Chemical migration from packaging into foods and beverages: A framework to evaluate different packaging options

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1. Introduction

Packaging plays an important role in the production, processing, transporting, and storing of foods and beverages. Packaging also enables the current global food system, prevents food from spoilage, and increases convenience for the consumer. However, packaging for food and beverage is generally used only for short periods of time and then quickly turns into waste that is an increasing global environmental burden. In addition, many chemicals that are present in the packaging may be transferred into the food while the food is in contact with the packaging. This process is called *chemical migration*. As some of the migrating chemicals are known to be toxic, they can have detrimental effects on human and environmental health (when packaging is littered or landfilled or composted) (Muncke et al. 2020).

The process of chemical migration depends on the type of packaging, the packaged foods and beverages, and the conditions of use. Given the multiple factors that need to be considered, choosing sustainable and safe packaging is challenging and requires careful investigation. Therefore, this choice needs to be supported by transparent and scientific criteria that simplify and enable decision-making.

Here, we describe an approach that allows for the comparison of different packaging options in terms of chemical migration potential for seven different food types. This approach was developed within a revision of the Packaging Fact Sheets ("Verpackungsmerkblätter") published by the *Association of the Swiss Organic Agriculture Organisations* (*Bio Suisse*).

Besides addressing the migration potential, these fact sheets also provide scorings for five other categories:

- product protection,
- consumer acceptance,
- handling & additional use,
- waste & recycling, and
- environmental impact.

Taken together, the Packaging Fact Sheets inform about sustainability and safety aspects of common food packaging options and are aimed at members and licensees of Bio Suisse.

2. Background

Chemical migration from packaging into foods and beverages is a complex process that is firstly influenced by the food contact material (FCM) used (Figure 1). Depending on the FCM, the number and concentrations of migrating chemicals can vary significantly: Whereas plastics and paper & board release many different and often high amounts of chemicals, materials such as glass and stainless steel are almost inert and very few chemicals transfer at low levels. The migration from multi-material packaging (e.g., beverage cartons) and coated metal packaging depends, among other factors, on the composition of the layer contacting the food. In some cases, the migration can be reduced by including an internal barrier layer that stops the transfer of chemicals from outer material layers into the food.

To understand chemical migration, it is a prerequisite to know the type of FCM(s) from which the food packaging is made. However, even if the material types are identified, their exact chemical compositions still often remain unknown because there is almost an endless set of combinations of raw materials, additives, and processing approaches that can be used to produce FCMs (Groh et al., 2021; Grob et al. 2006). Manufacturers often treat the exact compositions of FCMs they produce as propriety information and do not share it with downstream users.

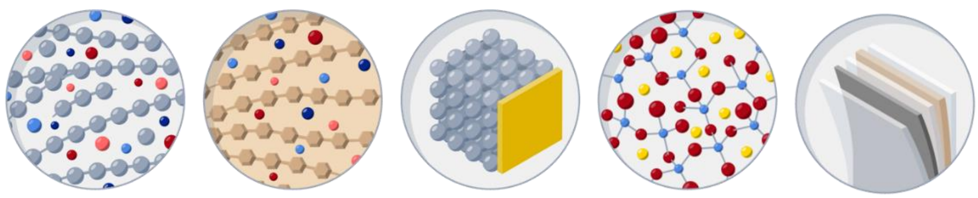

Figure 1. Schematic illustration of five commonly used food contact materials (FCMs). From left to right: Plastics, paper & board, coated metal, glass, and multi-materials.

Secondly, the type of foods and beverages has an impact on the chemical migration from the packaging (Figure 2). A high fat content, for example, increases the transfer of fat-soluble chemicals from the packaging into the food. Similarly, acidic foods and beverages can also raise the migration levels of certain chemicals. Additionally, it makes a difference whether solid or liquid foods are in contact with the packaging. When migration into solid foods occurs, the chemicals are mainly measured in the portion of the foods that is in close distance to the packaging, whereas chemicals are more evenly distributed in liquid foods and can therefore reach higher overall concentrations over time.

Figure 2. Examples of packaging for fatty and acidic foods.

Thirdly, high storage temperatures and long contact times increase the migration rates and final concentrations of chemicals (Figure 3). Furthermore, the surface-to-volume ratio between the packaging (surface) and the food (volume) influences the migration behavior. This means that a small packaging item releases relatively higher amounts per unit of food because the surface-to-volume ratio is higher in smaller sized packaging, and therefore the migration is proportionally greater than packaging with larger volumes.

Figure 3. Temperature, time, and relative packaging size influence migration.

In conclusion, to understand chemical migration from packaging into food, ideally information should be available on:

- the detailed chemical composition of the packaging,
- the food type (fatty, acidic, aqueous, emulsion, etc.), and
- the conditions of use of the packaging (temperature, storage time, filling conditions, in-packaging treatment, etc.).

Since this information is often not available, there is a strong need for a general scoring scheme that supports choosing a packaging that has low migration and does not release hazardous chemicals into the food and beverages.

3. Methodology: Three Scoring Approaches

The evaluation of different food packaging items was carried out using the information on food contact chemicals (FCCs) from two databases compiled by the Food Packaging Forum:

1. the FCCmigex is a database on migrating and extractable food contact chemicals and is based on empirical evidence (i.e. chemicals measured in FCMs) (Geueke et al. 2022)
2. the FCCdb is an overview of chemicals that are likely used in the manufacture of FCMs worldwide, based on lists of government-authorized chemicals and industry inventories (Groh et al. 2021).

In addition to these two databases, the results of an expert survey and generally applicable factors that influence migration of chemicals from packaging into food were incorporated. Since packaging often consists of very complex materials (e.g. multilayer plastics that are coated and printed, with labels applied using adhesives, etc.), simplified assumptions had to be made. No individual measurements of the available samples were integrated. We are therefore aware that in some cases the evaluation may not accurately represent the reality of a specific food packaging article, but instead it may rather reflect a worst-case assumption. Depending on future findings, these scores may also change. This precautionary approach helps to both protect public health while also encouraging data generation to fill data gaps for even more accurate assessments in the future.

Due to these data gaps and related uncertainties, we combined three different approaches to evaluating 73 packaging items that are used to pack seven different types of organic foods and beverages (milk, salad, cheese, yogurt, beverages, fresh produce (mainly vegetables), and dry pastries) in Switzerland.

Figure 4. Framework of the three scoring approaches. Each approach contributes 1/3 to the final score. For step 1, the FCCdb and FCCmigex databases compiled by the Food Packaging Forum were used.

For each of the three approaches, the best possible score that can be obtained for a packaging item is 5. A score of 5 would describe a packaging that does not release any chemicals into the packaged foods or beverages. A score of 1 is the lowest possible result and represents packaging with the highest migration potential. The final score is calculated based on the three individual scores that were obtained from the different approaches as described in Figure 4. More details about each of the three scoring approaches are explained in the annex of this report.

4. Results & Discussion

Chemical migration from packaging into foods and beverages is influenced by properties of the packaging material, physico-chemical properties of the packaged foodstuffs, as well as the filling, storage, and use conditions. Ideally, detailed data from all these fields are available to evaluate the chemical safety of a food packaging item that is brought into contact with a specific foodstuff. However, food producers often do not know the exact composition of a packaging article, or packaging manufacturers may not have the information about the type of food that will be stored in the packaging or how the packaging will be used. In addition, the composition of a packaging item can vary strongly between manufacturers or even between individual batches made by the same manufacturer. Because of such variations and knowledge gaps, general recommendations regarding the safest packaging option are difficult to make. In this report, we present an integrated and pragmatic approach that is intended to provide guidance and can help in decision-making in the absence of detailed data. This approach can also support packaging manufacturers to identify opportunities for improving their materials by understanding the key aspects that are relevant for chemical migration, and in addition by highlighting where key data gaps need to be filled.

4.1 Food Contact Chemicals

The 73 packaging items that were rated in this study were used to pack milk, salad, cheese, yogurt, beverages, fresh produce, and dry pastries. In total, the 73 packaging items were assigned to 14 different FCM types (Table 1). For each FCM type, scores were given based on the number of known FCCs and FCCoCs. The numbers of detected FCCs per FCM type varied between 37 and 842 for glass and non-specified plastics, respectively. The scores that were calculated based on these numbers were between 4.8 and 1.0. The numbers of detected FCCoCs per FCM type were in the range of 7 to 83, resulting in scores between 4.7 and 1.0.

Based on these numbers, it is possible to get an idea about the chemical complexity of an FCM: The more FCCs have been detected in migrates and extracts, the greater the chemical complexity is likely to be. In addition, if some of these chemicals have hazardous properties of most concern that make them FCCoCs, it is even more important to avoid FCM types containing such harmful chemicals. However, this approach also has certain limitations: (i) Well-studied materials may obtain a comparably low score because more FCCs and FCCoCs have been found over time and data are available to rule out hazard properties of concern. (ii) Some FCM types are clearly specified while others represent less defined groups, which has an impact on the comparability. (iii) The FCCmigex database does not contain concentrations of FCCs. So, it may happen that an FCM type with a high number of FCCs has a lower overall migration rate than another FCM from which only few FCCs have been detected at high concentrations. Nevertheless, this scoring is based on very recent, comprehensive, and systematically compiled databases that provide the best possible aggregate information on FCCs and FCCoCs available to date.

Table 1. Evaluation of food contact chemicals (FCCs) and food contact chemicals of concern (FCCoCs) per food contact material (FCM) type.

FCM type	Number of packaging items per FCM type	FCCs per FCM type		FCCoCs per FCM type	
		Number of FCCs	Score	Number of FCCoCs	Score
glass	3	37	**4.8**	7	**4.7**
aluminum	2	50	**4.8**	11	**4.5**
steel	1	210	**4.7**	29	**4.5**
wood	1	149	**4.3**	13	**4.4**
unclear/unknown FCM	1*	233	**3.9**	32	**3.5**
other FCM	1	259	**3.8**	22	**3.9**
PS	5	272	**3.7**	44	**2.9**
PET	12	300	**3.6**	40	**3.1**
multilayer plastic	6	455	**2.8**	36	**3.3**
PP	4	467	**2.8**	49	**2.6**
PE	11	583	**2.2**	42	**3.0**
multi-materials	18	614	**2.1**	39	**3.1**
paper & board	3	765	**1.4**	72	**1.5**
plastics, non-specified or other	4	842	**1.0**	83	**1.0**
not applicable	1**	-	-	-	-

*sticking label, material not specified, **natural branding laser could not be assigned to an FCM type

4.2 Expert Opinion

The overall migration potentials of 73 packaging items that were used for the seven different food and beverage categories were rated by ten experts. Experts could choose between five different answers (very low overall migration (OM), low OM, medium OM, high OM, very high OM) that were translated into scores between 1 and 5. These results were visualized as box and whisker plots to display key values (e.g., the mean and the 25% percentile), show the data distribution, and recognize outliers. In many cases, the distribution of the answers covered a broad range, and statistical outliers were identified using the 1.5-fold interquartile range. Therefore, applying the precautionary principle, we always selected a value representing the 25% percentile and included it in the further rating of the food packaging items. Figure 5 shows an exemplary box and whisker plot for the different milk packaging options and the distribution of scores given by the experts.

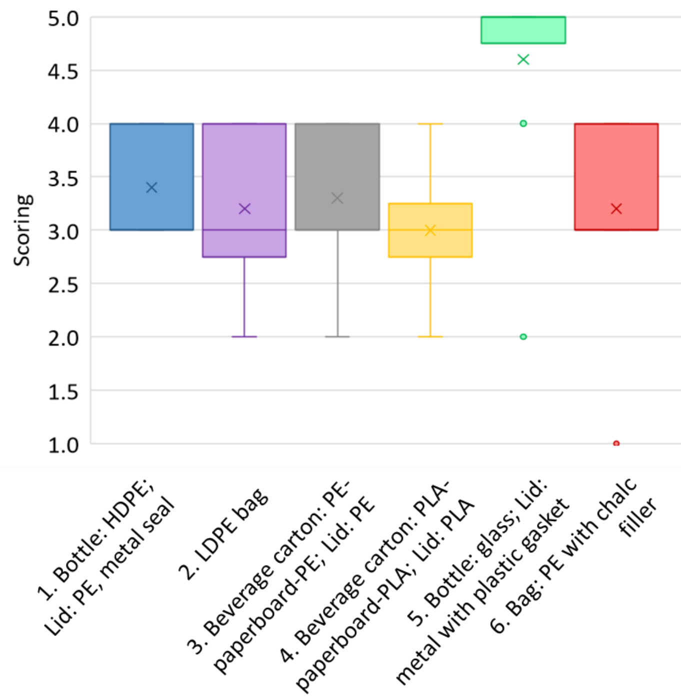

Figure 5. Example results of the expert survey: Scoring of the six different packaging options for milk. The cross symbol denotes the mean value (50%), while the boxes contain the 25th to 75th percentile of the datasets. The whiskers mark the 5th and 95th percentiles, and outliers are marked with dots.

4.3 Food-Packaging Interactions

The type of foods and beverages as well as the storage conditions have a strong influence on the chemical migration from food packaging. In order to map these food-packaging interactions, we developed a matrix that considers important factors of the these interactions (Table 4). In Table 2, these interactions were then mapped based on typical storage conditions, food properties, and packaging sizes for the seven food and beverage types.

Table 2. Typical food packaging interactions for six different food and beverage types.

Food and beverage type	Storage time	Storage temperature	Fat content	Acidity	Contact type	Typical packaging size	Average
Milk	4	4	4	4	2	5	**3.8**
Salad	5	4	5	5	5	3	**4.5**
Cheese	3	4	1	3.5	2.5	2	**2.7**
Yogurt (cups)*	3	4	4	3	3	2	**3.2**
Yogurt (cup lids)*	3	4	4	3	5**	4	**3.8**
Beverages	1	2	5	2	2	4	**2.7**
Fresh produce	5	4	5	5	5	4	**4.7**
Dry pastries	1	2	2	5	4	2.5	**2.8**

* Yogurt cups and lids were analyzed separately because they usually consist of two very different materials.

** The yogurt cup lids got the best possible score for “contact type” because yogurts are typically stored upright, which prevents contact with the lid.

4.4 Overall Evaluation

The scores of the three individual approaches that were explained in the previous sections were used to calculate the final migration score for each of the 73 packaging items. Table 4 shows how this calculation was carried out using six different types of milk packaging as an example. The two scores describing the potential presence of FCCs and FCCoCs in the packaging items each contribute 1/6 to the final migration score, while the expert opinion and food-packaging interactions scores contribute with 1/3 each. The data sets for the other food and beverage types are part of the Packaging Fact Sheets (in German), which are published by the *Association of the Swiss Organic Agriculture Organisations* (*Bio Suisse*).

Table 3. Example of aggregated data of six packaging options for milk. The final scores were calculated based on the numbers of food contact chemicals (FCCs) and food contact chemicals of concern (FCCoCs) per food contact material (FCM), the expert opinion, and typical food-packaging interactions between milk and its packaging.

Milk packaging	**Number of FCCs**	**Number of FCCoCs**	**Expert opinion**	**Food-Packaging Interaction**	**Final Migration Score**
Share of total score	**1/6**	**1/6**	**1/3**	**1/3**	
1. Bottle: HDPE; Lid: PE, metal seal	2.2	3.0	3.0	3.8	**3.0**
2. LDPE bag	2.2	3.0	2.8	3.8	**3.0**
3. Beverage carton: PE-paperboard-PE; Lid: PE	2.1	3.1	3.0	3.8	**3.0**
4. Beverage carton: PLA-paperboard-PLA; Lid: PLA	2.1	3.1	2.8	3.8	**3.0**
5. Bottle: glass; Lid: metal with plastic gasket	4.8	4.7	4.8	3.8	**4.5**
6. Bag: PE with chalc filler	2.2	3.0	3.0	3.8	**3.0**

5. Conclusions

By integrating the most recent, systematic evidence on the presence of food contact chemicals (FCCs) and FCCs of concern (FCCoCs) in food packaging, including implicit scientific knowledge about FCMs, and considering typical food-packaging interactions, we rated 73 food packaging items with respect to their migration potential. The results help decision makers to choose more sustainable and safer food packaging options in the absence of context-specific experimental migration data.

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Abbreviations

FCC	Food contact chemical
FCCoC	Food contact chemical of concern
FCM	Food contact material
FCCmigex	Database on migrating and extractable food contact chemicals
FCCdb	Food contact chemicals database
OM	Overall migration

ANNEX I

Approach 1: Food Contact Chemicals

Share of the total score: 1/3

The chemical complexity of an FCM and the presence of chemicals of concern were estimated based on two databases on FCCdb and FCCmigex as summarized in Section 3 and Figure 4. To develop scoring for the numbers of FCCs and FCCoCs, we asked the following two questions:

- How many food contact chemicals have been detected in migrates/extracts of the food contact material?
- How many of these chemicals are of concern?

First, we analyzed the number of total FCCs that have been detected in the migrates and extracts of specific FCM types. This approach allowed us to draw initial conclusions about the chemical complexity of a material. The recently published Database on Migrating and Extractable Food Contact Chemicals (FCCmigex) was used as a resource (Geueke et al. 2022). The database gives a systematic overview of more than 3000 FCCs that have been measured in migrates and extracts of 28 different FCM types. For each of the 73 food packaging items that were the subject of this evaluation, we assigned one of the 28 predefined FCM types. We then used the FCCmigex to determine how many chemicals have been detected in published scientific literature in migrates and extracts of the respective FCM. The FCM with the highest number of FCCs obtained a score of 1, and a hypothetical FCM without any migrating and extractable FCCs would have received the best score of 5. All other scores were calculated proportionally within this range.

Second, we investigated whether and how many migrating and extractable FCCs have hazardous properties that make them "chemicals of concern". In agreement with the EU's Chemicals Strategy for Sustainability (CSS), human as well environmental health need to be protected by avoiding exposure to substances that are carcinogenic, mutagenic, or toxic to reproduction (CMRs), persistent and bioaccumulative, and/or endocrine-disrupting chemicals. The CSS also specifically aims to reduce exposure to FCCs with these hazardous properties. Based on the information about FCCs that are known to have hazard properties defined by the CSS as most harmful (Zimmermann et al. 2022), we monitored how many of these food contact chemicals of concern (FCCoCs) have ever been reported to be detected in migrates and extracts of different FCMs. To translate these numbers into the scoring system applied here, the FCM with the highest number of FCCoCs obtained a score of 1, and a hypothetical FCM without any migrating and extractable FCCoCs would have received the best score of 5. All other scores were calculated proportionally.

Approach 2: Expert Opinion

Share of the total score: 1/3

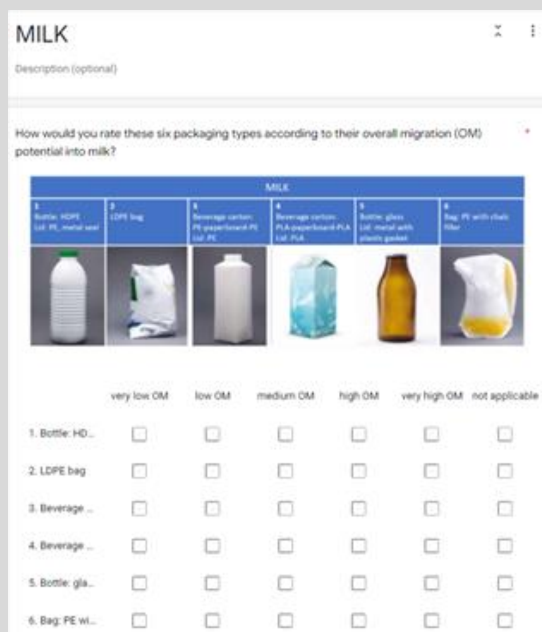
The inertness of a material is associated with the total amount of migrating chemicals. Materials within which the chemicals are strongly bound have a higher inertness than those materials formed by only loose networks and allowing diffusion of unbound chemicals. For food packaging items, the inertness can be determined by measuring the "overall migration" levels, meaning the total amount of migrating chemicals. Since data on overall migration are scarce, we carried out an expert survey addressing this question. The survey was sent to experts in the FCM field who have in-depth knowledge of migration testing and the different FCM properties. We defined experts as scientifically trained professionals that have been working on FCMs and chemicals for 10 years or longer. The experts were not expected to answer this survey by referring to scientific literature but by using their professional judgement. The survey text that was sent out together with the survey questions is shown in Box 1, together with an example of a question that was included in the survey. The data of the survey were analyzed as box and whisker plots. The boundaries of the box and whiskers as well as the statistical outliers were calculated by using Excel 365.

Box 1.

On the following pages, please rate the overall migration potential for each packaging article used in specific groups of foods and beverages. Use your personal judgement based on typical conditions of use. You are not expected to check the scientific literature to complete this survey.

Note that:

- Overall migration is independent of chemical hazards. Do not consider the hazard of the chemicals that might migrate when completing this survey.
- High chemical inertness of a packaging material means low overall migration into food and beverages.
- Low chemical inertness of a material can lead to high overall migration into food.
- In addition to inertness, chemical migration is also dependent on other factors, such as food type, storage time and temperature.



Approach 3: Food-Packaging Interactions

Share of the total score: 1/3

In addition to the food packaging material, also the conditions of use (during filling, transport, preparation, and consumption) and the chemistry of foods and beverages have an influence on the chemical migration, because the way packaging interacts with the food is affected by these parameters. To address these food-packaging interactions, we established an evaluation scheme comprising six factors that influence chemical migration (namely: typical storage time, storage temperature, fat content of the food, acidity of the food, aggregate state of the food, and the volume of a packaging as indicator of the surface-to-volume ratio), regardless of the packaging material, for each of the six food and beverage types (Table 2). In practice, we made general assumptions about all six food and beverage types studied and assigned sub-scores according to Table 4. For example, a food that is typically stored for less than 4 days, gets the best possible score of 5 for this category. In contrast, a food type with a fat content above 30% gets the worst possible score of 1. We calculated the average score for the food-packaging interactions based on these predefined factors.

Table 4. Scoring scheme evaluating six factors of the food-packaging interactions based on typical storage conditions and physical-chemical properties of the foods and beverages.

Storage time		Storage temperature		Fat content (of foodstuff)		Acidity (of foodstuff)		Aggregate state of the food		Typical packaging size	
< 4 days	5	<0°C	5	0-2%	5	pH >7	5	solid food with punctual contact	5	> 1 L or > 1 kg	5
4-7 days	4	0-8°C	4	3-10%	4	pH 5-7	4	solid food with full contact	4	0.5-1 L or 0.5-1 kg	4
8-14 days	3	9-18°C	3	11-20%	3	pH 3-5	3	semi-solid food	3	0.25-0.5 L or 0.25-0.5 kg	3
15-30 days	2	>18°C	2	21-30%	2	pH <3	2	liquid food	2	0.1-0.25 L or 0.1-0.25 kg	2
> 30 days	1	any heating >40°C in the packaging	1	>30%	1	not applicable	1	not applicable	1	<0.1 L or <0.1 kg	1

Annex II

Table 5. Overview of the 73 packaging items and their scorings resulting from the three approaches.

Food / beverage	Packaging type	1. Approach			2. Approach	3. Approach	Final Score	Comment
		FCM type / FCCmigex	Number of known FCCs, 1/6	Number of known FCCoCs, 1/6	Survey results (25th percentile), 1/3	Migration potential food type, 1/3		
Milk	Bottle: HDPE; Lid: PE, metal seal	PE	2.23	2.98	3	3.83	3.0	FCCmigex/FCCoC data based on container, not the lid
Milk	LDPE bag	PE	2.23	2.98	2.75	3.83	3.0	
Milk	Beverage carton: PE-paperboard-PE; Lid: PE	multi-materials	2.08	3.12	3	3.83	3.0	FCCmigex/FCCoC data based on container, not the lid
Milk	Beverage carton: PLA-paperboard-PLA; Lid: PLA	multi-materials	2.08	3.12	2.75	3.83	3.0	FCCmigex/FCCoC data based on container, not the lid
Milk	Bottle: glass; Lid: metal with plastic gasket	glass	4.82	4.66	4.75	3.83	4.5	FCCmigex/FCCoC data based on container, not the lid
Milk	Bag: PE with chalc filler	PE	2.23	2.98	3	3.83	3.0	
Salad	Bag: PE, printed	PE	2.23	2.98	2	4.50	3.0	
Salad	Tray: PP; Bag: PP	PP	2.78	2.64	3.75	4.50	3.5	
Salad	Bag: OPP	PP	2.78	2.64	3	4.50	3.5	
Salad	Bag: PLA	plastics, non-specified or other	1.00	1.00	3	4.50	3.0	
Salad	Bowl: A-PET/R-PET; Lid: PE, OPP or PET	PET	3.57	3.07	3.75	4.50	4.0	FCCmigex/FCCoC data based on container, not the lid
Salad	Bowl: bagasse; Lid: R-PET	PET	3.57	3.07	2.75	4.50	3.5	FCCmigex/FCCoC data based on container, not the lid
Salad	Bowl: PE-coated cardboard; Lid: PET	multi-materials	2.08	3.12	2.75	4.50	3.5	FCCmigex/FCCoC data based on container, not the lid
Cheese	Tray: A-PET; Lid: PET printed	PET	3.57	3.07	3	2.67	3.0	FCCmigex/FCCoC data based on container, not the lid
Cheese	Tray: PS; Lid: PA/PE, printed	PS	3.71	2.88	2.75	2.67	3.0	FCCmigex/FCCoC data based on container, not the lid
Cheese	Bag: OPA/PE, printed	multilayer plastic	2.84	3.27	2.75	2.67	3.0	
Cheese	Bag: PET/PE, printed	multilayer plastic	2.84	3.27	2.75	2.67	3.0	
Cheese	Paper, PE coated and printed	multi-materials	2.08	3.12	2	2.67	2.5	
Cheese	Box: wood; Shrink foil: PE	PE	2.23	2.98	2	2.67	2.5	FCCmigex/FCCoC data based on foil, not the box
Cheese	Paper, OPP-coated, metallized	multi-materials	2.08	3.12	3	2.67	3.0	
Cheese	Aluminum foil, coated	multi-materials	2.08	3.12	3	2.67	3.0	
Cheese	Shrink foil, PE/PP	multilayer plastic	2.84	3.27	2	2.67	2.5	
Cheese	Box: paperboard; PE/OPP coated paper	multi-materials	2.08	3.12	2	2.67	2.5	
Cheese	Kraft paper, PE coated	multi-materials	2.08	3.12	2	2.67	2.5	
Cheese	Bag: PET/PEM, printed	multi-materials	2.08	3.12	3	2.67	3.0	
Yoghurt cups	Cup: PS; Sleeve: paperboard	PS	3.71	2.88	3	3.17	3.0	FCCmigex/FCCoC data based on the inner layer
Yoghurt cups	Cup: PS	PS	3.71	2.88	3	3.17	3.0	
Yoghurt cups	Cup: PS; Sleeve: plastic	PS	3.71	2.88	3	3.17	3.0	FCCmigex/FCCoC data based on the inner layer
Yoghurt cups	Cup: PET	PET	3.57	3.07	3.75	3.17	3.5	
Yoghurt cups	Cup (big): PP	PP	2.78	2.64	3	3.17	3.0	
Yoghurt cups	Pouch: PE-Alu-PE	multi-materials	2.08	3.12	3	3.17	3.0	
Yoghurt cups	Cup: PLA	plastics, non-specified or other	1.00	1.00	2	3.17	2.0	
Yoghurt cups	Cup: glass	glass	4.82	4.66	5	3.17	4.5	
Yoghurt lids	Paper-PE-composite	multi-materials	2.08	3.12	2.75	3.83	3.0	
Yoghurt lids	Aluminum, hot-sealing lacquer	aluminum	4.76	4.47	3	3.83	4.0	
Yoghurt lids	PET, hot-sealing lacquer	PET	3.57	3.07	3	3.83	3.5	
Yoghurt lids	PET	PET	3.57	3.07	4	3.83	3.5	
Yoghurt lids	PE	PE	2.23	2.98	3	3.83	3.0	
Yoghurt lids	Aluminum-coated PET	multi-materials	2.08	3.12	4	3.83	3.5	
Yoghurt lids	Tinplate, PVC-free gasket	steel	4.73	4.52	3	3.83	4.0	
Beverages	PE-paperboard-Alu-PE; Lid: PE	multi-materials	2.08	3.12	3	2.67	3.0	FCCmigex/FCCoC data based on container, not the lid
Beverages	Beverage carton: PE-paperboard-Alu-PE	multi-materials	2.08	3.12	3	2.67	3.0	
Beverages	Beverage carton: PLA-paperboard-Alu-PLA; Lid: PLA	multi-materials	2.08	3.12	2.75	2.67	2.5	
Beverages	PET; Lid: HDPE and metallized plastic seal	PET	3.57	3.07	3.75	2.67	3.0	FCCmigex/FCCoC data based on container, not the lid
Beverages	Bottle: glass; Lid: aluminum with plastic gasket	glass	4.82	4.66	5	2.67	4.0	FCCmigex/FCCoC data based on container, not the lid
Beverages	Can: aluminum, coated, printed	aluminum	4.76	4.47	3	2.67	3.5	
Beverages	Box: cardboard; Bag: PE	PE	2.23	2.98	3	2.67	3.0	FCCmigex/FCCoC data based on the inner layer
Beverages	Cup: PS with carboard sleeve; Lid: PE and metallized seal	PS	3.71	2.88	3	2.67	3.0	
Beverages	Pouch: PE-Al-PE	multi-materials	2.08	3.12	3	2.67	3.0	
Beverages	Bottle: PET; Lid: HDPE and metallized seal	PET	3.57	3.07	3	2.67	3.0	
Beverages	Bottle: PET; Lid: HDPE and metallized seal	PET	3.57	3.07	3	2.67	3.0	
Beverages	Bottle: HDPE; Lid: PE and metallized seal	PE	2.23	2.98	3	2.67	3.0	
Fresh produce	Tray: cardboard, printed; Wrap: PP	paper & board, virgin or non-specified	1.37	1.53	3	4.67	3.0	
Fresh produce	Tray: PP; Wrap: PP	PP	2.78	2.64	3.75	4.67	3.5	
Fresh produce	Tray: wood; Wrap: PP	wood	2.78	2.64	3	4.67	3.5	
Fresh produce	Tray and lid: PET	PET	3.57	3.07	4	4.67	4.0	
Fresh produce	Tray: R-PET; Wrap: PP	PET	3.57	3.07	3.75	4.67	4.0	
Fresh produce	Bag: LDPE	PE	2.23	2.98	3	4.67	3.5	
Fresh produce	Net: PE	PE	2.23	2.98	4	4.67	4.0	
Fresh produce	Label, undefined material, compostable	unclear/unknown FCM	3.89	3.46	2.75	4.67	3.5	
Fresh produce	Natural branding laser	na	na	na	na	na	1.0	FCCmigex/FCCoC data cannot be used, since this is no packaging
Fresh produce	Tray: cardboard with grass fibers; Wrap: PP	paper & board, virgin or non-specified	1.37	1.53	2.75	4.67	3.0	
Fresh produce	Net: cellulose	other FCM	3.77	3.94	2.75	4.67	4.0	
Fresh produce	Tray: PLA; Wrap: LDPE or PLA	plastics, non-specified or other	1.00	1.00	3	4.67	3.0	
Fresh produce	Shrink foil: LDPE or LDPE/PP	PE	2.23	2.98	3	4.67	3.5	
Fresh produce	Bag: recycled paper with PP foil	paper and board	1.37	1.53	2.75	4.67	3.0	
Dry pastries	Bag: metallized BOPP/PET; Box: cardboard, printed	multi-materials	2.08	3.12	3	2.75	3.0	
Dry pastries	Bag: PET/BOPP; Box; cardboard printed	multilayer plastic	2.84	3.27	3	2.75	3.0	
Dry pastries	Inner bag: plastic; Outer bag: paper-plastic composite, printed	plastics, non-specified or other	1.00	1.00	3	2.75	2.5	
Dry pastries	Bag: metallized PET	multi-materials	2.08	3.12	4	2.75	3.0	
Dry pastries	Bag: OPP/PET; Label: cardboard	multilayer plastic	2.84	3.27	3	2.75	3.0	
Dry pastries	Tray: A-PET; Bag: metallized PET/PE; Box: cardboard	PET	3.57	3.07	4	2.75	3.5	
Dry pastries	metallized OPP/PET/CPP	multilayer plastic	2.84	3.27	3	2.75	3.0	