETY SCIENCE & RESEARCH CENTRE

PROJECT SUMMARY: RECYCLED PACKAGING: DEFINITIONS, DESCRIPTIONS, CHALLENGES AND SOLUTIONS

OVERVIEW

The food supply chain is dependent upon food packaging to maintain food safety and quality as well as minimise food waste and allow transportation around the globe. In response to concerns expressed by consumers, advocacy groups and governmental agencies many countries have set ambitious goals to reduce the economic and environmental costs associated with food packaging, which includes the establishment of targets (voluntary or regulated) for the adoption of recycled packaging.

In recycled packaging the presence of non-intentionally added substances (NIAS), from the previous use or misuse of the material or the occurrence of intentionally added substances (IAS), such as plastic additives or printing inks, at higher-than-normal use concentrations, have the potential to impact on the safety and quality of the packaged product. Further, as plastics, paper and paperboards undergo gradual chemical changes during recycling, recycled packaging can have different physical properties than virgin packaging, which can affect its functionality.

The risk that NIAS or IAS pose to product safety or quality is dependent on the nature of the substances present, their concentrations, and their ability to migrate from the recycled packaging into the product. The migration of a substance is dependent on the concentration present, the packaging material type (e.g., paper, PET, PP) and properties (thickness, porosity), the food product's composition (level of fat), and physicochemical properties (pH) and the conditions (temperature, time, humidity) under which the packaged product is stored.

It is worth noting that many New Zealand primary products can be considered to be relatively suspectable to the adverse effects associated with the migration of NIAS substances from packaging owing to their composition (high fat content), storage conditions (often at ambient) and long shelf-live.

In interviews carried out with New Zealand brand owners concern was expressed that, despite scientific data clearly highlighting that recycled packaging contains more NIAS than virgin packaging, packaging companies were not doing enough to explain the processes they follow and the checks they employ to ensure the safety of the recycled packaging they manufacture/sell. There was a desire for packaging companies to clearly demonstrate that they take risk assessment-based approaches that identify risks and establish and monitor critical control points designed to control the identified risks. The lack of New Zealand-specific guidelines (or regulation /standards) for recycled packaging was also noted as being problematic, with some brand owners stating that they were required to ensure that critical safety steps in the production of recycled packaging were being controlled (Mirosa and Bremer, 2022).

It is concluded that when using recycled packaging it is important that brand owners implement risk assessment-based approaches that can identify critical packaging parameters and generate acceptable quality limits (taking the form of a product specification), which can be used to control the identified risks (Bremer and Mirosa, 2022).

THE RECYCLING PROCESS

Plastic recycling

Effective waste collection is a vital first stage for efficient recycling. By separating waste correctly at the point of collection, the recycling process is more efficient and will increase the quality and quantities of recycled products. The second crucial stage involves the plastic being sorted based on resin and colour. The collected sorted plastic is then turned into new packaging via either a mechanical or a chemical recycling process.

Mechanical recycling involves intact plastic being shredded and the fragments treated with chemicals that assist in removing impurities and contaminants such as food and chemical residues. This eliminates impurities like labels or NIAS, using a range of washing steps that incorporate various degrees of friction and wash temperatures depending on the resilience of the plastic. The cleaned material is then melted and usually extruded into the form of pellets which are used to manufacture the recycled packaging, which may or may not incorporate a percentage of virgin plastic.

Chemical recycling involves using energy to break down collected sorted plastics into monomers and other basic chemical elements ("depolymerization"). This process enables materials that are difficult to be recycled by mechanical means to be recycled and it removes all contamination. Chemically recycled monomers can be used as virgin material alternatives in the manufacture of new polymers. There are different types of chemical recycling processes, including pyrolysis, gasification, solvent dissolution and chemical depolymerisation and other specialist processes which are evolving.

Paper / Board Recycling

The making of recycled paper / board starts with collecting and sorting recovered material from curb side recycling or post-industrial sources, into types or grades. The collected material is shredded, water and chemicals are added, and it is pulped to break it down into strands of cellulose, or fibres. The paper pulp is screened to remove contaminants, de-inked, beaten until the fibres swell, bleached and any required additives are added. The resulting pulp is squeezed and dried to form recycled sheets.

SOURCES AND DETECTION OF NIAS AND IAS

Substances (NIAS/AIS) that may be present in packaging originate from a wide variety of sources and reactions (Extabide, Bremer, Young and Kilmartin, 2022; Bremer, Etxabide, Young and Kilmartin, 2022). IAS include substances used for the initial polymerization step in the making of virgin plastics, such as monomers or catalysts and their impurities or additives that are included during the manufacturing process to achieve the desired material properties (e.g., plasticizers, antioxidants, light stabilizers, thermal stabilizers, lubricants, antistatic agents, slip additives) and their impurities; starting substances from the incomplete polymerization during the formation of polymers, and solvent residues. Note that impurities, reaction intermediates (oligomers), breakdown products, oxidation products formed by the reaction of package components with exterior oxygen or degradation products formed during the recycling of packaging material are all considered NIAS.

NIAS also include inorganic elements such as silicon, calcium, iron, and aluminium, absorbed organic compounds from the food, that the recycled packaging previously contained such as flavour or odour compounds (for instance essential oils from soft drinks residues) or the residues from non-food grade

materials (e.g., mouthwash, personal hygiene, household cleaners, cosmetic products) and compounds present owing to the re-use of packaging to store non-food grade materials prior to its disposal. The multiple uses and reuse of plastic containers and bottles means that material obtained from post-consumer waste streams (e.g. kerb side collection) are more likely to contain NIAS that material obtained from the more defined and controlled pre-consumer / post-industrial waste streams.

For the analysis of NIAS, two strategies may be applied: targeted analytical methods for the detection of predicted NIAS, or non-targeted or screening methods designed to detect and analyse a broad range of substances which may differ significantly in their physical or chemical properties. As recycled materials are likely to contain more degradation products, non-targeted screening should be considered when assessing contaminants in either the packaging material or substances that have migrated from the packaging material. The detection of IAS and NIAS in packaging or the food it contains generally involves the use of gas and/or liquid chromatography-based methods. Selecting the correct analytical conditions to detect NIAS is challenging as all extraction methods have blind spots, i.e., compound(s) that will not be extracted or will be lost during sample preparation. It is therefore recommended to use a range of extraction and detection techniques when undertaking non-targeted studies.

Over 6000 substances have been reported to be found in plastics (e.g., additives, NIAS, solvents, unreacted monomers, starting substances, and processing aids), including substances which have not been fully evaluated for their potential to migrate from packaging into food (Aurisano et al., 2021; Van Bossuyt et al., 2016).

MIGRATION OF SUBSTANCES

A number of NIAS or IAS have the potential to migrate from the packaging into the food it contains. Migration is considered to be a four-step process involving diffusion-desorption-sorption-absorption, where chemicals that diffuse through the packaging material are ultimately absorbed by the food they contain (and vice versa). This process is strongly influenced by the interactions of components of the food with the packaging material.

EU regulation set an overall migration limit (OML) of 60 mg of the total migrated substances (total sum of IAS and NIAS)/kg food or 10 mg of total substances/dm^2 food contact surface, as well as specific migration limits (SML) for each migrated IAS from food packaging material into food ((EC) No 282/2008; (EU) No 10/2011).

SAFETY IMPLICATIONS OF NIAS AND IAS

Not all detected NIAS in recycled packaging have been identified and neither has the origin of all of the NIAS detected been established. Many identified substances (IAS or NIAS) present in packaging material (recycled or virgin), and/or which had migrated into the food (simulant), are substances not included in the EU list of substances allowed to be used in materials intended to come in contact with food. Some substances (IAS & NIA) have been detected in food at concentrations higher than their migration limit (SML, 10 µk/kg for NIAS). In addition, some substances identified in both recycled plastic and recycled board are substances (e.g. some phthalates) that have been classified as being

substances of very high concern (SVHC). However, few toxicity studies have been carried out on substances that have the potential to migrate from packaging into foods and very few studies have calculated the daily intake of substances (NIAS or IAS) that have the potential to migrate from recycled packaging material into food.

QUALITY IMPLICATIONS OF NIAS, IAS AND POLYMERS

For both polymers and paper/paperboard, the impact of the recycled content on product quality can be measured and the suitability of the packaging for a given application assessed (Silcock and Bremer, 2022).

Many analytical techniques are available to characterise the recycling-induced changes, however, attention should focus on properties that directly reflect product performance. This means focusing on the relevant mechanical properties, presence of odours and visual defects. When considering how recycled packaging may influence food quality the key questions are: will the packaging protect and contain the enclosed product?; and will the packaging give rise to off odours/flavours which will adversely affect its contents? These questions suggest that technologists should focus on mechanical and sensory-based tests already established by standards associations.

Mechanical tests are required as large variations in mechanical properties can arise owing to differences in polymer type (ie non-target packaging material) and sub-types, (due to polymer synthesis-induced variation in polymer molecular weight, degree of branching, branch lengths and crosslinking) which makes it difficult to draw general conclusions on the performance of recycled polymers compared to virgin polymers.

Sensory tests are recommended as they can be used to detect a wide range of odour/flavour defects (in a nonselective manner) in a product more easily than VOC analysis methods such as GC-MS. In addition, sensory-based, visual tests, such as colour, are well-established QA tools.

CONCLUSIONS

In general, a larger number and a higher concentration of substances (NIAS or IAS) are generally found in recycled packaging compared to virgin packaging materials.

The number and concentration of substances (NIAS or IAS) in recycled packaging materials increase as the number of times the material is recycled increases.

The rate of migration of IAS and NIAS from packaging into food is dependent on the nature and concentration of the substance present, the packaging material use, the food type and the storage conditions.

The presence of IAS and NIAS in recycled packaging can impact product safety and quality.

The occurrence of contaminating polymers in plastic packaging can impact the physical quality of the packaging.

When using recycled packaging it is important that brand owners implement risk assessment-based approaches that can identify critical packaging parameters and generate acceptable quality limits (taking the form of a product specification) that can be used to control the identified risks.

Further, as recycled packaging can contain a greater diversity and higher concentrations of NIAS and IAS than virgin packaging, it is important that recycled packaging manufacturers have a good understanding of the nature of the material they are recycling and work within a safety and quality framework that identifies risks and establishes and monitors critical control points designed to control the identified risks.

To protect the New Zealand food industry, food processors and recycled packaging manufactures / suppliers should work together to develop a shared understanding of the safety and quality risks associated with each product / packaging application and to design appropriate safety and quality assurance programmes.

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