Towards a Generic Set of Packaging Material Key Figures

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Abstract:
Many companies consider the reduction of packaging material as a relevant development direction, either required by cost savings, supply chain efficiency, sustainability or substantiated by regulations (directive 94/62/EC). This aligns with an eco-efficient redundancy perspective on packaging. Research shows that material efficiency requirements in packaging design briefs are often only justified by aims towards cost reduction; commercial viability is regularly prioritized over sustainability aims.
Insights collected from current material quantification analyses like product-packaging life cycle assessment (LCA) and costing (LCC) are not directly applicable during generative development processes. Packaging material key figures can be useful for that, as the middle ground between design guidelines and rules-of-thumb but research in this area is limited. Key figures are established in other sectors like electrical appliances' energy use, automobile fuel economy, or housing energy efficiency.
Based on existing studies about eating patterns of Dutch consumers the research determined typical fast moving consumer goods consumption patterns that are grouped according to product type and use scenario, which lead to daily product consumption patterns. Key figures of used amount of packaging material per product type are determined by looking at packaging solutions present in the market. These figures are linked to the consumer patterns. The outcome is compared with annual packaging waste figures as validation. The research shows for example that packaging material use for food products is currently over 6 times higher than material use for non-food products, and that beverages and products required for dinner require the highest amount of packaging.
The research contribution is a collection of packaging material key figures, grouped per product type and use scenario. The range of key figures (minimal and maximum material amounts) is useful as starting point for efficient material use in packaging design.

Keywords: packaging design, packaging material, design brief, sustainability, key figures, benchmarking.

1 Introduction

In the packaging industry, the use of (scarce) resources is an important topic, in which the reduction of material usage is often used as one of the key performance indicators for sustainable packaging development. Consequently, organizations address packaging material reductions as an important (near) future direction of development [1]. Drivers for this development aim include desired cost savings, sustainability considerations, or governmental regulations, such as EU directive 94/62/EC [2], aligning with an eco-efficient redundancy perspective on packaging [3]. Material efficiency requirements for packaging development are often mainly justified by cost reduction aims; commercial viability is regularly prioritized over sustainability considerations [1, 4].
Targets for packaging material reduction and resource avoidance and similar aims are becoming a de facto standard in sustainable strategies. However, such strategic aims are not by default incorporated in operational packaging development processes [5-8]. On a daily basis, packaging design processes are not managed solely on amount of packaging material in weight. In fact, there are strong indicators that weight is not a top priority as more intricate issues such as production; brand image; quality assurance and safety are top of mind for the various actors involved [1].
When given priority, achieving such reduction targets requires considerable effort, involving hard-to-make decisions and considerations on e.g. the required functions, especially related to the (food)

product [9], life cycle engineering issues - taken into account all packaging-, product- and material chains [10], and consumer behavior and attitudes towards packaging related to sustainability [11].
Concrete aims for materials reduction are potentially powerful mechanisms in concretizing the holistic ideas of sustainable development. It does however come with important restrictions that are not easily expressed in quantifiable targets such as protection of the content, preserving the desired brand image, ease of use and logistical performance.
From practice [12, 13] it is evident that benchmarking is an important, if not indispensable step in achieving these goals [14]. However, the packaging industry has no standardized and agreed upon benchmark data publicly available. As such, benchmarking is often a singularized endeavor, while the packaging industry as a whole has no data to determine and justify its position.
This paper provides insights into the added value of packaging material key figures, and illustrates this relevance by means of a case study of Dutch food packaging available for the consumer. Based on an overview of previous benchmark studies and available resources for benchmark data, a generalized approach towards data gathering and representation is proposed. The primary aim is to investigate the possibilities for an understandable and widely usable set of key figures based on amounts of packaging material per amount of packed product, related to portion sizes. Furthermore, we investigate the influence of functions on the required amounts of packaging material and outline a future agenda.
Overall, this paper is an attempt to regenerate the debate on standardized key figures for the packaging industry as a means to steer (sustainable) packaging development.

2 State of the art

Industry has made several attempts towards setting or gathering comparable benchmark data of used amounts of packaging material. To illustrate the diversity in approaches some key studies are briefly discussed. Data published or provided by material associations are not taken into account in this brief overview as our primary objective is to establish key figures for the entire packaging industry. Moreover, as our starting point is formed by on-the-shelf packaging, and a considerable amount of packages consists out of more than one material, these data sources are of limited use.

2.1 Benchmark studies

INCPEN has published a study in which an attempt has been made to get insight in changes of use of packaging material based on demographic developments (e.g. smaller families, more people living on their own, new types of food that are introduced and more single servings) [9]. While the data itself is dated, the study adequately addresses three important stakeholder groups when it comes to sustainable development: industry, legislation and consumer. Based on an environmental assessment of the impact of packaging in UK-based food systems, the study proposes several guidelines specifically aimed at the various stakeholders, in which the need for addressing sustainability issues collective is highlighted. This study puts packaging in context of food products, production and consumption, stressing the need to align packaging development with consumer's needs (right portion sizes and buying behavior, demographic changes), the entire life cycle of the food chain and links sustainable packaging development not primarily with reduction of packaging material but with the prevention of food waste first.
The relation between the amount of required packaging material and demographic changes touches upon the very essence of why key figures are needed. The question how much extra packaging material will be used if for example family sizes reduce or if an increase in single-person households cannot be answered without solid benchmark data available as reference. Emerging trends such as consuming on-the-move (OTM) or out-of-home (OOH) [15, 16] stress the need for these data; without it none of the involved stakeholders can adequately determine strategies and efficient next steps.
INCPEN published a benchmark study after energy cost to feed one person [17]. The study presents the role of packaging as a benchmark of energy use compared with other activities like room heating and driving a car and presents the energy use of all steps in the packaging chain of one person eating.

In 2010 the Dutch National Institute for Public Health and the Environment (RIVM) executed a research on functionally comparable wine bottles sold in Dutch supermarkets with a volume of 0.75 liters. The measurements established for this brief study indicate a significant difference and started a debate that eventually lead to establishing a lightweighting goal. The lightest bottle weighted 306 grams, the heaviest 645 grams. The average weight was 468 grams out of a batch of 86 bottles [18], all from a different brand, taken from eleven supermarkets, all of different chains (some of them cooperate in purchasing).

In the Netherlands sectors devise innovation plans for sustainable packaging as agreed in the Framework Agreement for Packaging 2013-2022 [19] . One of the sectors is the Dutch organization of wine sellers. Annually, this organization determines the average weight of used bottles on base of research executed by an external agency. In 2014 the average weight per liter is 520 grams, equal to 390 grams per bottle of 0.75 liter. An overview over the years is presented in figure 1. Based upon this study, the branch has set targets to reduce the average weight of glass bottles for wine with 1% per year.

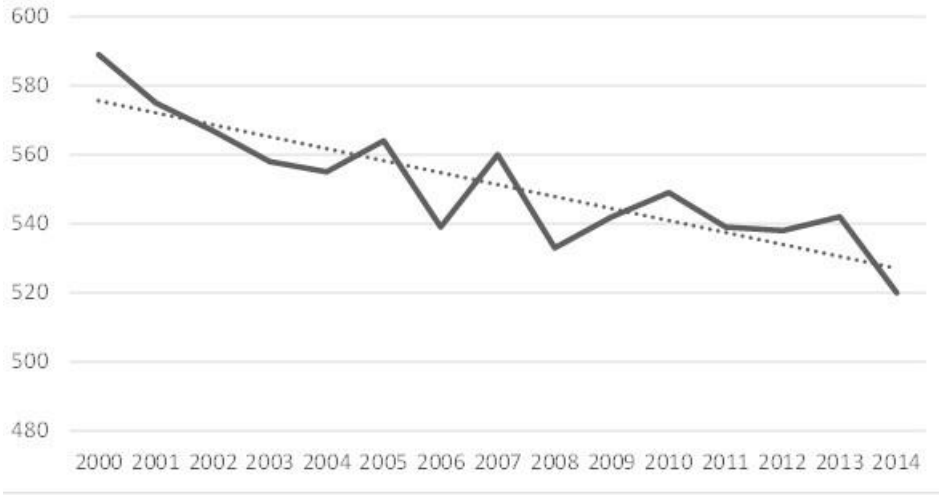

Figure 1: Average weight of glass bottles on base of weight per liter with trend line [Sector Innovation Plan Wine [20] [g/liter]

The examples of the determined weight of wine bottles show that analyses of packaging in the market give insight in used amounts of material for the same function fulfillers. Further analyses in the case of wine bottles could give insight in reasons for different used amounts of weight per bottle or bottle type like the way of transport, the transport distance, the shape of the bottle determined by the region of production (Bordeaux shape versus Bourgogne shape for example) in relation to the content, to translate the key figures to design rationales.

In 2012 in Spain a study was executed in which the relation between the amount of packaging waste and associated factors like demography, technical developments, type of shops, was executed [Evolution of the generation of packaging waste and study of associated factors [21]. One of the conclusions presented a key figure: “To contain and distribute 1 kg of product, currently 68 grams of packaging is used, compared to the 80 grams that were needed in 1999.”

2.2 Resources for benchmark data

The Sustainable Packaging Coalition has several publications available on material data, of special interest is their Metric Framework for Sustainable Packaging [22]. The framework does not actually provide data, but states important requirements for data gathering. It proposes an elaborate set of standardized indicators and metrics for the entire packaging chain that extends beyond the scope of this research and is also suitable for data gathering for life cycle inventory databases. With a comparable initiative [23], Europen and ECR Europe published a report in 2009 in which they state about measuring the impact of packaging in your business: “The most important of these is that targets should be measurable against key benchmarks. Only if these targets are properly established will it be possible for an effective strategy cycle to exist.”
Several organizations have published statistics, set up from a waste perspective [24], [25]. Key findings counter the public opinion that packaging is considered a negative contributor. Key findings report that in fact the amount of packaging material is declining at a slow pace, and recycling rates are higher than in other industries.
The amount of packaging waste in the Netherlands is published by the organization Afvalfonds Verpakkingen annually [26]. Companies have to register the amount of packaging they put on the market if it exceeds 50 tons. Collected amounts are measured and on base of these sources the total amount of packaging material is presented.

In total 2,787 kton of packaging material is put onto the market in 2014. This accounts for all packaging materials, also for non-food. The share of food is estimated at 70%, the share of the food related companies according Afvalfonds and the share of used packaging materials for food according the World Packaging Organization excluded industrial and bulk packaging [27]. The number of inhabitants in 2014 was 16.8 million. This would mean that on average per person 455 grams is used in total and 318 is used for food packaging.

In a technical study executed by LEITAT and JRC IPTS for Cosmetics Europe [30] the weight of the packaging is compared to the packed weight of the product, the Weight/Content Ratio. After research, the formula was extended and other parameters apart from the weight were taken into account (Packaging weight / content ratio, renewable, recycled and refillable packaging), named the Packaging Impact Ratio" (PIR). The current weight/content ratio limit is 0.3 g of packaging for 1 g of product. According to Ecoembes103, weight packaging for packaged products in Spain has decreased by 6% from 2006 to 2010. The presented figures of Weight/Content Ratio are:

- average of 0.19 g packaging/g product with a range of 0.1 to 0.29 in 2012
- average of 0.15 with a range of 0.1 to 0.2 in 2006.

Many brands that are on the market in Spain are on the market in the rest of Europe as well and the study presumed that the figures will probably account also for the rest of Europe.

From a very different angle, the Dutch RIVM has executed an extensive research of what people eat on daily base in the Netherlands, the 'Dutch National Food Consumption Survey', executed from 2007-2010 [28]. The research presents the amounts of food people consume in age classes every day on average base in 17 food categories. These figures can be used to calculate the related amount of material for every day by use of the database with weights per unit of product.
In the Dutch Survey "the average food consumption over 2 days was calculated for each participant. From this, the median consumption per food (group) was estimated for each age gender group, as well as the 5th and 95th percentile of consumption. As the distributions were skewed, medians are presented in this report, as mean intakes would not reflect an accurate 'average'".
The RIVM research presents figures on base of the population of 2010. The diet of children and adults aged 7 to 69 years are presented in the 6 age groups. The age groups represent in total 13.5 million inhabitants of a total from 16.6 million. The amount of inhabitants of 2010 is scaled up to the amounts of 2016 by use of the figures of the national statistical office in the same age groups. It is presumed that people in the same age group eat the same in 2016 as in 2010. The weighted average of the 6 groups on base of the population of 2016 is taken as the overall average consumption pattern.

While there is a wide variety of resources and studies available, we have not found one dominant source for benchmark data. Perspectives, scope and measures vary greatly, despite numerous attempts there seems to be no consensus on what actually key figures should entail. Surprisingly, very few studies focus on the packaging that is available for the consumer. As such, there is currently no solid common ground for benchmarking in the packaging industry, let alone a set of figures that is widely usable for key decision makers throughout the development life cycle of packaging. The application of key figures is therefore currently limited.

3 Approach

3.1 Purpose

The aim of the research is to establish a base for key figures that adds value in multi-stakeholder decision making processes when executing structural packaging design processes. In the first place to be able to focus a design project on the amount of used packaging material. In the second place the attempt is to look if it is possible to find relations between functions of packaging and the used amount of material. If key figures can be determined, they could also be used to determine needed amounts of packaging material related to consumption patterns.

3.2 Definition and principles

For this study, the following definition of packaging is applied:

"A packaging is a (set of) physical artefact(s) that temporarily or unremittingly assumes the functions preserving, protecting, enabling use & handling and conveying formal & informal information of the related product" [10].

Due to its nature, packaging cannot be viewed in isolation, but should always be viewed in light of its packed product [9], [Kooijman] [29]. Consequently, reasoning from a sustainable development viewpoint, there are two primary life cycles – of both the product and the packaging - to take into account. Moreover, in determining a baseline all functions should be considered. Not only to investigate the relation of weight with specific functionality, but also to prevent a singular minimized weight bias. As such, this study tries to determine a weight-content ratio based on quantifiable measures without losing sight of the more intricate elements of packaging and packaging design.

3.3 Method of determining packaging weight per product

In order to determine the weight-content ratio, the weight of the packaging has to be determined. In order to come to a reasonable measure, we propose to combine a hands-on approach with a more formal check. Primary source will be weighing the packages using commercially available scales for practical reasons. Weighing should be executed after emptying the packaging, cleaning and drying. The weight of the packages is compared on different scales. These measures will then be justified using other sources, e.g.:

- Specification from known packaging items
- Calculations based on the density, thickness and surface of plastic films and aluminium lids for those items from which the details like the thickness are known.

3. 4 Consumption patterns and daily profiles

This study is primarily focused on the consumer's use of predominantly primary packages. In choosing this consumer perspective, we aim to set a base for key figures that are understandable and interpretable for a broad public. Furthermore, such a perspective complements the already existing studies reasoned from either a waste perspective or from a material perspective. More importantly, with a consumer perspective, the possibility arises to determine the amount of packaging material on daily base for food of a consumer as a key figure. Data sources should therefore be useable to determine profiles related to the population and consumption.

4 Case study

As stated in the approach, this study starts from a consumer's perspective and then sets out to find key figures that can be used in steering design processes. The case study is focused on packages available in Dutch retail. As the overall goal is to determine key figures for the use of packaging material on base of daily profiles and consumption patterns, this study doesn't start with the packages itself but with data on consumer behavior.

4.1 Consumer consumption data

In order to establish a base for consumer consumption, two approaches have been chosen:

1. An overview of what people eat daily, based on the research executed by RIVM [28];
2. Possible scenarios of food transportation, preparation, and consumption throughout the day.

The 'Dutch National Food Consumption Survey' [28] – addressed in section 2 – is applied as a reference point for determining consumption patterns. Complementary to this study, the researchers determined patterns using a number of daily use scenarios. On base of a daily profile of eating, amounts of related packaging material have been gathered as well. The daily profiles that have taken are based on the way most people take food and drinks over the day: starting with breakfast, lunch at noon and dinner in the evening with in between drinks and some snacks.

4.2 Scope and limitations

To get insight in the amount of used packaging material per amount of product the focus has been set on primary packaging. Most secondary packaging, like plastic crates, carton trays and boxes, are not actively used by the consumer. With excluding the secondary packages for practical reasons, this study partly excludes this relation between the primary and secondary packaging. It is decided to focus on

primary packaging first and based on the outcome of this research to take secondary packaging into account in a consecutive phase.

4.3 Method

To be able to get insight in used amounts of packaging material per amount of packed product, a method has been chosen that can be described as expedient and effective. Products are taken from Dutch supermarkets and shops. After emptying they are weighted and taken up in a database with the packed amount of material.

The variety of packaging solutions is large and convergent. Diversification is found in the following factors: the packed products can be different with different vulnerabilities, for example a shelf life of two weeks or two months for the same product like nuts packed in PET cups and in laminates; the packed amounts can be different; the type of packaging can be different like a carton versus a cup; the product can be consumed at home or on the move. Nevertheless, there are large categories of packed products from which the type of material and the used amount can be compared. To make a start the focus that is chosen is on product level, for example orange juice or yoghurt. The type of packaging has to be taken up and if a product is fresh or prepared will be mentioned in the database.
The total packaging is weighted, including all items like cap, label, sleeve etc. If possible parts have been weighted separately as well. The materials are split up according type of material: glass, metal, paper/board, plastics and wood. Coatings are not taken listed separately, just as e.g. aluminium in a laminated board (like wax-paper-plastic-aluminium-plastic, for a drinking carton) or a laminate like PET-aluminium-PE. From many packaging materials the construction is not known exactly; thickness and type of material for coatings, adhesives, layers in laminates, amount of adhesive for labels, inlay or compound in caps. In that case, the total weight of the material or part of the packaging is taken as measure.

4.4 Data

The weights of 463 food (and 50 non-food packages) – a selection out of a larger sample – are taken up in an xml database. Products are grouped in the following categories: bakery, fruit, vegetables, dairy, meet/fish/chicken, soup, snacks, beverages, bread spreads, oils and fats, herbs and spices, take away, ready meal. Taken up are the weight of the total packaging, of separate items if possible, the amount of packed product according the label, the weight of the used materials and the brand name to be able to monitor the packaging weight over a longer period. The amount of packaging material in grams per amount of packed product is calculated: the Weight/Content Relationship [30].
If products have to be packed by consumers themselves, an amount of product that is taken is estimated. For example fruits and vegetables are often offered in carton boxes and plastic crates are put in free HDPE bags of 4 grams each. The bags can contain more than 1 kg of weight but 0.5 kg looks more comfortable. In that case 4 grams of plastic is used to pack 0.5 kg of product, equal to 8 grams per kg, if applicable this number will be used. A reliable figure can only be determined if exactly the amount of tomatoes and the amount of bags used to take them home is known.

4. 5 Findings

For all products variety in used amounts of packaging material is found. Sometimes the variety is very large like for tomatoes (see Figure 4). There are different types of tomatoes and the packaging have different functions. Some types of packaging are used for different products like the same plastic trays for fresh meat, fish and chicken. The trays with top seal have the same weight; the weight of the product differs. This gives different outcomes for the Weight/Content Ratio.
Different products are often packed in the same amount of material. There can be several reasons for this:

- The same packaging is used, for example the same dimensions and same type of film or folding boxboard
- Smaller companies often buy standard packaging out of stock like standard bottle designs, standard boxes etc.
- An A-brand company or a Private Label producer can produce several brands and often the same packaging types are processed

The findings are presented at three levels of benchmarking. At first at the level of products within the same category, fulfilling the same functions: the micro level. Then at a higher level – determined by the

micro level – like fruits or meals, the meso level to see if certain products use varying material amounts. The meso level is based on the Dutch National Food Consumption Survey [28]. At last the macro level; a profile of use of packaging material over the day that is formed by the findings at meso level.

Benchmark at micro level

The amount of product per packaging varies a lot. There are portion packs and family packs for deserts for example. Branding is of importance; some brands use thicker films than functionally needed because it probably fits to the luxury position in the market. Some products are pasteurized; others are sterilized with different shelf lives. Transportation distances can be different like wine coming from Australia or from France. Dispensers need different stiffness of a container than squeezable bottles. One or more of the functions has to declare that it defines the bottleneck of the needed amount of material according the essential requirement of EC 94/62 about prevention. The following examples illustrate that for every product, comparisons can be made this way and that diverse design solutions can be compared.
Figure 2 presents the weight of PE bottles with cap and label used for packing liquid margarine in g of packaging material per kg of product. The content of the bottles varies from 0.435 to 0.75 liter and are from A-brands and Private Labels. While the functions of all bottles are the same: a squeezable PE bottle that portion, conserve, distribute, present and sell liquid margarine, a significant variance in weight is found. The examples show that questions can be asked after the found different amounts of packaging material needed to pack the same product, from 4.1 to 8.1 g to pack one kilo.

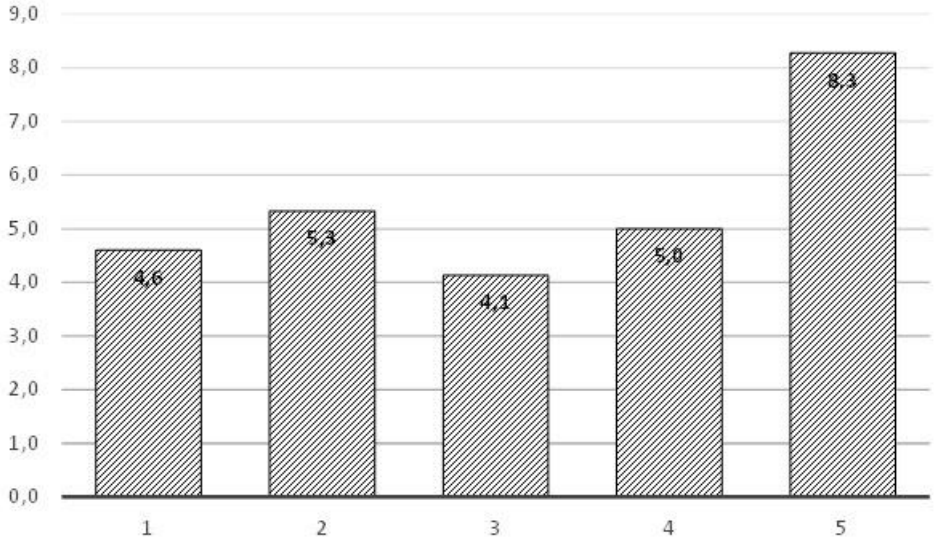

Figure 2: The table shows the weight/content ratio, the amount of packaging material of liquid margarine packaging; the weight of PE bottles with cap and label in grams packaging material per kilogram margarine [g/kg]

The found amounts of packaging material for chocolate sprinkles, used in the Netherlands on bread shows a similar image (figure 3). All packaging are made from printed solid bleached sulphate. The contents of the packaging vary from 400 to 600 grams.
Square and rectangular boxes are used. It is remarkable that the package with 400 grams uses less packaging material per amount of product. Intuitively, one might expect that packages with the most content use the least amount of material but for these boxes that is not the case. One possible explanation for such a ratio is that the lay out, in combination for instance with the needed grams of the cardboard box, renders this unexpected result.

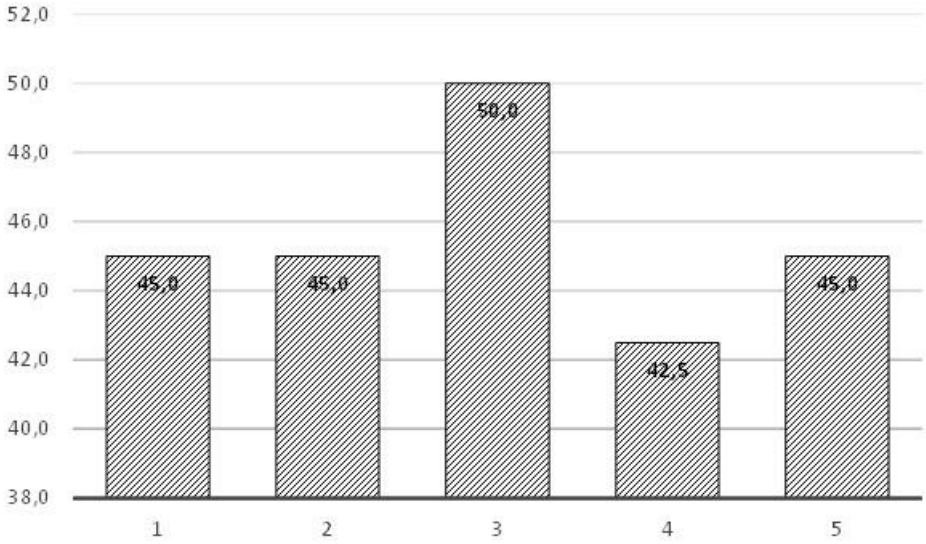

Figure 3: Found amounts of packaging material in grams per kg product of different brands of chocolate sprinkles [g/kg]

Benchmark at meso level

Tomatoes are found in the supermarket in a variety of types and sizes, sold either separate and in bunches. Beefsteak tomatoes are offered separately in plastic crates or carton boxes. Other tomatoes are offered on black PET trays packed in a BOPP flowpack. Cherry tomatoes are packed on trays in flowpacks, in square cups with a clam shell lid and in buckets with print on the outside to get kids interested in eating tomatoes (instead of products that are seen as unhealthy). Presenting tomatoes on a tray and probably adding extra protection this way asks for more packaging material per kg of product, from 14 grams of packaging material per kg of tomatoes for large tomatoes up to 76 g/kg for cherry tomatoes (19 grams packaging material for 250 grams of bunch cherry tomatoes). The weight of the bucket with lid is 30 grams for 500 grams of tomatoes, which means 60 g/kg. Cherry tomatoes are packed in 14 (cup with lid), 60 (bucket for children) and 76 (luxury presentation on a tray) grams per kg. More analysis is needed but it could be presumed that getting children interested costs 46 g per kg and luxury presenting costs 62 g per kg.
Figure 4 shows the amount of used material for packaging of tomatoes.

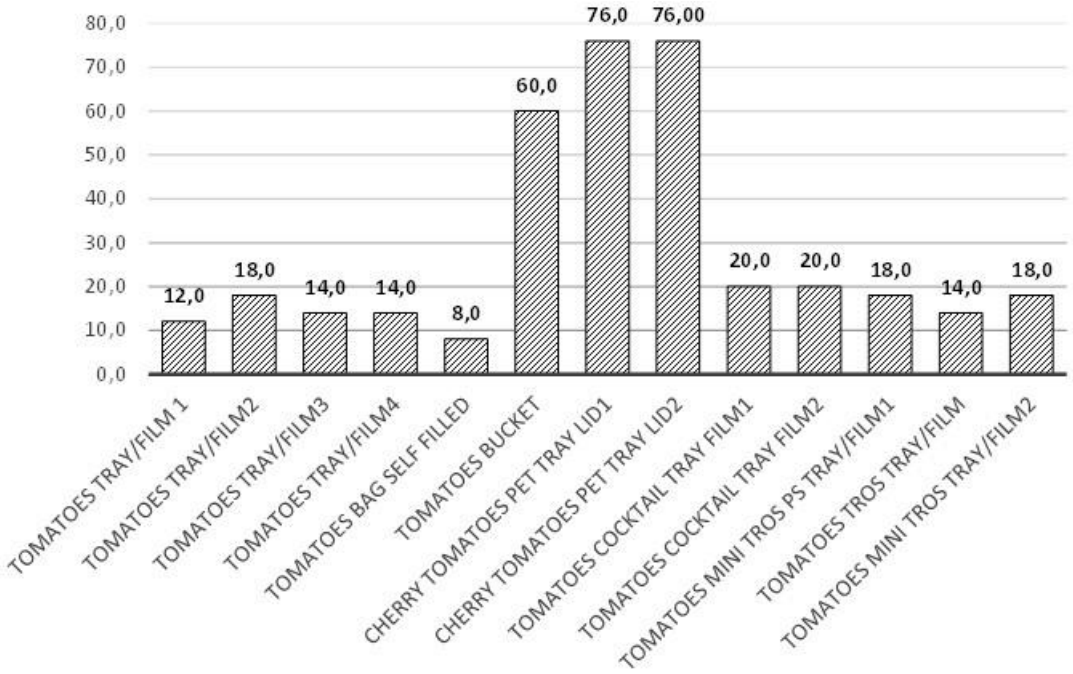

Figure 4: Used amounts of packaging material in grams per kilogram product of different types of tomatoes, packed in different ways [g/kg]

Another example at meso level is presented in figure 5: different types of fruits. The example shows that the amount of packaging material per kg has a very wide spread, from 3 g per kg packed fruit up to 58 g. The functions for different types of fruit are not the same. Some pieces of fruit do not have to be protected against mechanical load by the packaging like apples, oranges, mandarins, while other fruit needs clamshells or cups to be able to transport them home without damage like berries. However, at a micro level benchmark figures of the same products show a significant differences like mandarins packed with 3 grams of packaging material up to 8 grams per kg product, both prepacked and apples from 5 grams per kg in a bag compared with 30 grams per kg for prepacked apples.
Biological products are packed in a distinctive way so they can be recognized from other products. The preferred package for these types of biological fruits seems to be a pulp tray and packed in a flowpack. The amount of packaging material per packed product is therefore higher.

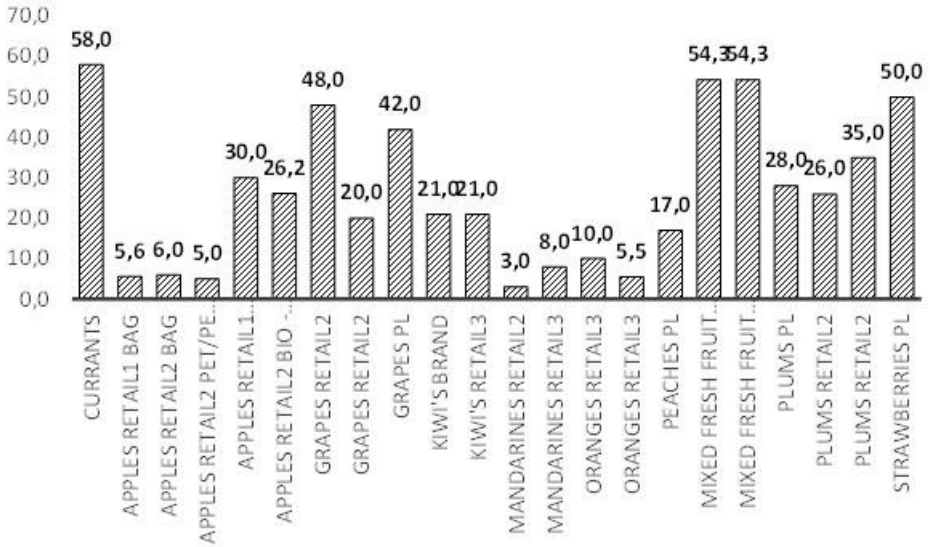

Figure 5: A comparison of different fruit packaging for different types of fruit is presented, from PE bags to cups, trays etc. in grams packaging material per kg of product [g/kg]

Benchmark at macro level

The database of weights of packaging material has been used to calculate the amount of packaging material related to the average consumption pattern. If the minimum and maximum found amounts of packaging material are used, the daily amount of packaging material varies from 390 to 673 grams in total.

Dutch inhabitants g/day packaging material	min		Dutch inhabitants g/day packaging material	max	
13. Non-alcoholic beverages	116,9	30,0%	13. Non-alcoholic beverages	150,4	22,4%
07. Meat and meat products	52,9	13,5%	05. Dairy products	110,7	16,5%
14. Alcoholic beverages	46,6	11,9%	07. Meat and meat products	78,9	11,7%
05. Dairy products	40,7	10,4%	14. Alcoholic beverages	67,8	10,1%
08. Fish and shellfish	28,1	7,2%	15. Condiments and sauces	47,3	7,0%
15. Condiments and sauces	24,8	6,4%	06. Cereals and cereal products	44,6	6,6%
11. Sugar and confectionery	30,0	7,7%	08. Fish and shellfish	41,9	6,2%
06. Cereals and cereal products	13,8	3,5%	11. Sugar and confectionery	40,8	6,1%
04. Fruits, nuts and olives	8,2	2,1%	16. Soups, bouillon	33,9	5,0%
02. Vegetables	6,9	1,8%	02. Vegetables	18,0	2,7%
16. Soups, bouillon	6,1	1,6%	04. Fruits, nuts and olives	14,4	2,1%
12. Cakes	6,6	1,7%	01. Potatoes and other tubers	8,6	1,3%
10. Fat	3,4	0,9%	12. Cakes	6,7	1,0%
09. Eggs and egg products	2,9	0,7%	10. Fat	3,8	0,6%
01. Potatoes and other tubers	1,1	0,3%	09. Eggs and egg products	3,5	0,5%
03. Legumes	0,8	0,2%	03. Legumes	0,8	0,1%
17. Miscellaneous	0,7	0,2%	17. Miscellaneous	0,7	0,1%
	390,42	1,00		672,8	100,0%

Table 1: An overview of the 17 used food categories and calculated minimum and maximum amount of packaging material based on the database of weighted packaging ordered by quantity [g]

Table 1 shows that a few categories determine most of the used packaging material: beverages (non-alcoholic and alcoholic), meat and meat products, dairy products, fish and fish products, condiments and sauces and cereals, sugar and confectionery and cereal products. Figure 6 presents the results of the research of preparing a meal. Next to a set of alternatives available from retail, two take-home options are taken into account as references. It shows that there is a large difference in amounts of packaging material needed for a hot meal. If a meal is prepared out of basic, fresh ingredients, even less than 10 grams of packaging material is needed. All the ingredients are packed in plastic bags. If a meal is prepared out of readymade basics, the total weight can go up to almost 400 grams, which is significantly higher than all other alternatives.

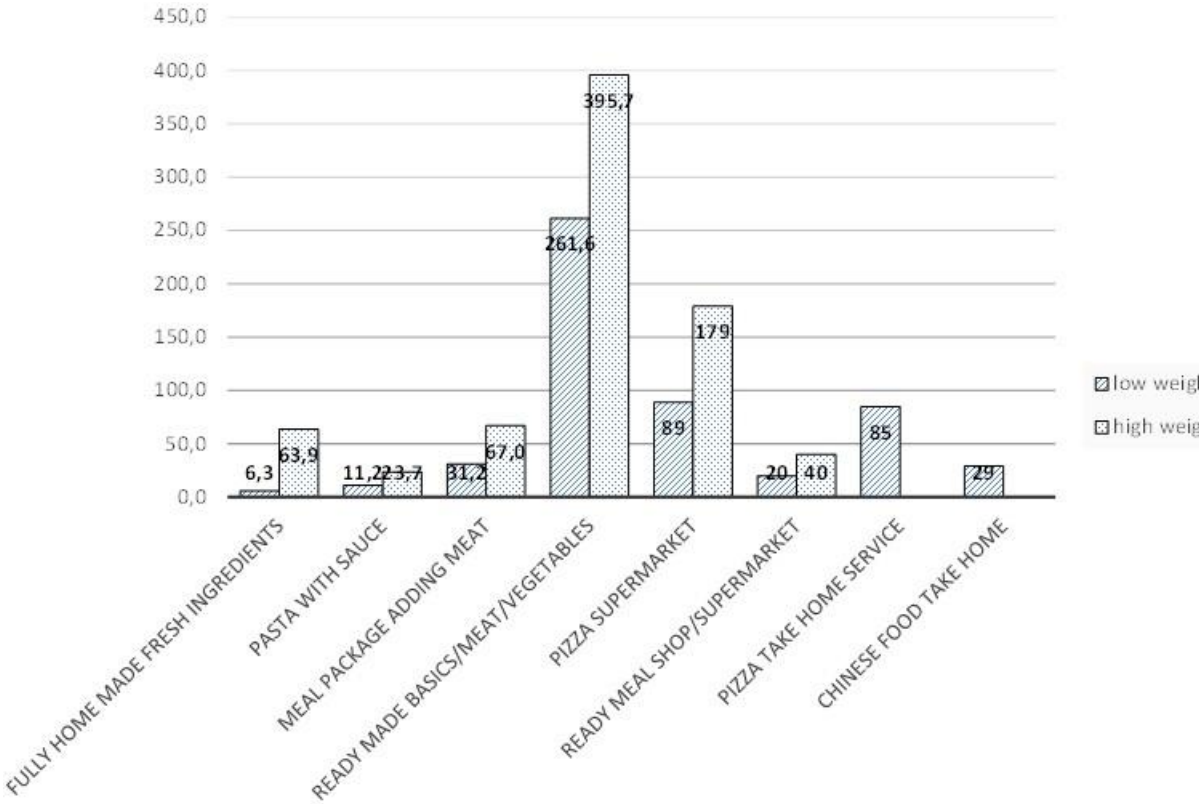

Figure 6: Weight of used packaging in grams in total of possible ways to prepare a hot meal. The minimum and maximum found amounts of packaging material have been used [g]

A fresh pizza from the supermarket uses more packaging material than a pizza from the take home service. This can probably be linked to the functions of the different packaging; the fresh pizza with a long chain, the pizza from the take home service with a short chain. Ready made parts of the hot meal like readymade mashed potatoes, readymade meat and vegetables, use most packaging material. The products are vulnerable and the packaging can be used in an oven or microwave. Preparing the hot meal out of ingredients uses least amounts of packaging material.

In table 2 an overview is presented of the minimum and maximum found amount of packaging material per amount of product, based on daily profiles without the take home meals. The amount of packaging material is 57 grams at least and 830 at maximum. Dinner and beverages determine the total amount for a great deal.

	min. found	max. found		
Breakfast	2,5	4,4%	19,3	2,3%
Coffee etc.	2,1	3,6%	13,9	1,7%
Lunch	20,4	35,5%	34,1	4,1%
Break	4,1	7,1%	18,2	2,2%
Diner	6,3	10,9%	395,7	47,7%
1 piece/portion of fruit	0,5	0,8%	9,3	1,1%
Salad	2,2	3,8%	18,4	2,2%
Desert	6,0	10,5%	16,5	2,0%
1 piece/portion of fruit	0,5	0,8%	9,3	1,1%
Beverage	4,3	7,4%	134,2	16,2%
Coffee, tea	2,1	3,6%	13,9	1,7%
Snack	2,3	4,0%	13,0	1,6%
Beverage	4,3	7,4%	134,2	16,2%
	57,3	100,0%	829,9	100,0%

Table 2: Minimum and maximum found amounts of packaging material in grams per day per inhabitant based on profiles of having food all over the day.

On base of the database different daily profiles can be set up. The presented daily profile is used as an example of a possible eating pattern throughout the day.

4.6 Conclusions

Benchmarking at micro level by weighing packaging is a mean in finding key figures of packaging weight. For the micro level, only weights of packaging with a comparable set of functions should be compared. The technical shelf life of the products has to be the same as well. The case study indicates that there are large differences in used amount of packaging materials for packaging solutions with the same functions for the same products. Additional research should clarify whether these differences are justified (by e.g. the specific chain) or not.
By comparing found amounts of packaging materials and different functions of the same product, the functions can be accounted to the extra needed amount of packaging material, as the example showed with the packaging of tomatoes; getting children interested in eating tomatoes costs 46 per kg and a luxury presentation costs 62 g per kg.
At meso level different solutions can be compared as the example with fruit showed. This gives insight in differences between functions and used amount of packaging materials to fulfil these functions like protection of vulnerable fruit and presenting fruit. More research is needed after functions and behavior of the packaging in the chain.
At macro level different ways are used to get insight in used amounts of packaging material on base of food consumption. On base of the RIVM food consumption study the weight of packaging used on average per day is between 390 and 666 grams. On base of daily profiles of eating food over the day the weight of used packaging material is between 57 and 830 grams.
Dinner, beverages, dairy products, meat and meat products, fish packaging, condiments and sauces, take most packaging material of the food consumption; in total between 79.4% and 73.9% depending on the minimum or maximum found amounts of packaging material per unit of product.

5 Discussion

5.1 Limitations

The database contains the weight of 463 packages of food products and the research was focused on extremes. This research after used packaging is far from complete. These figures represent larger numbers of packing in total because many products are packed in the same packaging but an extensive research is needed to be able to determine the average weight of a packed product and to find the lightest and heaviest packaging that are used in the market. The way of weighing is expedient and

effective but not without flaws. It takes time to collect data, especially reliable data. For more reliable figures connection with data from producers, packers or from an existing database is advised.

It has to be researched if reliable and accurate sources of data can be used and this is considered as a logical future step.
The study focused on food packaging because 70% of the total amount of packaging material is determined by food. Further research has to show if the same approach accounts for non-food as well.

5. From Weight/Content Relationship to Product Impact Ratio

The Weight/Content Ratio is a first step towards understanding the use of needed packaging material. The boxes of sprinkles showed that it is not always smart to rely on logic; smaller packed amounts had a lower Weight/Content Ratio. The used material, the design, the stiffness of the box, all determine the total weight. An open source accessible for designers and public can help in reducing the amount of packaging material unless proven otherwise. To come to more sustainable solutions, the Product Impact Ratio approach could be used. A start can be made at micro level to understand the reason(s) behind the differences of the used packaging solutions for the same product.
A next step could be to link the database to life cycle inventory databases but this needs research as well.

5.3 Structural Packaging Design

To manage the amount of packaging material used for food packaging goals could be set about targets for new structural packaging designs in relation to functions they fulfil. This is in line with the essential requirement as defined in [2]. In the design brief the amount of material per packed volume can be taken up as a requirement or guideline but not without a description of the functions the packaging has to fulfil. Further research has to proof if the environmental footprint of the packaging can be improved. To be sure that the approach will not lead to falsified solutions, limitations should be taken into account like: product loss in the chain, the relation between primary and secondary packaging, efficiency on the packaging line, logistical efficiency, left over in the packaging etc.
Research has to give insight if additional material is needed for added functions and if such an approach can be used as a challenge for designers: find solutions for the fulfilment of the wanted function with as little material as possible in line with the essential requirement regarding prevention (EC 94/62). Bottlenecks that determine the amount of needed packaging material could probably be declared better on base of public data. Companies can use it but also society can get insight in needed amounts of packaging material. Even hard goals could be set on the level of a branch.
At meso level solutions can be searched to reduce the total amount of packaging material for a certain category of products like fruits or vegetables. Research can be executed if packaging solutions that are used for other products can be useful for a packaging that has to be redesigned. The database can give insight in amounts of material that are linked to certain solutions.
At macro level the total amount of packaging waste can be managed. Especially because of the changing way of consuming food. Changes in total amounts of packaging material could be linked to developments in society and demographic developments. A first key figure that can be used is that consuming food takes about 318 grams of packaging material a day with a minimum of ca. 60 grams for preparing dinner out of ingredients that can go up to 800 grams for partly prepared dinner items.

6 Concluding remarks

This paper reports on the first steps towards establishing a base for key figures that adds value in multi-stakeholder decision-making processes when executing structural packaging design processes. With a hands-on approach reasoned from a product and consumer perspective the case study performed with packaging available in Dutch Retail, indicate significant variances for functionally comparable packaging. Differences in weight can also be related to different functions the packaging fulfills. For product categories and daily profiles such as preparing a meal, greater differences are observed. However, it is too early to conclude that standardization is applicable for these cases, additional research is needed into the specific chains.
By continuing weighing packaging the database will grow and will keep on growing throughout the years. New items that are being weighed have to be dated according the year the product is packed this way

(2016, 2017, etc.). In this way it is possible to get insight in changes in used solutions and to monitor the use of packaging material of products at micro level, of categories at meso level and in total at macro level throughout the years. A link with demographic developments can be made.
Moreover, for structural packaging designer a challenge can be introduced in the design process. By enumerating functions, comparisons can be made with other packaging solutions that fulfil the same function. If possible the amount of material related to functions can be taken up as a goal to achieve during the design processes. It could mean that a set of data could be used to determine the amount of packaging material with which a design can be realized.
While the established ratio measures alone for now are too limited to directly use in decision processes, the possibility to aggregate these measure for profiles is promising. Furthermore, a unification of various sources could enrich the data, moving from weight ratio towards a packaging impact measure.

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