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Maria F Poças, Jorge C Oliveira, Henrique J Pinto, Maria E Zacarias,  
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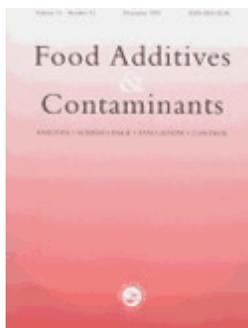
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# Characterization of Patterns of Food Packaging Usage in Portuguese Homes

Poças<sup>1&4\*</sup>, M.F.F.; Oliveira<sup>2</sup>, J.C.; Pinto<sup>1</sup>, H.J.; Zacarias<sup>3</sup>, M.E.; Hogg<sup>1&4</sup>, T.

<sup>1</sup>Packaging Department. Biotechnology College. Portuguese Catholic University. Rua Dr. António Bernardino de Almeida, 4200-072, Porto, Portugal;

<sup>2</sup>Process and Chemical Engineering Department. University College Cork, Ireland

<sup>3</sup>Logoplaste Technology, Ltd. Estrada da Malveira da Serra, Cascais, Portugal

<sup>4</sup>CBQF/ESB – UCP Rua Dr. António Bernardino de Almeida, 4200-072, Porto, Portugal;

## Abstract

This study aimed to permit further refinements in exposure assessments for migrants from food-contact materials by contributing to the characterization, at the household level, of the food packaging usage (amount and type) of Portuguese urban families. Packages from domestic use were collected from a sample of 105 consumers from 34 households over a 30 day period. Collected packages (more than 6 000 items) were characterized in the laboratory and data were used to estimate: (i) global packaging usage and food intake; (ii) the consumption factors (CF) that describe the fraction of the daily diet expected to contact specific packaging materials and (iii) the food-type factors (FTF) that reflect the fraction of all food contacting each material that is different in nature according to 6 major types: aqueous, acidic, alcoholic, milky, fatty and dry. The daily intake of packaged food and beverages consumed at home ranged from 5 to 50 g/kg<sub>bw</sub>. Considering all materials, total package usage ranged from 0.1 to 0.6 dm<sup>2</sup>/day.kg<sub>bw</sub>. The ratio between package surface area in contact and the quantity of food was determined for all packaging items collected and an average value of 25 dm<sup>2</sup>/kg<sub>food</sub> was recorded. Data were gathered and presented in a manner compatible with current probabilistic approaches to exposure assessment. In this way, relevant

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\* Corresponding author [mfpocas@esb.ucp.pt](mailto:mfpocas@esb.ucp.pt)

consumption patterns from this type of population can be best represented in exposure assessments and consequent risk assessments.

**Key words:** food packaging, migration, packaging usage, exposure assessment

#### Abbreviations and symbols

A, B, C, E, D, None	Food simulants
BIB	Bag-in-box
BW	Body weight, kg <sub>bw</sub>
C	Concentration of migrant in food or food simulant, mg/kg <sub>food</sub>
CF	Consumption factors
DSC	Differential scanning calorimetry
E	Exposure mg/person.day or mg/kg <sub>bw</sub> .day
FTF	Food type factors
FW	Food weight, kg <sub>food</sub> /person.day or kg <sub>food</sub> /kg <sub>bw</sub> .day
LDPE	Low density polyethylene
HDPE	High density polyethylene
Max	Maximum
Min	Minimum
N	Number of household members
PET	Polyethylene Terephthalate
PP	Polypropylene
PS	Polystyrene
PW	Packaging weigh, kg
S	Packaging surface area of contact, dm <sup>2</sup>
SML	Specific migration limit mg/kg <sub>food</sub>
μ	Average
σ	Standard deviation

#### Indices

i	Household
j	Packaged food item
m	Packaging material
n	Member of household
t	Type of food: aqueous, acidic, ethanolic, dairy, dry
bw	Body weight

## Introduction

Exposure, in a dietary context, is defined as the amount of a certain substance that is consumed and is usually expressed as the amount of substance per mass of consumer body weight per day (Holmes et al., 2005). When applied to food contact packaging, exposure can be expressed in terms of the concentration of the substance that migrated from the material in contact and the amount of food contained in the package consumed per day (1). In order to assess the exposure to packaging chemicals, it is necessary to know what type of food (chemical and physical nature) is packaged in what type of material, as this determines the presence and concentration of the chemical and influences the potential for migration into the type of food (Poças & Hogg, 2007).

$$\text{Exposure (mg / person.day)} = C (\text{mg / Kg}_{\text{food}}) \times \text{FW} (\text{Kg}_{\text{food}} / \text{person.day}) \quad (1)$$

The concentration data (C) may be obtained by analysing real food/packaging systems collected from the market (monitoring real food systems) or through migration experiments carried out under controlled conditions of time and temperature of contact between the materials and a food simulant instead of the food itself. Mathematical models may also be used to estimate migration data (Poças et al., 2008).

The food consumption term (FW) represents the amount of food eaten that was in contact with a packaging material from which migration occurred. Therefore, this term is linked to the packaging usage - the amount of packaging used to pack the food that the consumer eats. Packaging usage data are very scarce and most consumption surveys have been designed to gather information on the food, regardless of their packaging systems. Thus, adequate information of packaging usage, usable to assess exposure to migrants from packaging, is not readily available.

Data on almost all aspects of food packaging in Portugal are virtually nonexistent. A report with market data collected through statistics of national and trade associations and through interviews to major food companies and packaging suppliers was published in 1995 (Poças & Xará, 1995). However, this report lacks obvious updating, as well as the detail required for this specific purpose. The Euromonitor Report provides data

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3 (volume and value) on Packaged Food in Portugal but it does not give details on the  
4 packaging systems used (Euromonitor, 2008).  
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9 The methods for estimating consumer exposure can and should follow a hierarchical,  
10 stepwise approach, proceeding from the level of more conservative assumptions and  
11 lower accuracy, often corresponding to point estimates, to the more refined probabilistic  
12 approaches. When the less exact, first level, results do not rule out the possibility of  
13 non-compliance with the relevant food safety objective, then more refined approaches  
14 are required. Different levels of refinement may be achieved depending on the type and  
15 quality of data available for each term of equation (1) and the scenarios behind. An  
16 approach between the simplified point estimates based on worst-case assumptions for  
17 both the concentration and food intake terms of the exposure equation and the  
18 elaborated probabilistic approaches considering variability and uncertainty of the inputs  
19 in the exposure equation, may consist in the adoption of a similar approach to the one  
20 followed by the official agencies of the US (Poças et al., 2007). The FDA defines a  
21 consumption factor (CF) that describes the fraction of the daily diet expected to contact  
22 specific packaging materials and a food-type factor (FTF) that accounts for the variable  
23 nature of food contacting each type of packaging material (USFDA, 2007). This  
24 corresponds to a more refined first-step approach when compared to that applied in the  
25 EU. The application of this approach here would require the development of a  
26 framework, bringing together CF and FTF derived and adapted to the European  
27 consumption patterns of packaged food. An application of this FDA concept to the  
28 exposure of Irish children to packaging migrants was reported by Duffy et al. (2007).  
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46 The focus of this paper is on the use of consumption and food-type factors derived  
47 from data collected at consumer level. The data collected allow for a probabilistic  
48 approach as an example provided, and was collected in the scope of a national funded  
49 research project MIGRAMODEL. One of the objectives of the project was the  
50 development of a framework for exposure assessment of packaging migrants. The  
51 project focused on the collection of updated and more complete data on packaging  
52 usage enabling the refinement and possible correction of current EU assumptions to  
53 exposure estimations and to assist on prioritization of market surveillances. The data  
54 include packaging usage data collected at consumer level complemented by data  
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3 collected at industry level (packaging and food associations were contacted in order to  
4 gather statistic national data).  
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## 8 **Materials and Methods**

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11 The collection of data within the project scope was performed in three trials that took  
12 place during 2007 and 2008: the first during 1-week period from a sample of consumers  
13 connected to the project; the second during 1-week period from a sample of consumers  
14 participants in a scheme of door-to-door collection of packaging waste in Porto city; and  
15 the third during a 1-month period from a second sample of consumers connected to the  
16 project. The data from this latter trial were used in the work presented here. Packages  
17 used domestically by the consumer sample were collected during 30 subsequent days  
18 and analyzed in the laboratory. This collection period was selected because in previous  
19 work a one-week period proved to be insufficient.  
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30 The elements of the consumer sample were members of MIGRAMODEL project team,  
31 relatives and faculty members. The sample was composed of 34 households, accounting  
32 for a total of 105 persons. Separate collection of those packages used by children under  
33 12 years only was requested. The household was characterized through a short  
34 questionnaire, considering: number of persons, weight, age and gender of each  
35 household member and level of household annual income. The household member  
36 responsible for package collection was instructed by the project team as to which  
37 packages and food contact materials should be considered. Consumers tend to disregard  
38 items such as wrapping film, bread or fruit bags as packaging. Persons were encouraged  
39 to include any item in the case of doubt. A leaflet with pictures of examples was  
40 distributed and a phone contact with the project team was available during the collection  
41 period.  
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53 The packaging materials and systems used (consumed) by each household were brought  
54 into the laboratory and analyzed for the characteristics bellow described. A total of  
55 6 297 packaging items were handled.  
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59 Type of package: each package or material was classified as bottle, jar, can, cup/lid,  
60 tray/lid, tray/wrap, flexible, liquid carton, box, and folding carton.

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5 Packaging material: the packaging materials were segmented as: glass, tinplate,  
6 aluminium, all-plastic multilayer, multilayer (multi-material), paper, coated paper (wax  
7 or PE coating), carton board and plastics. The latter were further segmented into  
8 different major types of plastics: PET, PP, HDPE, LDPE, PS. Material identification  
9 was, in most cases, based on previous knowledge and experience and confirmation,  
10 when required, was done by DSC.  
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17 Closures for glass packages were not accounted for. Nevertheless, their amount can be  
18 estimated from data on the type of package. The data on polymeric coatings of tinplate  
19 and aluminium packages are associated to the data on these metal packages, not to the  
20 plastic class. All-plastic multilayer included laminates used mainly in flexible  
21 packaging and lids of rigid packages, made exclusively from several plastic layers.  
22 Multilayer group of materials, included liquid cartons (board, plastic and aluminium;  
23 board and plastic) and flexible packaging composed of plastic, paper and metal or  
24 metalized film. The differentiation between the major plastics was performed taking  
25 into consideration the major plastic component of the package. Polyethylene was  
26 divided into two major groups only, corresponding to high and low densities. No other  
27 differentiation between different grades of a plastic was performed.  
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39 Packages characteristics:

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41 – Geometry - the packages were classified according to their general geometry as  
42 rectangular, cylindrical, pyramid truncated, cone truncated, sphere or flexible for  
43 non rigid packages;  
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45 – Capacity - the nominal amount of food product according to the labelling  
46 information was recorded; when it was not possible to know the amount of food  
47 contained/in contact with the material, the surface area was determined and the  
48 EU conventional ratio between the surface area of the package and amount of  
49 food –  $6 \text{ dm}^2/\text{kg}$  – was assumed;  
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51 – The weight and surface area in contact with food of package was measured and  
52 ratio package surface area/mass of food was calculated for all packaging items  
53 handled in the laboratory;  
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All materials considered were in direct contact with the food products, except carton board, which was in all samples, a non-direct contact material. However, because migration can also occur from non-direct contact materials, carton board was also considered in the consumption factors estimation.

Food items were grouped according to the list presented in Table 1. The list was based on the list prepared under the scope of the European FACET project (Oldring et al, 2009). This list is still in draft form and a simplified version of it was used here. The authors of the present article employed a compatible coding of food-types in order to allow for future integration if so desired.

Each food item was assigned into a food type, corresponding to food simulants, according to European food contact legislation (Council Directive 85/572/EEC and Commission Directive 2007/19/CE): A - water, B - 3% acid solution, C – 10% ethanolic solution, D – olive oil, E – 50% ethanolic solution to mimic milk and some other dairy foods. In the case of food items requiring more than one testing simulant, the fattier simulant one was considered. A “None” was assigned for the cases in contact with dry, solid, non-fatty foods, like bread or flour.

The data were used to estimate:

- The global amount of used packaging material: this was calculated as the sum, for all food items, of the package surface area and weight. The total amount (all materials together in kg) were averaged by the 30 days period and by the total number of persons (2);

$$Global\ Packaging\ Usage = \frac{\sum_i \sum_m \sum_j S_{imj}}{30 \sum_i N_i}, \quad dm^2/person.day \quad (2)$$

- The global amount of food (in kg) consumed by the population sample was calculated as above but using the item food weight  $FW_{imj}$  in equation (2);
- The packaging usage of each household  $i$ , per body weight of the household, for all materials together, was calculated as (3):

$$\text{Packaging Usage per BW} = \frac{\left[ \sum_m \sum_j S_{mj} \right]_i}{30 \left[ \sum_n BW_n \right]_i}, \text{ dm}^2/\text{kg}_{bw} \cdot \text{day} \quad (3)$$

- The amount of food weight of each household, per body weight of the household, was calculated as above but using the  $FW_{mj}$  in equation (3);
- The ratio - package surface area/mass of food for each type (4) of packaging material (distribution of values):

$$\left[ S / FW \right]_m = \frac{\left[ S_{ij} \right]_m}{\left[ FW_{ij} \right]_m}, \text{ dm}^2/\text{kg} \quad (4)$$

- The estimates of consumption factors (CF) that represent the fraction of the daily diet expected to contact specific packaging materials (USFDA, 2007) was calculated as indicated in equation (5):

$$CF_m = \frac{\left[ \sum_i \sum_j FW_{ij} \right]_m}{\sum_m \sum_i \sum_j FW_{mij}} \quad (5)$$

- The estimates of food type factors (FTF) that reflect the fraction of all food contacting each material  $m$  which nature is according to the types  $t$  of foods: aqueous, acidic, alcoholic, fatty, dairy or dry (6). This corresponds to an adaptation of the USFDA approach to the simulants foreseen in the European legislation.

$$FDF_{tm} = \frac{\left[ \sum_i \sum_j FW_{ij} \right]_m}{\left[ \sum_t \sum_i \sum_j FW_{tij} \right]_m} \quad (6)$$

Food eaten out of the home was not accounted for in this analysis, which obviously contributes to underestimation of the absolute values for consumption.

#### *Example of an exposure calculation*

The exposure of the Portuguese consumer to 2-aminobenzamide (2-ABA; CAS 88-68-6) was estimated using the data gathered in this study. 2-ABA may be used as a scavenger for acetaldehyde in PET bottles. In European legislation it is authorised for

PET for water and beverages with a SML=0.05 mg/kg<sub>food</sub> (Commission Directive 2002/72/CE). USFDA limit the use of 2-ABA subject to the restriction of levels in the finished container not to exceed 500 mg/kg in bottles intended for water and levels not to exceed 250 mg/kg in bottles intended for non-water, aqueous, acidic and low-alcohol food applications. Information from the safety evaluation (SCF, 2003) indicates that the migration of 2-ABA from PET bottles containing 500 mg/kg of the substance to water, 3% acetic acid, and 10% ethanol was found to be maximum 0.04 mg/kg<sub>food</sub> in 10% ethanol after 30 days at 40°C. For the exposure calculation examples a single estimate of the concentration of 2-ABA was set at the SML value. The exposure is estimated under the conditions foreseen by different scenarios: i) USFDA, ii) European conventional assumptions, iii) using the CF and FTF derived in the present work and iv) using a partially probabilistic approach by combining the single-point estimate for the concentration as above described but considering the whole distribution of values found for the food intake per kg<sub>bw</sub> in the sample of consumers. The software Crystal Ball 7.2.2. (Decisioneering, Inc.) was used to fit the probability distributions to the values of the food intake FW (in kg<sub>food</sub>/kg<sub>bw</sub>.day) and to perform the probabilistic simulation. Monte Carlo was used as sampling method with 10 000 trials for each run.

## Results and discussion

### *Characterization of the consumer sample*

The data collected through the questionnaire were used to characterise the consumer sample. Average results for bodyweight and age are presented in Table 2. Results for the children are presented separately. Figures 1 and 2 represent the distributions of weights and ages, respectively of the whole sample population, adults and children together, which is evident from the bimodal shape of the distributions. The national statistics for population indicators was used to assess how representative the consumer sample is of the whole Portuguese population. The consumer sample used in this work was taken from the Metropolitan Porto area which represents 12% of the total population, 45% of which is classified as urban. The national average household size is 2.8 members which can be compared to the 3.1 of the present sample. The Portuguese population as a whole presents an age distribution with 15% individuals younger than 14 years and 56% in the range of 24 to 64 years old. The sample in this study had a relatively higher percent of consumers in these two ranges of age, 24 and 66%

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3 respectively, and a lower percentage of elderly people, 4% whereas the national average  
4 is 17%. The differences in terms of distribution by gender are not relevant with values  
5 around 50% of each gender in both cases.  
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### 10 11 *Global amount of food consumed and packaging material used*

12 The average amount of food consumed at home and the packaging materials used by  
13 adults and children together and by children alone, are presented in Table 3. The  
14 average value for daily intake of packaged food of all consumers is close to the value  
15 assumed for the EU (1 kg/day.person) for the assessment of safety of substances  
16 intended to be used in the production of plastics packages. The value found for the  
17 average daily intake when expressed per kg body weight is the same as the value  
18 typically assumed: 17g/kg<sub>bw</sub> (EFSA, 2005). However, these values are most probably  
19 underestimated because the packaged food consumed out of the home was not  
20 accounted for, as explained above. Figure 3 presents the distribution of values found  
21 that range from 5 to more than 35 g/kg<sub>bw</sub>. The types of food according to the simulants  
22 foreseen in the EU, accounted as the percents of food taken at home are: 18% aqueous,  
23 10% acidic, 5% ethanolic, 25% milky and 14% fatty.  
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36 The values found for the children's sample only are considerably lower than the results  
37 found for Irish children between 5 and 12 years old. Duffy et al. (2006) estimated a  
38 mean daily consumption of packaged food, by these children, of 1.2 kg/day,  
39 corresponding to 39 g/kg<sub>bw</sub>, compared to the 21 g/kg<sub>bw</sub> found in this study for  
40 Portuguese children. The value found in this study for food intake per child - 0.483  
41 kg<sub>food</sub>/day.child - is also low when compared to the value found for British children -  
42 0.823 kg<sub>food</sub>/day.child (FSA, 2006). The way of data gathering followed in this study,  
43 does not account for the fact that in each household some of the packages items  
44 collected are in fact shared by both adults and children although ending on the adult bin,  
45 thus contributing to lowering the values found for children. The value found in this  
46 study for the whole sample data (0.947 kg<sub>food</sub>/day.person) is higher than for the children,  
47 as was to be expected.  
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60 Figure 4 presents the distribution of values found for the packaging usage, in terms of  
surface area of all packaging materials that a consumer uses per day and per kg of body

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3 weight. The results obtained in this study confirm the values previously found in a one-  
4 week study, and show values ranging from lower than  $0.1 \text{ dm}^2/\text{day.kg}_{\text{bw}}$ , which  
5 corresponds to the value assumed in European legislation, to values around  $0.6$   
6  $\text{dm}^2/\text{day.kg}_{\text{bw}}$ , a much higher value. The average value is  $0.2 \text{ dm}^2/\text{day.kg}_{\text{bw}}$  (standard  
7 deviation =  $0.11 \text{ dm}^2/\text{day.kg}_{\text{bw}}$ ). This value is lower than the European average value  
8 estimated by ILSI of  $20.1 \text{ dm}^2/\text{person/day}$  that corresponds to  $0.34 \text{ dm}^2/\text{day.kg}_{\text{bw}}$   
9 (Brown et al., 1997). ILSI estimates indicated a value of  $12.4 \text{ dm}^2/\text{person/day}$  for  
10 plastics that compare to the value found in this study –  $8 \text{ dm}^2/\text{person/day}$ .  
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#### 18 *Ratio - packaging surface area per amount of food in contact*

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20 The ratio of packaging surface area to the amount of food in contact (S/FW) was  
21 calculated for each material (Table 4). Packages made from glass and tin plate present  
22 average ratios around  $10 \text{ dm}^2/\text{kg}_{\text{food}}$  and relatively low standard deviation. This could be  
23 expected because the range of formats and shapes in these packages do not vary as  
24 much as in the case of other materials. In the aluminium group are included rigid cans  
25 for foods and beverages, semi-rigid shallow trays and wrapping foil. This variation in  
26 the formats, shapes and sizes originates a higher average and spreader ratios. A large  
27 proportion of PET is used in beverage packaging and in capacities as large as 5 L. Trays  
28 for confectionery and cakes, products with low density, contribute to the higher range of  
29 the distribution of values for the ratio S/FW found for PET. These light products,  
30 including bread, are major applications for flexible PP, thus yielding high values of ratio  
31 S/FW. PP secondary packaging and paper for tea bags present values around  $600$   
32  $\text{dm}^2/\text{kg}_{\text{food}}$ . PS entries in the data base include cups for solid yogurts and other dairy  
33 products, cakes and baked products as well, and trays for meat, fresh cheese and some  
34 fruits. Average ratio values of  $S/FW=12.6 \text{ dm}^2/\text{kg}_{\text{food}}$  ( $\sigma=7.3$ ) were found. Liquid  
35 cartons (aseptic and non-aseptic) are included in the group of materials referred to as  
36 Multilayer. The S/FW of milk and juice liquid cartons ranges from  $5.75 \text{ dm}^2/\text{kg}_{\text{food}}$  for  
37 packages of 1.5L to ca.  $13 \text{ dm}^2/\text{kg}_{\text{food}}$  for smaller packages of 0.2L. Although many  
38 other types of flexible packages, made from metalized materials and combinations of  
39 paper, aluminium foil and plastic, are included in this group, liquid cartons account for  
40 94% of total package surface area and 97% of the food weight of this group. Paper is the  
41 material presenting the highest values of S/FW due to its use for dry, powder and light  
42 in weight products. Figure 5a presents the distribution of values of S/FW when all  
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3 materials are considered together, and Figure 5b presents the distribution of values for  
4 the PS, as an example.  
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8 These results emphasize conclusions drawn before by other authors that the assumption  
9 that packages geometry may be described, for safety assessments, as a cube of surface  
10 area  $6 \text{ dm}^2$ , containing 1 kg of food, is inappropriate today, because globally packages  
11 sizes tend to decrease which leads to an increase in contacting surface area per kg of  
12 food (Dionisi & Oldring, 2002; Grob et al., 2007; Poças & Hogg, 2007). In a similar  
13 study performed in The Netherlands values for the S/FW ratio varying from 6 to 95  
14  $\text{dm}^2/\text{kg}_{\text{food}}$  were found (Bouma et al., 2003).  
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### 22 *Estimates of consumption factors (CF)*

23 CF represent the ratio of the weight of all food contacting a specific packaging material  
24 to the weight of all food packaged consumed. CF was calculated with equation (5),  
25 according to the procedure followed by FDA (Cassidy and Elyashiv-Barad, 2007).  
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31 Figure 6 and 7 represent the consumption factors for adults and children together and  
32 for children alone, respectively. A comparison between the two Figures show that  
33 multilayer materials (mostly liquid cartons) have a lower use as compared to the value  
34 found when children only is considered. In the whole sample, glass accounts for ca 6%  
35 of the food intake, but this material is almost not found in the case of children's  
36 consumption. Plastics all together account for more than 50% of the daily diet. PET  
37 accounts for 26% of the food (mostly drinks). The remaining plastics split among  
38 themselves ca 33% of the food. The plastic PS has a higher relative importance (10%)  
39 in children's diet, as compared to the importance when adults are also considered (4  
40 %). This may be explained by the expected higher consumption of dairy products by  
41 children and the fact that these products are typically packaged in PS packages in  
42 Portugal.  
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53 The percentages of the food consumed contacting specific materials are compared to the  
54 USFDA CF in Table 5. In order to allow a comparison between the results of this study  
55 and the USFDA CF, some grouping of the classes of materials was made: consumption  
56 factors of aluminium and tinplate in this study were added together and compared to the  
57 sum of the factors for metal coated and metal uncoated in FDA; plastics and all-plastics  
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3 multilayer were added together and compared to plastics from FDA; coated paper and  
4 multilayer multimaterial together were compared to coated paper values from FDA;  
5 uncoated paper and carton board were compared directly. USFDA segments of  
6 adhesives, retort pouch and microwave susceptors were not considered. The comparison  
7 shows a lower usage of glass and metal in Portugal as compared to USA and a higher  
8 percentage of plastics and multimaterial. The CF of some specific plastics are also  
9 presented in Table 5. After appropriate manipulation to conversion into the same base,  
10 the values found for HDPE, LDPE and LLDPE together, and PS are very similar to the  
11 FDA values for these plastics. The value for PET, however, is very different. Results in  
12 this study show that ca 26% of the food consumed at home was packaged in PET, while  
13 the correspondent CF for USA is only 7%. Since a large proportion of the PET entries  
14 in the study database is for drinks, this difference is coherent with the lower values  
15 found for Portuguese usage of the other materials very much used for drinks – glass and  
16 metal, as a certain compensation between materials used for drinks may occur.  
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30 The results for CF obtained in this 1-month study are presented for adults and children  
31 together and for children only. The latter are compared with the results presented by  
32 Duffy et al. (2007). Unfortunately, due to the use of a different fragmentation between  
33 the packaging materials, it is only possible to compare glass, paper and board classes.  
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#### 39 *Estimates of food type distribution factors (FTF)*

40 The FTF for the different packaging material are presented in Table 6. The results  
41 presented indicate that:  
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- 44 – Glass is used 64% for alcoholic products and the remaining is distributed for the  
45 different types of products and fatty products account for 8%;
- 46 – Tin plate is used in mainly 3 type of products/simulants: aqueous, acidic and  
47 fatty;
- 48 – PET, as expected, has a major application in aqueous and acidic products,  
49 related to soft drinks;
- 50 – PP is apparently used in significant proportions in dry products, as well as in  
51 fatty foods;
- 52 – HDPE is primarily used in dairy products for which simulant E is defined;
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- PS finds its major application in products for which simulant E (dairy foods) and D (fatty) are assigned;
- Multilayer (multi-material) packages have a significant proportion of liquid cartons, used for milk and juice, as the food type factors reflect;
- Carton board, is mainly used for non-contact applications thus no simulant is specified.

The results are not directly compared with the FTF from FDA since the classification of foods followed is different, according to the food simulants foreseen in Europe.

The use of the CF and FTF require the complete understanding of the classification behind the factors derived. For example: if the factors are to be used to estimate the exposure to an additive migrating from the LDPE family of films, the following must be taken in consideration:

- the percentage of daily food intake packaged in LDPE single-layer material is 5% (Table 5) from which ca 75% is for dry food and 25% is for fatty food (Table 6);
- PE based films are likely to be the contact layer in the Multilayer and Plastics-multilayer classes; the percentage of daily food intake in contact with Multilayer is 22% (Figure 6) from which 12% is acidic foods and 85% is milky food (Table 6); the percentage of daily food intake in contact with Plastics-multilayer is 6% (Figure 6) from which 54% are fatty foods, 28% are dry foods and 14% are ethanolic (BIB,s for wine); these contributions should all be accounted for.

#### *Example of exposure calculation*

The results from the exposure calculations with the different assumptions and scenarios are presented in Table 7. In all cases the concentration of the migrant is the same single value set at the maximum migration limit. The USFDA scenario yields an exposure of 4.8  $\mu\text{g}/\text{person}\cdot\text{day}$  that is 10 times lower than the scenario from EU conventional, i.e., without considering the CF and FTF - 50  $\mu\text{g}/\text{person}\cdot\text{day}$ . When the CF and FTF obtained in the study are considered and combined with the food intake data for the studied sample, the value is closer to the USFDA value – 11  $\mu\text{g}/\text{person}\cdot\text{day}$ .

For the probabilistic approach, all values of the consumer's food intake FW in  $\text{kg}_{\text{food}}/\text{kg}_{\text{bw}}$  were considered, instead of the average value only. The distribution of

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3 probability values was found to be better described by a Lognormal distribution. The  
4 distribution function was truncated at the minimum and maximum values found on the  
5 study data base. The estimates for the exposure are presented in Figure 8. The  
6 distribution of estimated values is better fitted to the Weibull probability distribution  
7 function. The values range from 0.059 to 0.426  $\mu\text{g}$  2-ABA/ $\text{kg}_{\text{bw}}$ .day. From the Figure  
8 the different percentiles can be read out if required.  
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## 15 **Conclusions**

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17 The results achieved contribute to a refinement and possible correction of current EU  
18 assumptions for exposure assessment when applied to a particular population, in this  
19 case largely Portuguese urban families of working age, in which concerns migration of  
20 substances from the package into the food. For any particular section of the population,  
21 Portuguese consumption patterns may reasonably be expected to be similar to those in  
22 other southern European countries with globally similar dietary habits and lifestyles.  
23 Therefore results of this pilot-study may have significance beyond the strict national  
24 scope. The data collected on consumption and food-type factors, in spite of the  
25 limitations inherent to the resources required to conduct such a study, allow for the  
26 adoption of a more realistic and more refined approach than the worst-case estimates,  
27 combining a probabilistic approach to model variables for which the distribution of  
28 values are known. The amount of packaging (in terms surface area) that the consumer  
29 uses and the food intake can be combined with migration data for a certain and specific  
30 substance that is present in the packaging material in question, and used in equation (1)  
31 to estimate the exposure. The major limitation may be the size of the sample.  
32 Nevertheless the number of packaging items was similar to other studies. For example  
33 the study conducted in British children handled 6500 items (FSA, 2006). The sampling  
34 method followed proved to be sufficient to gather data for the adults and children  
35 together, but not to consider the children only. This consumer segment should be further  
36 investigated. In any case the data framework will be complemented with analyses of  
37 data obtained from the industry sources.  
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Table 1. Food groups

	Beer
	Wine
Beverages	Spirits/liquors
	Water
	Juice & juice drinks
	Soft drinks
	Coffee
Dry Beverages	Tea
	Others (chocolate powder)
Biscuits and Crackers	
Cakes	
Bread	
Breakfast cereals	
	Chewing gum
Confectionary	Sugar confectionary
	Chocolate confectionary
Snacks	
	Sugar and substitutes
	Flour, cake mixes, baking powder
	Rice
	Dry pastas
Culinary ingredients	Sauce and condiments
	Jam, marmalade, honey, compote
	Chocolate spreads
	Eggs
	Dietary supplements
Oil	
Olive oil	
Fats	
	Hard
	Soft
Cheese	Fresh
	Spreadable/processed
Butter	
Milk	Liquid
	Powder
Yogurt	Liquid
	Solid
Cream	
Dairy desserts	
	Fresh
Meat	Processed/cured
	Fresh
Fish	Processed/cured
	Whole
Fruit	Fresh
Vegetables	Ready meals
Frozen	Vegetables
	Meat

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3		Fish
4		Ice cream
5		Desserts
6		Ready meals
7	Chilled	Fish
8		Meat
9		Vegetables
10	Preserves	Fruits
11		Ready meals
12		Soups
13	Dehydrated	Fruits
14		Vegetables
15	Dried	
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17	Take-away and vending	
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19	Baby food	Dry
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Table 3. Global results averaged by day, person and by average person body weight

		Food weight, kg	Package surface area, dm <sup>2</sup>	Package weight, kg
	Total	2 982	34 341	303
Children plus adults	Total/day.person	0.947	10.9	0.096
	Total/day.kg <sub>bw</sub>	0.017	0.192	0.002
Children only	Total/day.child	0.483	5.9	0.027
	Total/day. kg <sub>bw</sub>	0.021	0.249	0.001

Table 4. Statistics for the distribution of values of the ratio surface area/ food amount ( $\text{dm}^2/\text{Kg}_{\text{food}}$ ) for each packaging material.

	$\mu$	$\sigma$	Min.	Max.
All materials together	24.89	48.62	0.13	700.00
Glass	9.81	4.55	4.72	70.40
TinPlate	10.64	4.16	1.67	21.90
Aluminium	49.98	23.60	3.81	72.00
PET	9.97	9.35	3.20	80.00
PP	34.32	47.66	1.00	700.00
HDPE	15.35	12.06	3.43	105.26
LDPE	16.56	15.58	2.33	92.11
PS	12.60	7.26	4.17	80.00
Plastic Multilayer	35.48	42.54	2.84	646.15
Multilayer	13.13	42.91	2.22	646.15
Paper	104.01	163.34	0.13	686.67
Coated Paper	45.02	41.15	2.22	142.86

Table 5. Comparison between estimates of consumption factors and USFDA values

	FDA Adults & Children	PT Adults & Children	PT Children 1-12 years	IE Children 5-12 years
Glass	10	6	1	2
Metal (coated+uncoated)	20	4	2	6
Plastics	40	56	41	80
PS	4 <sup>+</sup>	4	4	-
PET	7 <sup>+</sup>	26	14	-
HDPE	5 <sup>+</sup>	5	4	-
L(L)DPE*	7 <sup>+</sup>	5	1	-
Multimaterial	20	23	43	-
Paper and board	10	12	16	13

\*LDPE and LLDPE were not distinguished

<sup>+</sup> PET is 16% of plastics; PS is 10% of plastics; HDPE is 13% of plastics; plastics are 40% of diet

Table 6. Food type distribution factors for each packaging material

	A	B	C	E	D	None
Glass	13	14	64	0	8	1
Tinplate	8	53	4	3	22	10
Aluminium	1	7	9	0	80	3
PET	73	18	0	1	5	3
PP	4	2	0	0	19	75
HDPE	0	5	0	47	11	37
LDPE	1	1	0	0	25	73
PS	1	1	0	34	50	14
Plastics multilayer	3	0	14	1	54	28
Multilayer	0	12	0	85	2	1
Paper	1	0	0	0	12	88
Coated paper	0	0	0	0	92	8
Carton board	0	0	1	3	9	87

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Table 2. Characteristics of the consumers' sample: adults and children\*

	Parameter	Value
Adults and children	N° of persons in sample	105
	N° of homes	34
	Average weight, kg ( $\pm$ St.dev.)	56.6 $\pm$ 23.1
	Average age, years ( $\pm$ St.dev.)	30.2 $\pm$ 17.8
Children only	N° of children	20
	Average child weight, kg ( $\pm$ St.dev.)	23.6 $\pm$ 10.1
	Average child age, years ( $\pm$ St.dev.)	6.7 $\pm$ 3.4

\*  $\leq$  12 years old

Table 7. Exposure estimation of 2-ABA with origin in PET bottles packaging materials.

Assumptions/ scenario	USFDA	EU conventional	PT deterministic	PT probabilistic
FW	3 kg <sub>food</sub> /person.day	1 kg <sub>food</sub> /person.day	0.95 kg <sub>food</sub> /person.day	LN distribution μ=0.017 kg <sub>food</sub> /kg <sub>bw</sub> .day σ=0.008 Min=0.005 Max=0.036
C <sub>2-ABA</sub>	0.05 mg/kg <sub>food</sub>	0.05 mg/kg <sub>food</sub>	0.05 mg/kg <sub>food</sub>	0.05 mg/kg <sub>food</sub>
BW	--	60 kg <sub>bw</sub>	57 kg <sub>bw</sub>	
FTF <sub>PET</sub>	0.01 Aqueous	--	0.73 A	0.73 A
	0.97 Acidic	--	0.18 B	0.18 B
CF <sub>PET</sub>	0.082 PET/Polymers	--	0.26 PET/All	0.26 PET/All
	0.40 Polymers/All	--		
Exposure	4.8 μg/person.day	50 μg/person.day 0.8 μg/ kg <sub>bw</sub> .day	11 μg/person.day 0.2 μg/ kg <sub>bw</sub> .day	Weibull distribution μ=0.20 μg/kg <sub>bw</sub> .day σ=0.081 Min=0.059 Max=0.426

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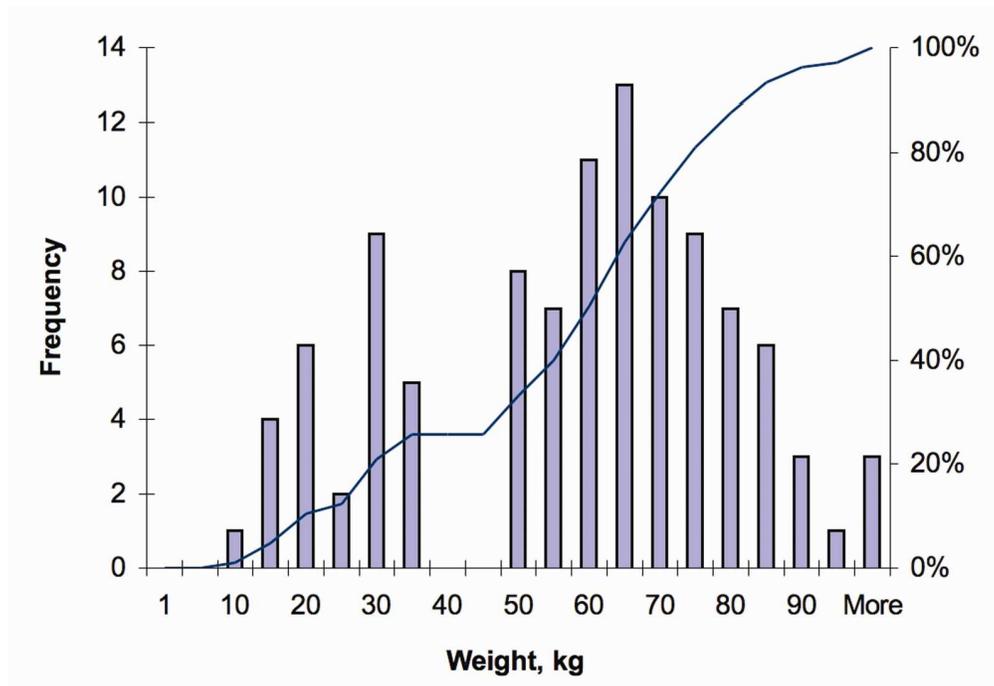


Figure 1. Weight distribution of person in the sample  
270x185mm (300 x 300 DPI)

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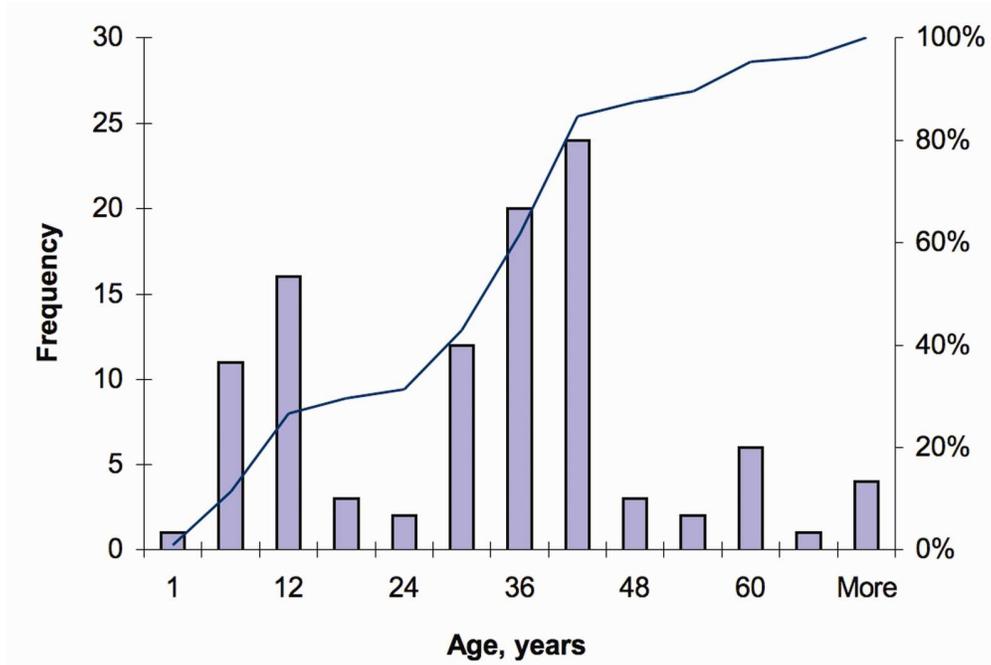


Figure 2. Age distribution of person in the sample  
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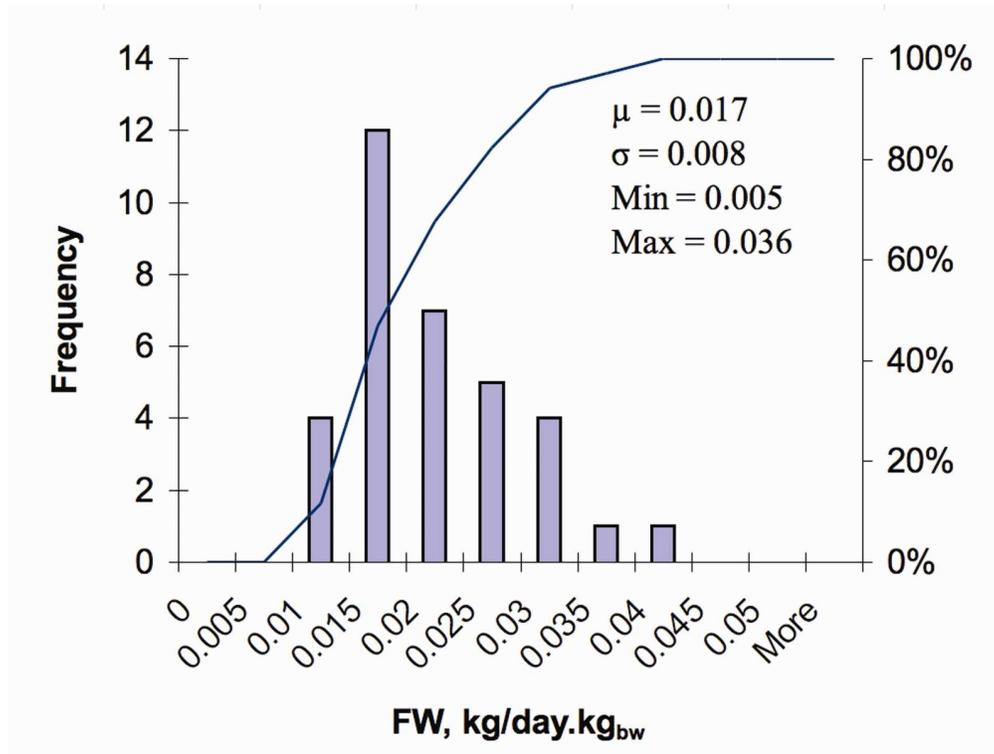


Figure 3. Distribution of values for packaged food consumed at home per day and per kg of body weight. Adults and children together.  
270x204mm (300 x 300 DPI)

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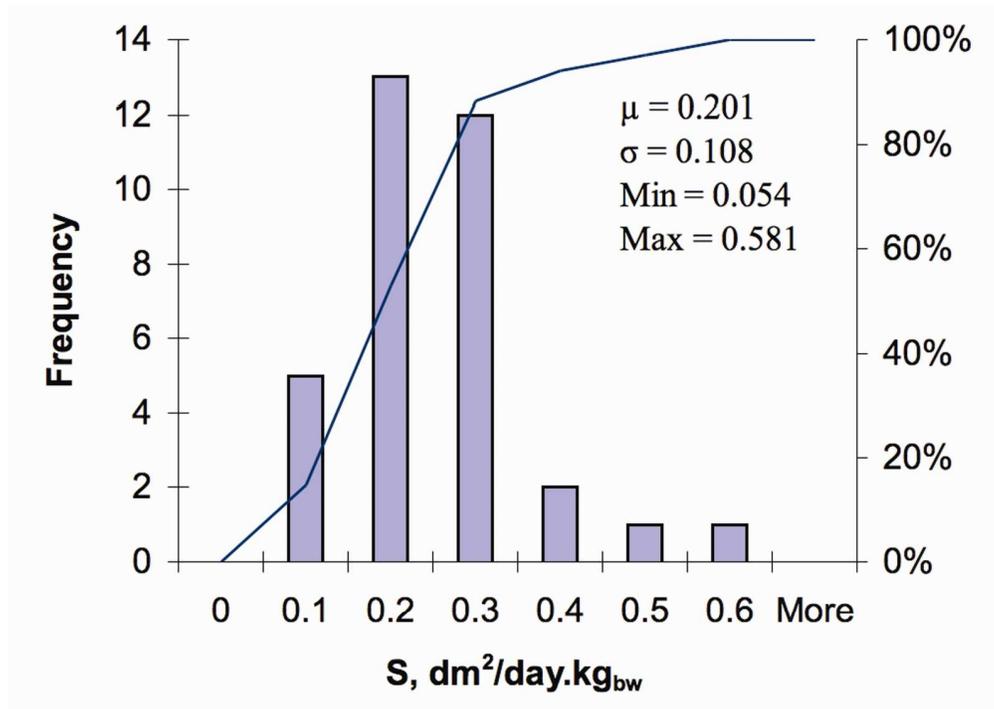


Figure 4. Packaging (all materials) surface area the consumers are exposed to, per day and per kg of body weight. Adults and children together.  
270x192mm (300 x 300 DPI)

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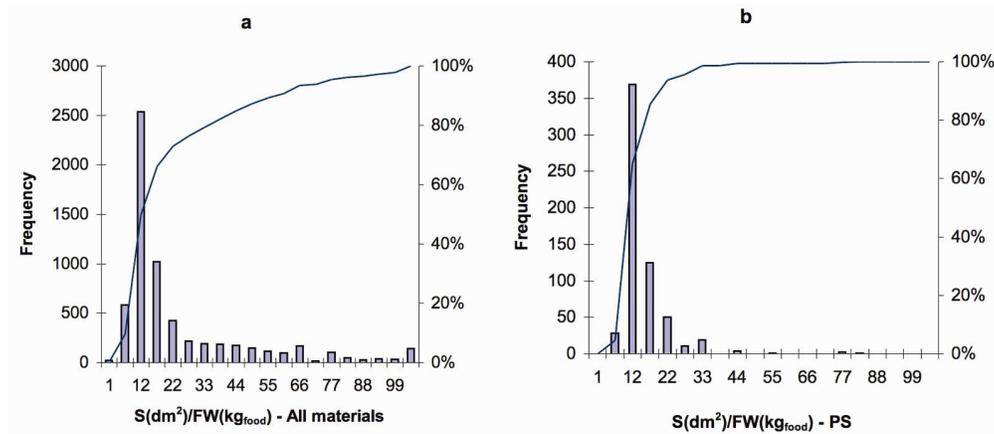


Figure 5. Distribution of ratio surface area/amount of food for all packaging materials together (a) and PS packaging only (b).  
540x235mm (300 x 300 DPI)

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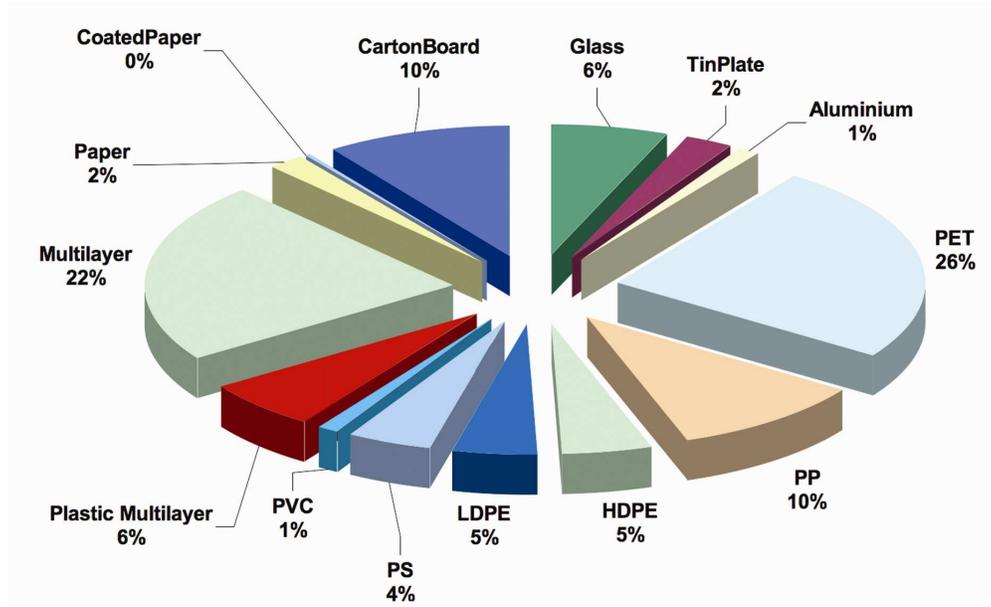


Figure 6. Percent of food consumed contacting specific packaging materials. Plastics specified. Adults and children.

315x192mm (300 x 300 DPI)

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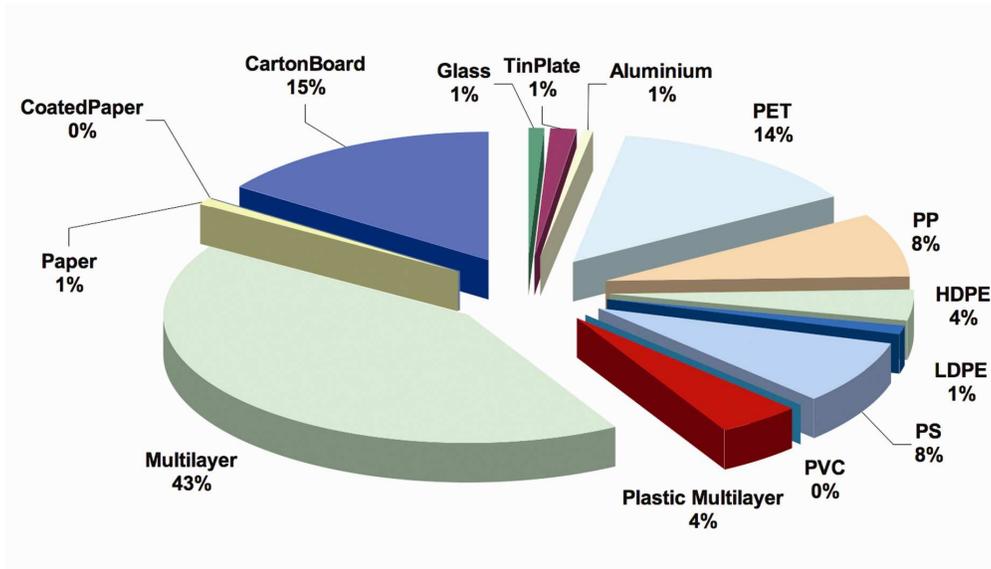


Figure 7. Percent of food consumed contacting specific packaging materials. Plastics specified. Only children.  
315x180mm (300 x 300 DPI)

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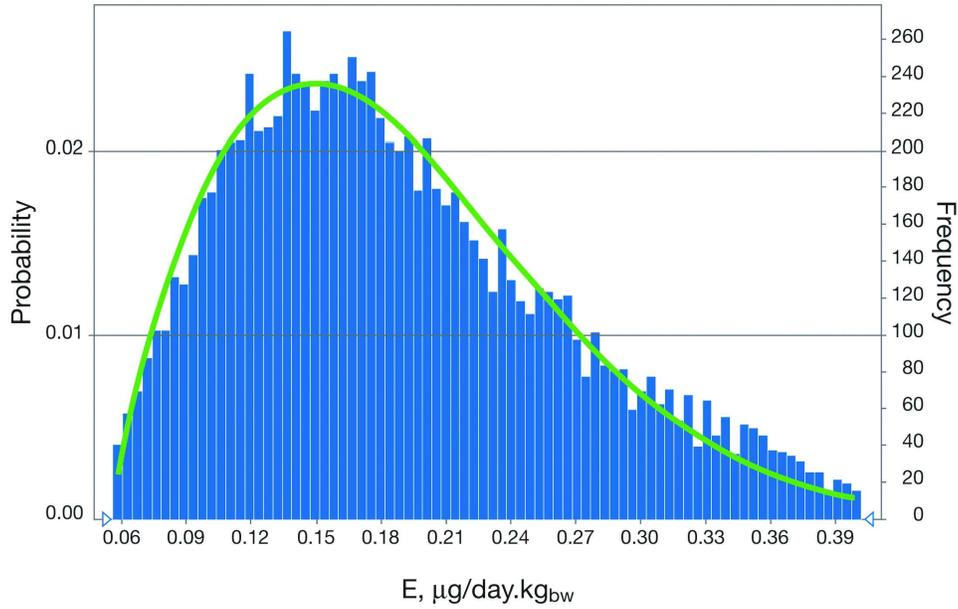


Figure 8. Distribution of values for the exposure estimate of 2-ABA from PET bottles.  
192x126mm (300 x 300 DPI)

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