FACET: Light Metal Packaging Methodology

by **P.K.T. Oldring**, Valspar Corporation
F. Savrij Droste, Ardagh Metal Packaging
R. Whitaker, Crown Cork & Seal
D. Smith, MPMA Ltd.
C. O'Mahony, Creme Global
and
L. Castle, The Food and Environment Research Agency

Light metal packaging for foodstuffs primarily encompasses cans, closures, and aerosols. For cans used in the European Union (EU), the majority are beverage cans with about 45 billion used per annum (pa) compared to approximately 20 billion food cans pa. Metal closures are subdivided into about 20 billion closures for jars and 80 billion crowns for bottles per year. The *ILSI Monograph on Light Metal Packaging for Foodstuffs*[1] contains background information for the reader unfamiliar with this type of packaging.

The FACET project (Flavours, Additives and food Contact materials Exposure Tool) was a four-year project that was partially funded by the European Commission within its Framework FP7 Programme. The project ran from September 2008 until August 2012. FACET was coordinated by University College Dublin and it involved 20 research partners from across Europe, coming from academia, industry, research centers, and small- to medium-sized enterprises. Hearty et al. provided an early overview of the project plan[2] and Oldring et al.[3,4] offered a view of the part of the project plan that dealt specifically with packaging materials. More recently, the use of FACET for assessing exposure to bisphenol A (BPA) from light metal packaging has been reported.[5] As the name indicates, the FACET exposure tool provides a single platform with the functionality to estimate consumer exposure to three types of food chemicals, namely chemical food additives ("E-numbers"), chemically defined flavoring substances added to foods, and substances used to make food contact materials. A PC-based desktop application, the FACET exposure tool is publicly available and free of charge. The software tool was developed and populated with data gathered throughout the course of the project, with the facility of uploading any additional data that the end-user might have. This article describes how the information was gathered for the light metal packaging portion of the FACET tool.

FACET is a probabilistic (or stochastic) approach for estimating consumer exposure to chemicals contained in foodstuffs, by combining the amount of foodstuff consumed with the concentration of the chemical in that foodstuff. This is repeated for every consumption event across the population surveyed, using national food consumption survey data. For more information on the probabilistic approach, consult Gibney and van der Voet,[6] Holmes et al.,[7] Leclercq et al.,[8] Petersen,[9] and Slob.[10] For packaging, the focus is on migrants from packaging into foodstuffs.

Since the FACET tool uses a diary-driven approach that starts at the food consumption event, a sequence of steps was necessary to decide if the chemical of interest might be present in that foodstuff, and at what concentration. The first action was to decide on a food coding system that suited packaging migration. The national food survey diaries contained, for each eating event by each consumer, a description and quantity of each foodstuff consumed over the duration of the survey. However, each of the eight national dietary surveys held in the

FACET databases was coded using a different system, unique to that country. So, the national food consumption database managers from the eight member states (Finland, France, Hungary, Ireland, Italy, Poland, Portugal, and the United Kingdom) involved in FACET re-coded their food consumption data according to a harmonized tiered categorization system. By developing a harmonized database of food packaging composition data linked to these diaries, the exposure algorithms presented a rational methodology for assessing dietary exposure to food packaging migrants based on real market data and conditions. The FACET food packaging codes are at three levels (tiers). At Tier 1, there are 18 broad food categories. Tier 2 contains 59 categories and Tier 3 has 174 food categories, i.e., the highest level of detail. More information can be obtained by consulting Oldring et al.[4] Not all of these food categories are packaged in light metal packaging.

While food consumption surveys in the EU member states provide information on the type and quantity of foodstuffs consumed (to enable nutritional data to be extracted), few—if any—contain information on the packaging of the foodstuff that was consumed. In some cases, such as for Germany, Ireland, and the UK, "canned" foodstuffs are identified and treated systematically because the heat treatment that the canned foodstuff undergoes, combined with the long shelf-life that canning affords, may change the nutritional parameters compared to the same foods when, for example, fresh or frozen. Generally, though, packaging information is either sparse or missing from most national food consumption surveys.

Thus, it was necessary to identify the foodstuffs at the Tier 3 level that could be packaged in light metal packaging. Euromonitor International (hereafter referred to as Euromonitor) is a global market research organization that provided data on the packaging of foodstuffs in retail outlets for about 20 EU member states.[4] These data were used as the basis for allocating market shares for different types of packaging materials for different foodstuffs. The data were from 2005 because, being somewhat older, they were affordable and were not as commercially confidential as the most up-to-date survey data. Also, none of the nutritional surveys was more recent than 2005; indeed, many were pre-2000.

To estimate the exposure to migrants from foodstuffs packaged in light metal packaging, it was necessary to determine which foodstuffs at FACET Packaging Category Tier 3 could be packaged in light metal packaging, what substances the coatings on these packages might contain, and at what concentration they could migrate into the foodstuffs.

METHODOLOGY

The European light metal packaging sector has a Joint Industry Group (JIG) whose membership includes the food industry, can/closure makers, and coating and raw material suppliers. The JIG formed a Technical Subcommittee (TSC) known as TSC 30 to supply data to the FACET project and it critiqued data originating from Euromonitor. The methodology used by Euromonitor applies to all types of packaging for food and is not restricted to light metal packaging.

Can makers (European Metal Packaging Association, EMPAC) and coating suppliers (European Council of the Paint, Printing Ink and Artists Colours Industry, CEPE) undertook different tasks with respect to light metal packaging. The JIG encompasses primarily food and beverage cans (and their components) and metal closures. Although aerosols and collapsible metal tubes are outside the scope of the JIG, EMPAC undertook the task to also collect data on these products. Moreover, CEPE supplies coatings for these end uses. The food industry and raw material suppliers supported and also undertook a wider role in the FACET project. The specific roles for EMPAC and CEPE were:

- EMPAC and CEPE agreed together on the coating categories to be used. CEPE (1) listed the substances in the different coating chemistries used for cans, ends, aerosols, and metal closures, as well as the probability of those substances occurring in a given coating, and then (2) provided migration or extraction levels of the substances for those different coatings.
- EMPAC (1) supplied information on the types and numbers of cans, aerosols, ends, and closures used for the different FACET food categories along with their surface-area-to-volume ratios; (2) listed the substances used and migration or extraction levels from gaskets used for vacuum metal closures; and (3) listed the polymeric materials used as the plastic lining seal for other metal closures such as crowns and roll-on pilfer-proof ROPP (see later).

The data relevant to metal packaging [cans (food and beverage), can ends (food and beverage), aerosols, metal closures for glass bottles or jars, and collapsible metal tubes] were derived from the Euromonitor data.[4,5] This gave the share of metal packaging for any one of the 174 FACET food categories at Tier 3. If there were more than one type of metal packaging component that could contain that food category, then the share per packaging component was allocated either from EMPAC-supplied data for types of food can or Euromonitor data for types of food can end. For example, food cans could be two- or three-piece and they could have classic or easy-open ends (EOE). Beverage cans all have easy-open ends, but these ends are different than those used on food cans.

RESULTS AND DISCUSSION

Coating Categories

Before substances in coatings could be addressed, it was necessary to agree on a list of coatings, along with their codes, to enable the substances to be correctly allocated. The list of coating categories along with their FACET material codes is given in *Table* 1.

Aluminum or steel is used for the manufacture of light metal packaging. There are two main types of steel: electrolytic tinplate (ETP) and tin-free steel (TFS), also known as electrocoated chromium steel (ECCS). Some types of packaging can be manufactured from any of these metals and, for others, only one of the types of metal is used. It is not unusual for cans to consist of more than one type of metal; for example, a beverage can could have a steel (ETP) body and an aluminum easy-open end or, alternatively, the body and end could both be made from aluminum. A three-piece food can will have an ETP body (to facilitate welding of the seam) and, in all probability, a TFS classic end. The opening end could be ETP or TFS.

Table 1—Coating Categories Used in the FACET Project

FACET Material Code 37. CAN COATINGS
37.1. Epoxy-
37.1.1. -phenolic
37.1.2. -anhydride
37.1.3. -amino
37.1.3.1 beverage
37.1.3.2 food
37.1.4. -acrylate
37.1.4.1 beverage
37.1.4.2 food
37.1.5. -other
37.2. PVC-
37.2.1 -epoxy containing
37.2.2 -other
37.3. Polyester-
37.3.1 -phenolic
37.3.2. -amino
37.3.3. -polyurethane
37.3.4. -other
37.4. Acrylic
37.5. Other
37.5.1. Polymer coated
37.5.2. Closures for Twist-off and PT

The coatings used for the different metals are normally different, but frequently contain the same major constituents, such as epoxy resins. Additives and minor constituents would be the main variations.

CEPE members reported their annual tonnages (wet) for the European market for each coating category listed in *Table* 1. CEPE collated the data and anonymously supplied to Creme Global (hereafter referred to as Creme) the market shares for each type of coating. These data are proprietary and cannot be entered into the public domain. The assumption was made that the market share for coatings (cured and ready for food packaging, and on an area-related basis) was the same as the market share by wet tonnage.

It should also be kept in mind that, for the same foodstuff, different coating chemistries can be used even for the same metal or type of can or closure. Furthermore, different types of metal might be used for the same foodstuff. Thus, allocating coating chemistries to food categories as wide as those resulting from the Euromonitor data could result in averaging, but, at each stage of the data collection, splits were allocated for different types of coatings in order to avoid averaging. For example, if there were multiple options for a given foodstuff and a pack type, they were split in order to be used by the probabilistic model.

Substances in Coatings

The starting point was the inventory list of substances in the latest version of Technical Document No. 1 of the Council of Europe Resolution AP(2004)1 on Coatings in direct food contact.[11] This contains over 1000 substances but not all are used for coatings on light metal packaging. Duplicate entries (e.g., synonyms) and generic descriptions were removed. Substances used solely as solvents were removed since the curing conditions (using high temperature and high air flow) would essentially remove solvents.

CEPE members indicated which substances were used in their coatings corresponding to the coating categories. Each company supplied a spreadsheet, with each column representing a coating category and each row a substance from the inventory list. This resulted in an occurrence table for each company submitting data—used YES or NO—for all substances and each coating category. Creme was supplied with market share data for each coating category by CEPE. Some members allocated data pro-rata according to their share for each coating, making allowances for how much of that substance would be in each coating category they supplied.

Others supplied a probability table (using another spreadsheet similar to that for occurrence data) of the probability (0–1) of that substance being used in that coating. This is important because for some coatings only one of two or more substances could be used.

Concentration Data

For concentration data, CEPE members supplied a range of extraction or migration data into simulants or solvents, such as acetonitrile, using a similar spreadsheet to that used for the occurrence data. It was agreed that the units for extraction/migration would be mg/dm^2. The spreadsheet cells were completed in the format of 0.01–0.02, i.e., with a hyphen between the lowest and highest value, with no spaces.

For some substances, member companies had a range of migration/extraction figures since they had been determined in a number of different simulants/solvents. To include all these data would overcomplicate the spreadsheets and add no value, as the food item descriptions in FACET do not reflect the relevant simulants for the food item descriptions. This is also the case with most food consumption diaries. It was agreed that, if this information were available, the figures should be given as a range from the lowest to the highest. If extraction (e.g., acetonitrile 24 hr @ ambient, which has been shown to be worst case for most types of coatings and foodstuffs packed) data were available, then only these were used to express the range, except for beverage coatings where acetonitrile values could grossly overestimate the migration. In these cases, data obtained using beverage simulants (3% acetic acid and/or 10% ethanol) were used.

Companies agreed to treat concentration ranges using a uniform distribution, as follows: (1) lowest determined value to highest determined value; (2) zero to limit of detection value; (3) zero to highest determined value; or (4) limit of detection value to highest determined value. The use of a uniform distribution means that any value in the range submitted is equally likely. The data that each company possessed dictated the approach for each substance.

Approach Where Concentration Data Were Lacking

In the minority of cases where data for the amounts extracted or migrating were not available, a protocol for allocating values was agreed upon. The following approach was adopted:

(a) If the substance had an specific migration limit (SML), for SMLs > 0.1 mg/dm^2, values were allocated the range of 0–0.1 mg/dm^2 (as 0.6 mg/6 dm^2 was about equivalent to 500 ppb), unless the SML figure was less than 0.6 mg/kg, in which case, the range 0–SML figure expressed as mg/dm^2 was allocated.

(b) For inorganics, such as titanium dioxide, a maximum value of 0.010 mg/6 dm^2 (converted to 0.002 mg/dm^2) was used. Thus, the range 0–0.002 mg/dm^2 was used. Since these substances do not migrate in appreciable quantities, this is a realistic upper limit. Solvents used solely as solvents were not considered because they leave the dry film during the curing process and are subject to good manufacturing practice. For solvents also used as monomers (e.g., butanol), a range of 1 ppm (0–0.2 mg/dm^2) was used. This is because the same solvent is frequently used as both a comonomer and a solvent for the resin.

(c) In some cases, data gaps could be filled through extrapolation. If companies had, for example, extraction or migration data for some acrylics but not for others, then those data were extrapolated across to the other acrylics for which data were lacking. As many acrylic resins are similar in migration characteristics, this was considered as an acceptable and workable solution as a first approximation to fill data gaps.

It should be kept in mind that if migration or extraction data are subsequently found for a substance for which only SML-derived data were used, then FACET can be run by entering the actual concentration found.

Types of Light Metal Packaging

There are a number of different types of metal packaging for foodstuffs,[1] including:

1. Beverage cans
2. Food cans with and/or without an easy-open end
   a. Three-piece cans
   b. Drawn and wall-ironed (DWI) food cans (two piece)
   c. Drawn and redrawn (DRD) cans (two piece)
3. Aerosols
   a. Three piece
   b. Two piece (monobloc)
4. Tins, with a slip-on reusable lid, for biscuits, sweets, etc.
5. Metal closures for jars and bottles
   a. Vacuum closures used on jars
   b. Crown closures used on bottles
   c. Roll-on pilfer-proof (ROPP) closures, used on spirit bottles
6. Can ends
   a. Classic ends
   b. Easy-open ends
   c. Domes and cones (aerosols only)

It should be noted that although collapsible metal tubes (e.g., for tomato paste) can be coated

Table 2—Allocation of Metal Packaging to Different Types of Cans[a] (Main Pack Type) at FACET Food Code Tier 3

FACET Food Code at Tier 3	Bev	Aero	Tin	3-piece food	DWI food	DRD food
P.01.1.2 Flavoured milk drinks	100%					
P.01.1.3 Drinking yoghurt	100%					
P.01.1.6 Condensed/evaporated milk				100%		
P.01.1.7 Powdered milk			100%			
P.01.1.8 Cream		100%				
P.01.2.2 Unprocessed cheese				100%		
P.02.1.1 Butter				100%		
P.02.2.1 Olive oil				100%		
P.02.2.2 Vegetable and seed oil		see text		see text		
P.03.2.2 Fruit, nut, trailmixes			60%	40%		
P.03.2.3 Jams and fruit preserves				100%		
P.03.2.4 Canned/preserved fruit				95%	5%	
P.03.4.1 Nut-based spreads				100%		
P.04.2.1 Preserved vegetables no sauces				100%		
P.04.2.2 Canned/preserved tomatoes				100%		
P.04.2.3 Canned beans and pulses				90%	10%	
P.04.2.4 Tomato paste/purees				50%		50%
P.04.2.5 Pasta sauces (tomato-based)				90%	10%	
P.04.2.6 Pickled vegetables				90%		10%
P.05.1.1 Sugar confectionery			100%			
P.05.2.4 Boxed chocolates			100%			
P.05.2.5 Seasonal chocolate			100%			
P.07.2.1 Bread				100%		
P.07.3.1 Sweet biscuits			100%			
P.07.4.3 Cakes			100%			
P.08.2.1 Processed meat and products				50%		50%
P.08.2.3 Preserved meat and products				70%		30%
P.09.2.4 Preserved fish/seafood no sauce				20%		80%
P.11.2.1 Honey				100%		
P.11.2.2 Ice cream toppings, etc.				100%		
P.12.1.05 Mustard				100%		
P.12.1.09 Pasta sauces				90%	10%	
P.12.1.10 Wet sauces				90%	10%	
P.12.1.11 Dips						100%
P.12.1.14 Bouillon/stock cubes, etc.			100%			
P.12.2.4 Canned/preserved soup				90%	10%	
P.12.3.1 Herbs and spices			100%			
P.12.4.1 Yeast			100%			
P.13.1.1 Infant milk formula				100%		
P.13.1.2 Dried baby food			100%			
P.13.2.1 Prepared baby food				100%		
P.13.2.2 Other baby food			100%			
P.13.3.1 Other nutritional foodstuffs				100%		
P.14.1.2 Packaged water	100%					
P.14.2.1 Carbonates	100%					
P.14.2.2 Juices	100%					
P.14.2.3 Functional drinks	100%					
P.14.2.4 Liquid concentrates				100%		
P.14.2.5 Powder concentrates (cold)			100%			
P.14.2.6 Ready-to-drink prepacked coffee	100%					
P.14.2.7 Ready-to-drink prepacked tea	100%					
P.14.3.1 Dry coffee			100%			
P.14.3.2 Dry tea			100%			
P.14.3.3 Other hot drinks powders			100%			
P.15.1.1 Beer	100%					
P.15.1.2 Cider	100%					
P.15.1.3 Flavoured Alcoholic Beverages	100%					
P.15.2.1 Wine	100%					
P.15.3.1 Spirits	100%					
P.16.1.1 Savoury biscuits and crackers			100%			
P.18.4.2 Canned/preserved pasta				90%	10%	
P.18.5.06 Canned/preserved ready meals				80%	10%	10%
P.18.5.07 Preserved fish/seafood + sauce				20%		80%

(a) Bev = beverage can (two-piece); Aero = aerosol can; Tin = metal containers with a slip-on reusable lid; three-piece can; DWI = drawn and wall-ironed food can (two piece); DRD = drawn and redrawn cans (two piece).

metal food packaging, the suppliers are not members of EMPAC or JIG and are not organized in a way that enabled collection of relevant data. As such, details have not been included here. The coating companies, however, do supply coatings for tubes. The usage of tubes has been extracted from the Euromonitor data. In Oldring et al.,[5] the use of collapsible metal tubes for different foodstuffs for the UK, derived from Euromonitor data, is given as an example of packaging use factors.

In *Table* 2, the different types of food and beverage cans are given, per FACET food category, along with an approximate market split for the can share. In addition, some foodstuffs are packaged in glass or plastic jars or bottles with metal closures (lids) and not cans. In these instances, the closures are not shown in *Table* 2. Where foodstuffs could be packaged in cans and/or jars/bottles, only the split of the cans is shown. It should be noted that some foodstuffs could be packaged in cans in one country and in jars in another, or even in nonmetal. The data in *Table* 2 represents a high level view of the European can usage market. The actual usage will be country- and foodstuff-specific, so there will be differences when comparing these data with those used in a worked example for assessing the exposure to BPA from light metal packaging.[5] *Table* 2 lists 63 FACET Tier-3 food categories from the total of 174. The other FACET Tier-3 food categories are not packaged to any appreciable amount in cans. Foodstuffs packaged in glass with a metal closure are considered separately.

Beverage Cans

All beverage cans (BEV CAN), except 3–5 litre beer keg cans, are manufactured the same way. A disk of metal [either aluminum or steel (ETP)] is forced through a series of dies of slightly differing (reducing) diameters to form a can with one end being an integral part of the can. The can is washed and coating is then sprayed onto the inside of the can. The coatings for both steel and aluminum beverage can bodies are similar, and, as of 2012, both are currently epoxy acrylate-based, although there can be differences in additives and crosslinkers. An easy-open end is seamed onto the can after filling. Sealants are used for seaming the end onto the body. Beer kegs are essentially three-piece cans with a novel system to enable discharge of their contents.

Food Cans

Food cans (FOOD) are divided into three-piece, DWI, and DRD, which reflects the methods of manufacture. Food cans have been split to reflect their respective shares of the different types per FACET food category.

A three-piece can has a precoated body which is rolled from flat coated sheet, welded together, and then coated with a side seam stripe. This coating is generally substantially chemically different from other coatings used and undergoes a different cure schedule. One end is a "classic" end, pressed from precoated sheet. An end (either a classic or an EOE) is seamed onto the can body, which is then shipped to the filler. To the "open" end of the can, an end is seamed on after filling with the foodstuff.

A DWI food can is made in a similar manner to a beverage can. The can is filled and either a classic or EOE is then seamed on.

DRD cans are made from a disk of metal which has the coating applied. The plug is then deformed into a can by the use of a tool in a press. Shallow drawn cans have one pass, whereas redrawn cans have two passes. One end is an integral part of the can. The can is filled and either a classic or EOE is seamed on.

Aerosols

Aerosols (AEROSOLS) are mainly used for cream or ice cream toppings and dessert sauces (FACET packaging codes P.01.1.8 and P.11.2.2). Although Euromonitor recorded vegetable and seed oil (P02.2.2) as being packaged in aerosols, none was reported as being consumed, because these aerosols are designed for spraying onto cooking equipment such as griddles. It is believed that the consumption of oils from aerosols was not recorded in the consumption diaries. Aerosols are either two- or three-piece. A dome (containing nozzle and valve) is seamed onto the open end of the aerosol. As a first approximation, the coatings for the dome are independent of whether it is a two- or three-piece aerosol. The three-piece aerosol is made (from ETP) in a similar manner to a three-piece can, with the body being rolled from precoated metal. The two-piece aerosol is made from a disk of metal (aluminum) being extruded into a can. This is then washed and the coating spray applied. In both cases, the dome and cone are formed from precoated metal and attached after filling. It should be noted that in *Table* 2, all aerosols were allocated as 250 g with a split of 90% steel (three piece) and 10% aluminum monobloc. These in turn had their coating chemistries allocated.

Can Ends

Food and beverage can ends are prepared from coated metal, either as a sheet or a coil. Classic ends are punched out from the coated sheet in a single operation. Easy-open end manufacture is more complex, involving a number of forming processes on either coated sheet or coil. Due to numerous and severe processing and deformations, it is necessary for the coating to be significantly more flexible than one used for a classic end. Euromonitor recorded the type of end used for opening by the consumer, by food can per food type, and these data were the basis for use in the FACET model. The split between classic and EOE for the different foodstuff categories (at Tier 2) are given in *Table* 3. As Euromonitor data contain information on the ends of food cans, the industry data were only used to fill data gaps. However, these data were for 2005 and since then there has been a significant increase in the number of easy-open ends compared to classic ones. Also, a new type of end—easy peel—was new on the market and this has seen a growth in numbers used. Easy peel (coated aluminum foil) ends are not considered in this round of data collection as the number is insignificant compared to the other two types of end.

Table 3—Distribution of Easy-Open Ends and Classic Ends by FACET Food Category (Tier 2)

FACET-Type of Ends for FOOD CANS				
FACET Food Code	**Product**	**EOE**	**Classic Ends**	**Peel-off Ends**
P.03.2	Processed Fruit	20%	80%	
P.04.2	Processed Vegetables	51%	49%	
P.08.2	Processed Meat	37%	63%	
P.09.2	Processed Fish	53%	45%	2%
P.12.1	Sauces	82%	18%	
P.12.2	Soup	57%	43%	
P.18.5	Ready Meals	66%	32%	2%
	Overall total split	53%	46%	1%

Domes and cones for aerosols require a flexible coating and are manufactured in a unique manner. The coating is normally an organosol or laminate.

Tins or Tin Boxes

The uses for different tins (TIN) are also summarized in *Table* 2. Since many tins are unlacquered and frequently there is not direct contact between the surface of the tin and its contents, any migration from any coatings was considered negligible based on expert judgement, particularly as the contact is mainly for dry foodstuffs and no heat processing of the contents is involved. In the event of a coating or other migrant being found in a foodstuff packaged in a tin, its concentration can be entered into the FACET model and resultant exposure estimated.

Closures

There are three different types of closure used for jars and bottles, namely, vacuum closures, crowns, and ROPPs. Vacuum closures are further subdivided into PT (press twist) and TWO (twist off),

Table 4—Different Size Vacuum Closures Areas (Averages for Each Range) and Their Market Shares per FACET Food Category (Mainly Tier 2)

A. Closure Areas

Closure Description	30-38 mm TO	43-48 mm TO	51 mm PT	53-58 mm TO	63-66 mm TO	70-77 mm TO	80-100 mm TO
Plastisol gasket exposed (mg)	90	135	125	155	200	230	285
Plastisol gasket exposed (cm^2)	1.6	2.0	1.6	2.6	3.0	3.5	4.2
Exposed coating surface (dm^2)	0.057	0.123	0.177	0.213	0.293	0.386	0.589
Coating SA:V (dm^2/litre) Lowest Typical Highest	0.057 0.143 0.345	0.154 0.308 0.572	0.885 1.383 2.213	0.367 0.710 1.158	0.241 0.733 1.526	0.480 0.965 3.271	0.248 1.473 1.785

B. Market Shares

Closure Description		30-38 mm TO	43-48 mm TO	51 mm PT	53-58 mm TO	63-66 mm TO	70-77 mm TO	80-100 mm TO
Food Code	**Food type**	% share	% share	% share	% share	% share	% share	% share
P.01.1	Dairy	60%	10%		10%	10%	10%	
P.03.2.(3&4)	Processed fruit		10%		20%		35%	35%
P.04.2.(1-5)	Processed vegetables				10%	30%	30%	30%
P.04.2.6	Pickled vegetables					20%	40%	40%
P.08.2.3	Processed meat			10%	10%	50%	15%	15%
P.09.2.(4&5)	Processed fish			5%		35%	35%	25%
P.11.2.1	Honey		10%		10%	10%	60%	10%
P.12.1.(1-8 & 10-12)	Sauces and cook-in sauces	60%			20%	10%	10%	
P.12.1.09	Pasta sauces				10%	80%	5%	5%
P.13.2.(1&2)	Baby food			95%		2.5%	2.5%	
P.14.2	Juices and drinks	40%	60%					
P.17.1	Yoghurt and desserts	100%						
P.18.5.(06&07)	Ready Meals					40%	30%	30%

A summary of vacuum closures is given in *Table* 4, along with the different diameters and market shares for different FACET food categories. CEPE supplied Creme with composition and extraction data for the coatings used for closures. EMPAC supplied Creme with substances used in, and migration data for, the sealing gaskets on the vacuum closures.

Unlike most of the light metal packaging data for potential concentrations of migrants in foodstuff, migration will be modeled for crowns and ROPPs, since both have a polymeric liner between the coated metal and the contents of the bottle.

Crowns are the traditional metal closures for bottles that are removed by a bottle opener.

ROPPs' aluminum closures have a liner (wad) between the coated metal and the contents of the bottle.

Can-End Sealants

Can bodies are double seamed with the end(s). In Oldring and Nehring,[1] a double seam is shown diagrammatically. Can-end sealants are used to seal the ends onto beverage and food cans, because a hermetic seal cannot be achieved by metal-to-metal contact. Aerosols also use sealants. Different sealants are used for different applications. There have been major issues collecting any data on sealant composition and extraction/migration. However, since the surface area in contact with the foodstuff is minimal, as a default the contribution is considered to be negligible. In the event of a substance originating from a sealant being found in the foodstuffs, then the concentration can be entered into the FACET model and exposure estimated.

FACET Codes for Light Metal Food Packaging

All pack-type combinations for food packaging were allocated a pack-type (PT) code for use with Euromonitor data and in the FACET software. Creme linked the information supplied by industry into a pack-type (PT coding system) for all the combinations, but it should be considered that in practice not all combinations of main pack and closure would exist (e.g., a beverage can will not have a roll-on closure (ROPP)—PT9). These have not been

Table 5—Beverage Can Sizes and Rationalization of Sizes

Commercial Can Volume (ml)	Allocated "Standard" (ml)	Surface Area/ Volume dm^2/litre	Market Share (%)
125 & 150	150	12.6	1.13
200	200	11.5	0.25
240 & 250	250	10.7	8.16
275, 284, 296 & 300	275	10.4	0.16
325, 330, 340, 345, 350, 355 & 375	330	9.7	55.9
420, 450, 470 & 473	440	8.8	6.8
485, 500, 530 & 550	500	8.5	27.5
690, 700 & 1000	1000	6.7	0.02
3000, 4000, 5000 & 6000	5000 (3-piece beer keg)	3.9	0.12

removed, in case packaging innovation produces "new" types of pack combinations. Since 2005, easy-peel ends for food cans (PT 28) have started to make inroads into the traditional types of food can packaging. When imports were examined, as part of the project to learn more about packaging of imported foodstuffs in light metal packaging, only two easy-peel ends were found. Those PT codes relevant to light metal packaging are (PT=pack type; M=main—the major part of the packaging in contact with the foodstuffs; C=Closure—seal for main, not always applicable); PT1–M: Aerosol can; PT3–M: Aerosol can, C: Plastic Other; PT8–M: Beverage Can; PT20–M: Food Can, C: Classic; PT21–M: Food Can, C: Easy Open; PT35–M: Glass Bottle, C: Metal Twist/Lever; PT41–M: Glass Jar, C: Metal Twist/ Lever; PT48–M: Metal Collapsible Tube, C: Plastic screw thread, although PT48 was outside the scope of TSC 30. Although no data were collected from the tube industry for PT48, Euromonitor data were used for allocating packaging.

Surface Area/Mass Ratios of Light Metal Packaging

Unfortunately, food consumption diaries do not discriminate between pack sizes, but rather only the amount of food consumed is recorded. To utilize extraction and/or migration data as well as concentrations obtained by migration modeling, it is necessary to relate the amounts in mg/dm^2 into mg/kg of foodstuff using actual contact areas. Euromonitor data record the size of the different pack sizes as cm^2/g foodstuff. Because light metal packaging is rigid, it is possible to calculate surface areas from can sizes. The light metal packaging industry also supplied information on surface-area-to-mass ratios for different sizes, to fill any data gaps. It should be borne in mind that a different coating is sometimes used on the ends than on the bodies of three-piece cans. For EOE, this is normally the case. Therefore, it is important to know the surface area of the different components of cans and aerosols.

Beverage Cans

Beverage cans come in a wide range of sizes, as shown in *Table* 5. For convenience, the sizes have been grouped as in *Table* 5 to reflect the major sizes found along with their percentage split.

The surface areas for the different can sizes have been calculated from their diameters and heights. This gives a total surface area in contact with the beverage. These data are shown in *Table* 5. The EOE for beverages has a completely different coating from that used for the body. Thus, the area of the end was subtracted from the total can surface area using the following rule for retail beverage cans (airline cans were not included in the Euromonitor data): for volumes ≤ 250 ml, the area of the end was 0.203 dm^2 and for volumes > 250 ml, the area of the end was 0.229 dm^2. The reason for using only two diameter ends is that for most beverage cans the diameter of the top is reduced ("necked") so that the same size end will fit different sized can bodies.

Large beverage beer keg cans were not included in this exercise for three reasons. First, the surface-area-to-mass ratio is significantly smaller than that of any of the other beverage cans. Second, their share of the beverage market is insignificant, being about 0.12% (see *Table* 5). Last, since these cans use a similar coating chemistry for the food contact layer to the DWI cans, the omission of the beer keg cans gives a more conservative estimate of the exposure to migrants from beverage cans, because the "missing" 0.12% is reallocated to smaller beverage cans.

The splits for the different types of chemistry for beverage can bodies and ends are given in *Table* 6.

Food Cans

Allocations of pack type and technology against food type as per FACET code Tier 3 are given in *Table* 2. Only three-piece cans have a side seam

Table 6—Types of Coating Used for Food and Beverage Cans and Their Market Shares

	Epoxy Phenolic	Epoxy Anhydride	Epoxy Amino	Polyester Phenolic	Polyester Polyurethane	PVC Organosol	Epoxy Acrylate Beverage
FACET Material Code	37.1.1	37.1.2	37.1.3.1 37.1.3.2	37.3.1	37.3.3	37.2	37.1.4.1
Beverage Cans							
Beverage bodies							100%
Beverage EOE			45%	5%		5%	45%
Food Cans							
3-piece body	60%	39%			1%		
Side stripe	60%		3%	10%		27%	
NEO	60%	22%		14%	1%	3%	
EOE food	37%	5%		10%	18%	30%	
Drawn/DRD	54%			3%	10%	33%	

and a side-seam coating. For simplification, the area allocated to the side-seam coating per can size was 7.5% of the total can area. For the refined deterministic approach used for assessing the exposure to BPA from light metal packaging,[5] 10% of the total can area was taken as being the area of the side seam. This did not affect any of the results, because the assumption used was that the body and side-seam stripe were both coated with epoxy phenolic coatings, which tend to give higher levels of extractable BPA than many others. The area of the side-seam stripe was subtracted from the total can area and the relevant coating chemistries allocated in FACET. The splits between classic and easy-open ends of all cans are given in *Table* 3. For any can ≥ 1 kg, only classic ends would be used. The EOE areas for food cans were apportioned as follows:

- Can size ≤ 300 g—65 mm dia end EOE
- Can size 301 to 500 g—73 mm dia end EOE
- Can size 501 to 1000 g—83 mm dia end EOE

For fish cans, a different rule was used.

- For fish can sizes ≤ 200 g, a can body area of 10 dm^2/kg and an end area of 6 dm^2/kg were used. All ends were considered as EOEs.
- For fish cans >200 g, the rules for food cans were applied.

It was assumed that the coating chemistries on the classic ends were the same as those on the can body for three-piece cans. For EOE and can bodies, the types of different coating chemistries were allocated according to the splits given in *Table* 6.

Due to the lack of data in the Euromonitor report about the specific shapes of cans and the lack of data in the consumption diaries about whether the food consumed was canned and whether it was in a cylindrical or rectangular can, those with unusual shapes, such as some meat pie and pudding cans, have been treated as if they were standard food cans. The amount of these cans used is small compared to the overall number of cans.

Aerosols

Table 7 contains the S/V ratios for aerosol cans used for foodstuffs. The area of the end is included.

Closures

In *Table* 4, the areas for the different diameter vacuum closures averaged across the size range split are given. The same diameter vacuum closure can be used on different sizes (weight) of jars or bottles. Therefore, for each diameter, a range is given of dm^2/kg-filled goods according to their most likely contents. Also given are the weight and area exposed of the plastisol (gasket). The migration/extraction data were supplied to Creme by closure and gasket manufacturers. Closures have a two-coat coating system, which has its own separate FACET material code—37.5.2. Data on composition and extractables were supplied to Creme by CEPE.

Of the 80 billion crowns used per year in the EU, beer accounts for 80% (64 billion) and carbonated/still drinks, juices, and water for the other 20% (16 billion). For crowns, the gasket area in contact per bottle is 5.0 cm^2. The following shows market shares for the different gasket materials by their FACET material codes (P): P06.2 LDPE—75%; P16.1 PVC plastisol—17%; and P16.2 PVC granulate—8%. For migration modeling, the typical gasket weight for LDPE is 190 mg, and for PVC it is 220 mg. The average gasket thickness for LDPE is 0.4 mm, and for PVC it is 0.31 mm.

ROPPs find applications for spirits primarily 30 mm diameter; wine which are mainly 30 mm but sometimes also 20 mm (travel pack) in diameter; and others which include water, juices, and oil with various diameters (20, 24, 30, 31.5, 38, and 48 mm). Three materials are used for the "wads" in ROPPs and these, along with their market shares, are P06.2 LDPE—45%; P13.0 PET—50%; and P16.2 PVC plastisol—5%. For FACET, it was assumed that all the liners were 30 mm in diameter and had a thickness of 0.03 mm. However, no information on any materials between the liner and the coated metal was supplied.

Uncertainties in the Data Collected and Submitted

The output of the FACET tool is accompanied by an extensive treatment and statement of uncertainties. There were a limited number of large multinational coating and can-making companies involved in the data collection, which could result in questions about the representativeness of the data collected. The main uncertainties identified were: market shares of different can types for a given foodstuff; the surface-area-to-mass ratios (i.e., size of can/jar/bottle) of the packaging of the foodstuffs consumed; the use of different coatings for the same type of can for the same foodstuff; different substances being present for the same generic coating and their market shares; and the use of simulant/extraction data rather than migration data. Upon consideration, it was concluded that most of these uncertainties will average out for major food commodities (uncertainty ca. ±20%), but for niche products, the effects could be greater (±50%).

Many of these uncertainties are ameliorated or even nullified if the loyalty flag is set when running the estimate of exposure using FACET. Packaging loyalty is explained in Oldring et al.[4] In brief, this means that, notwithstanding market shares, if the probabilistic model "decides" on the first eating occasion that the food item (or group) is packaged in metal with a particular size and coating chemistry and extraction value, etc. (for the chemical of interest), then all subsequent consumptions of that food item (group) by that individual would be taken to be have the same assumptions also. This has the effect of bypassing any figures on market shares and assuming 100% use.

Verification

As part of work to explore the impact of the uncertainties described previously and as part of verification of the FACET tool, the data collected and described here for light metal packaging were used to estimate consumer exposure to the chemical bisphenol A (BPA). After that work was completed, described fully by Oldring et al.,[5] the European Food Safety Authority (EFSA) published a new estimate of exposure to BPA[12] and it was of interest to compare the two estimates.

Table 7—S/V Ratios for Aerosol Cans

Volume or Weight (ml or g)	S/V Ratio dm²/L
200	11
250	11
400	9
495	8
500	8

There were methodological differences in the two approaches. For example, EFSA used a deterministic approach, whereas FACET uses a probabilistic approach. Also, EFSA used extensive concentration data of BPA in foods, following an EU-wide call for occurrence data, whereas FACET used simple solvent/simulant extraction values for the different coating chemistries. EFSA also estimated exposure for EU member states separately and took the highest country forward, whereas for this exercise the FACET tool was run using UK Food Consumption Survey data only.

For EFSA, the highest mean and the highest 95th percentile among all EU countries, for the three groups (1) men aged 18–45; (2) women aged 18–45; and (3) other adults aged 45–65, were in the range 126 to 132 ng/kg bw/day for average exposure and were 335 to 388 ng/kg bw/day for high (95th percentile) exposure. EFSA found that canned products dominated in all surveys, with the percentage contribution to BPA from canned foods mainly ranging between 75–90%. [12]

For the comparable results from FACET (for UK adults aged 19–64 years), the estimates of exposure for the population mean, the 90th, and the 97.5th percentile were 130, 290, and 590 ng/kg bw/day dietary exposure to BPA from light metal packaging.[5] The close agreement between the (conservative) estimate from FACET and the (conservative) estimates by EFSA, at the mean and also at high percentiles, is satisfactory.

CONCLUSIONS

In this work, we collected pan-European statistics describing the use of light-metal packaging used in contact with food and beverages. This was done to provide databases necessary for estimating exposure to chemicals that can migrate from the coatings using metal packaging. The data collection encompassed the approximately 45 billion beverage cans, 20 billion food cans, and 100 billion closures used in Europe per year. The types (sizes, shapes, and construction methods) of the packaging used for the 63 different food categories packaged in cans has been described along with the type of coating used on the food contact surface of the metal. For closures, the food categories tended to be at a higher level (Tier 2), due to the same type of closure being used for many similar (at Tier 3) food categories. Furthermore, the chemical substances used to make each type of coating have been listed, along with area-related extraction levels and a conservative estimate of migration levels that could occur. This body of data has been incorporated, encrypted, into the FACET tool so that it can be combined with national food consumption statistics for a probabilistic estimate of consumer exposure at the level of 95th (or whatever is required) percentile of individuals in EU member states. In addition to the databases—possibly more importantly—the methodology used for the data collection has been established as tools for the future updating that will inevitably be required. This represents a remarkable achievement by the Joint Industry Group of what was previously considered impossible—to gather such commercially sensitive data in a confidential way.

ACKNOWLEDGMENTS

Development of the FACET exposure tool was co-funded by the European Union under Grant Agreement 211686 (Project FACET: Flavours, Additives and food Contact material Exposure Tool), by a consortium of 12 packaging trade associations, and with top-up funds (to Fera) from the UK Food Standards Agency. The findings and the conclusions in this article are the responsibility of the authors alone and they should not be taken to represent the opinion of the funding bodies. The cooperation of the members of the light metal industry task force (TSC 30) and the FACET Industry Group enabled this work to take place. CT

References

1. Oldring, P.K.T. and Nehring, U., *Packaging Materials: 7. Metal Packaging for Foodstuffs,* ILSI Monograph, www.ilsi.org.ar/biblioteca/ILSI_Europa_Monografias/PM7Report%5B1%5D.pdf; 2007.
2. Hearty, A., Gibney, M.J., Vin, K., Leclercq, C., Castle, L., Mahony, C., Oldring, P.K.T., Volatier, J.L., McKevitt, A., Tennant, D., McAmara, C., and Kettlitz, B., "The FACET Project: A Chemical Exposure Surveillance System for Europe," *Food Science and Technol.*, 25, 26-29 (2011).
3. Oldring, P.K.T., Castle, L., and Franz, R., "Exposure to Substances from Food Contact Materials and an Introduction to the FACET Project," *Deutsche Lebensmittel-Rundschau*, 105, 501-507 (2009).
4. Oldring, P.K.T., O'Mahony, C., Dixon, J., Vints, M.J., Meghan, J., Dequatre, C. and Castle, L. "Development of a new modelling tool (FACET) to assess exposure to chemical migrants from food packaging." *Food Addit. Contam., Part A,* 2014, in press. DOI: 10.1080/19440049.2013.862348.
5. Oldring, P.K.T., Castle, L., O'Mahony, C. and Dixon, J. "Estimates of dietary exposure to bisphenol A (BPA) from light metal packaging, using food consumption and packaging usage data: a refined deterministic approach and a fully probabilistic (FACET) approach." *Food Addit. Contam., Part A,* 2014, in press. DOI: 10.1080/19440049.2013.860240.
6. Gibney, M.J. and van der Voet, H., "Introduction to the Monte Carlo Project and the Approach to the Validation of Probabilistic Models of Dietary Exposure to Selected Food Chemicals." *Food Addit. Contam.,* 20 (suppl. 1): S1-S7 (2003).
7. Holmes, M. J., Hart, A., Northing, P., Oldring, P.K.T., Castle, L., Stott, D., Smith, G., and Wardman, O., "Dietary Exposure to Chemical Migrants from Food Contact Materials: A Probabilistic Approach," *Food Addit. Contam.*, 22, 907-919 (2005).
8. Leclercq, C., Arcella, D., Ledonne, C., Piccinelli, R., Sette, S., and Soggiu, M.E., "Stochastic Modelling of Human Exposure to Food Chemicals and Nutrients within the Monte Carlo Project. An Exploration of the Influence of Brand Loyalty and Market Share on Intake Estimates of Intense Sweeteners from Sugar-Free Soft Drinks Performed," *Toxicology* 45 *Letters,* 11:443-457 (2003).
9. Petersen, B.J., "Probabilistic Modelling: Theory and Practice, *Food Addit. Contam.,*17, 591-599 (2000).
10. Slob, W., "Probabilistic Dietary Exposure Assessment Taking into Account Variability in Both Amount and Frequency of Consumption," *Food and Chemical Toxicology,* 44, 933-951 (2006).
11. CoE 2009 - Framework Resolution RESAP (2004)1 on Coatings Intended to Come Into Contact with Foodstuffs - Version 3 - 12 February 2009, www.cepe.org/EPUB/easnet.dll/ExecReq/Page?eas:template_im=100087&eas:dat_im=05043D.
12. EFSA 2013. Draft Scientific Opinion on the Risks to Public Health Related to the Presence of Bisphenol A (BPA) in Foodstuffs–Part: Exposure Assessment. Endorsed for public consultation, www.efsa.europa.eu/en/consultationsclosed/call/130725.pdf.

AUTHORS

P.K.T. Oldring, Valspar Corporation, Avenue 1, Station Lane, Witney, Oxfordshire OX28 4XR, UK (peter.oldring@valspareurope.com; **F. Savrij Droste**, Ardagh Metal Packaging (formerly Impress Group B.V.), Zutphenseweg 51, 7418 AH Deventer, The Netherlands; **R. Whitaker**, Crown Cork & Seal, Downsview Road, Wantage, Oxfordshire, OX12 9BP, UK; **D. Smith**, MPMA Ltd., The Stables, Tintagel Farm, Sandhurst Road, Wokingham, Berkshire RG40 3JD, UK; **C. O'Mahony**, Creme Global, The Tower, Trinity Technology and Enterprise Campus, Grand Canal Quay, Dublin 2 (Ireland); and **L. Castle**, The Food and Environment Research Agency, York, YO41 1LZ, UK.