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RESEARCH ARTICLE

Mapping Of The Potential To Substitute Plastic In Food Packaging In Finnish Supermarkets

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ABSTRACT

Single-use plastics (SUP), which are extensively utilized in food packaging, are one notable cause for the constantly growing littering issue. This novel study is one of the first attempts to systemically analyze food packaging data to reveal the potential for plastic packaging material reduction or substitution by utilizing a primary packaging material summary of single items sold in Finnish supermarkets. The outcome of the study indicates considerable dissimilarities among product groups concerning used packaging materials, weight, share of plastic, and sales volume. The analysis identified sweets and ready-to-eat meals as product groups for which there is a clear need, but also the most potential, to reduce the use of single-use plastics in food packaging.

KEY WORDS

Food package, littering, single-use plastics, Single-use plastics directive, substitution, sustainable food packaging

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ABSTRACT (CONT)

In these specific product groups, the sales share in euros is high (over 2%) and plastic is widely used (48–51%). The share of primary packaging material is also at a notable level (5–7%). Additionally, both product groups are significantly affected by the SUP directive and create a notable risk for littering. For ready-to-eat meals, the substitution potential of plastic is estimated to be close to 2,000 tonnes in Finland. Even so, sustainability is not solely accomplished by a replacement of the conventional packaging material with completely new solutions, and it is evident that there is no single and all-inclusive solution for future food packaging. Instead, the way to more environmentally friendly packaging combines several solutions of 4Rs - Reduce, Reuse, Replace, and Recycle.

INTRODUCTION

The world is encountering a serious littering issue, particularly as a consequence of the abundant amount of plastic waste found in the oceans [1]. Yet, plastic usage is anticipated to increase in time to come and the annual production has already nearly doubled (from 234 million tonnes (Mt) in 2000 to 460 Mt in 2019), more rapidly than previously expected [2], [3]. Currently, close to one-third of the total plastic produced is used in the packaging industry [2].

The majority of the plastic litter originated from the wide use of single-use plastics (SUP). SUP is often used by the packaging industry, thus the lifecycle of the material is extremely short [4], [5]. One prime cause for the littering issue is human behavior combined with the non-degradable nature of the traditional, fossil-based plastic grades, and the low recycling rates, when used in food packaging [6]. Still, plastics have multiple favorable attributes that will advance the use of various plastic grades also in the time to come, also when food is packed.

The principal function of food package is to prevent the food from being wasted and to maintain the good quality and safety of food by protecting and preventing potential misuse or tampering [7], [8]. At the same time, the packaging permits logistics, both transport and storage [8], [9], and commercializing. Furthermore, the package communicates to the consumer in multiple ways, for example, the brand, expiration date, nutritional value, and allergen content [7], [8].

Discarded food packaging is an obvious source of littering [8], [10], [11]. Food that is expected to be consumed as snacks or out of doors, for instance during hiking and backpacking, picnics, or other fresh-air activities leads to the greatest possibility of littering. Additionally, products sold in large volumes, measured as excessive amounts of primary packaging material used in grams or high sales volumes, have a notable volume of packaging material waste that could leak into nature. Since one of the primary properties of plastic is its lightweight, it may simply be carried by a gust of wind or by water. That is why in nature, the so-called “naturally biodegradable” packaging materials are found to be one alternative to reduce the negative environmental effects of plastic packaging [12].

Recent political decision-making promotes novel solutions for food packages that both minimize the volume of plastic waste and would be more sustainable in general [5], [13]. The European Commission’s circular economy plan and its ambitious plastics strategy emphasize the importance of the packaging industry as a foundation for a wider prospect of a sustainable plastic value chain [14]. Moreover, the SUP directive, which was originally enacted to prevent littering [15], has increased the willingness to take part in voluntary pledges [14].

There are several changes in the European Union (EU), either planned, under reading or implemented in the legislation for plastic usage in the packaging industry. The political guidance and law enactment are becoming more stringent, for instance through Extended Producer Responsibility (EPR), bans on certain items made of plastics, and amendments to the EU's packaging directive [15], [16]. Such powerful political measures are required to make sure that the volume of plastic litter can be reduced in the future [17] and to meet the targets for climate change mitigation. Consequently, innovations are directed towards solutions by which materials based on fossil raw materials can be replaced with renewable obtained from bio-based natural resources [18]. Moreover, the recycling targets for plastic packaging defined in the EU's Strategy for Plastics in a Circular Economy (adopted in 2018), are set even higher [19], [20]. The strategy contains multiple ambitious objectives for the manufacturing, use, and disposal of plastics [5], [21], [22]. Ultimately, plastic packages should either be reusable or recyclable by 2030 [21], [22]. The EU is also intending to reduce the use of packaging material in general [23].

Before legislative action, voluntary agreements are one possibility to encourage various actors to test and even establish concepts for future food packaging. Voluntary instruments are often softer, although they can be more comprehensive and easier to enhance further [24]. Not only the sphere of influence but also the scope of voluntary actions and agreements vary. The focus may range from preventing plastic pollution, reducing food waste, or mitigating carbon dioxide (CO_2) emissions. The initiatives can be divided into three levels: global voluntary agreements like the New Plastics Economy Global Commitment or Global Plastic Pact; regional voluntary agreements, such as the European Plastics Pact; or country-specific voluntary agreements, for example the UK Plastics Pact, the French Plastics Pact, the Courtauld Commitment in the UK, the Material Efficiency Commitment for Industry in Finland, and the Memorandum of Understanding (MoU) in Thailand to reduce SUP in food delivery [25], [26], [27], [28], [29], [30]. However, voluntary initiatives cannot solve the plastic problem and cannot alone drive the systemic change that is needed [30]. Instead, they must be complemented by regulatory actions.

To deepen the understanding of the possibilities for a transition to more sustainable packaging from the viewpoint of the SUP directive, i.e., littering perspective, the objective of this study was to systemically analyze the packaging materials of food items sold in Finnish supermarkets. This study is novel and among the first attempts to identify which product groups could hold the greatest potential and the need to substitute traditional plastics in consumer packaging. However, it is essential to note that for the all-inclusive conceptualization of the substitution of plastics in the packaging materials, all directly related levels of the package (primary, secondary, and tertiary) must be considered [31]. More sustainable or more environmentally friendly solutions are considered in this study solely from the littering viewpoint. Therefore, it is noteworthy that sustainability from other viewpoints such as climate change mitigation might be somewhat contradictory.

MATERIALS AND METHODS

Data Description

This research applies simple quantitative methods [32] and descriptive statistics [32], [33], [34]. For the empirical analysis, a packaging material summary of single items sold in Finnish supermarkets was constructed. The packaging material data were provided by the centralized product information service system Synkka administered by the Global Standards 1 system (GS1) [35], [36]. The Synkka service produces coherent product information on the commodities on sale in Finnish supermarkets [36]. It is noteworthy though, that the product data provided by the Synkka service does not include data of private label products, that is retailers' brands, sold in the supermarkets.

Since the collected data included entire product-related data of single items sold in Finnish supermarkets, partially the information was found not to be directly related to this study. Thus, a part of the data was excluded, and only the packaging-related information for food and specific beverages was included in the summary combined with the basic product-specific data. The data processing is depicted in Figure 1. From the database, all the entire non-food information, such as cosmetics, detergents, magazines, tobacco products, toiletries, as well as pet food and wines, was removed. Mild alcoholic beverages (beer, cider, and long drink) were incorporated into the data. Food items and their packaging details, that are shipped to be further processed at the supermarket and sold for example through service counters, were incorporated in the data. Thus, we did not restrict the size or the weight of the primary package in any way but relied on data only. The data on the packaging specifications of the food sold over service counters (for instance, bakery products, fish, and meat) was excluded as this data was not obtainable. Even though the data of the secondary and tertiary packaging materials were included in the data obtained from the Synkka service, these are disposed of by the retailers. Therefore, this study concentrated only on primary packaging materials, which are in most cases used and disposed of by consumers, either through waste disposal, recycling, or littering. By a primary package is meant in this study a package that is in direct contact with the food [37], [38] and it is in most cases, yet not always, the same as a consumer package [38].

The data were further processed in a way that the materials used according to the packaging material type for each product group were analyzed. Then, the analysis was enlarged to more detailed observations. For instance, the mean weight, share of plastics in percentages, and some basic ratio analyses were conducted. Additionally, the observations included an overall view of the used packaging materials by each product group. Several packages consist of multiple types of packaging materials. For example, the top can be a different material than the receptacle. In such cases, the analysis was based on the dominant material. If the item consisted of equivalent amounts of several packaging materials, then all the materials were included in the overall view analysis.

When processing the data, some inconsistencies were found which were most likely due to coding errors. For example, in some cases, similar types of products were categorized into several different product groups. To overcome these kinds of inconsistencies, they were corrected if detected and if it was distinct in which product group the certain product should be incorporated. In raw data, in some cases the title of the product did not tell if the product was processed or unprocessed meat product or sausage, for instance. In

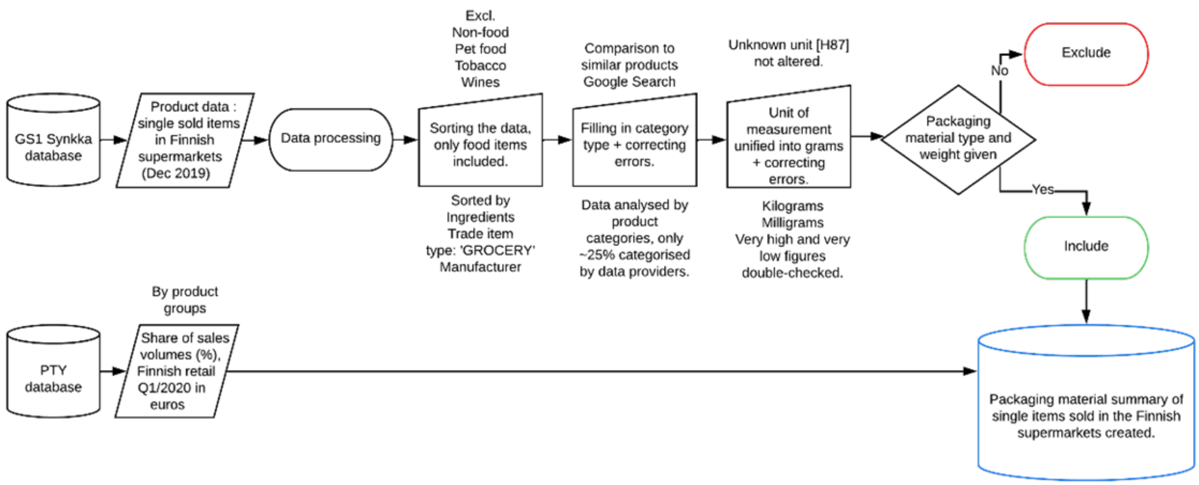

Fig. 1: Flow diagram of the data processing and the packaging material summary creation.

these unclear cases, a Google Search was used to find more information and to identify product. There were only a few dozen such cases in the material. Together in comparisons of how they were categorized and weighted in the GS1 data, the product was re-categorized accordingly. In a few cases where either the packaging material or the weight of the packaging material was not defined, the observations were excluded from the analysis.

The constructed summary was further supplemented by adding the sales share in euros (%) of the total sales volume for every food and beverage product group. These statistics were provided by the Finnish Grocery Trade Association (PTY) [39]. A shortcoming of this data is, however, that the sales volume figures are available only in euros. Thus, the total volumes of primary packaging material waste in tonnes (t) produced by the different product groups cannot be defined as it would call for more explicit sales volume data in terms of the number of pieces for single items sold in the supermarkets. This kind of sales volume data was not available. Additionally, while the product groups in the PTY data in some cases are different from the product groups employed in the GS1 data, the product groups without sales volume information available are indicated “N/A” in the forthcoming analyses and Tables.

It is also noteworthy that as a limitation of the data. there might be some inconsistencies, for instance, in polymer types. This is because not all the data processors and recorders, such as suppliers, importers, wholesalers, retail chains, and HoReCa (Hotels, Restaurants, and Catering) operators [35], were familiar with the differences in polymer types in the packaging. Hence, the data on the primary packaging material types are partially analyzed not by polymer type, but as plastic only. In part of the analysis, like the dominant material type for the product group, the type of the polymer is in addition applied. It is rather widely known which polymers are used in certain food packages and consequently, the feasible contradictions can be more easily noticed. Moreover, the composition of multi-layered packaging material was unknown based on the product information transmitted by GS1. Thus, these were incorporated under several codes used for packaging materials in the data.

Despite these limitations, the dataset is quite large constituting over 56,000 observations (half of the observations applied to the primary packaging). As a result of the processing, the data were categorized into a total of 44 different product groups. All the weight data was converted to grams. Hence, the reliability and validity of this study are anticipated to be satisfactory. However, as noted also in Hanssen et al. [40], who studied the packaging data of ready-to-eat meals in Norway, while it is challenging to find the weight details of the packaging material for a single portion, the analysis consists of primary packaging materials used in several, different types of product groups.

Research Methodology

After constructing and processing the packaging material database, several variables were analyzed to determine 1) which primary packaging materials were utilized in different food and beverage categories, 2) what the volumes of the primary packaging materials used in terms of the weight in grams (single items) and sales volumes in retail were, and 3) which are the product groups whose conventional plastic packaging material substitution with more environmentally-friendly material would bring the most effectiveness in reducing the littering problem. The third point is analyzed in terms of packaging material volumes, the type of polymer used, difficulties in handling or recycling the packaging materials, and the feasible effect of the SUP directive.

First, the main primary packaging materials of single items of each product group were evaluated both by single packaging material types and by a pre-defined grouping of materials (*ceramic*, *composite*, *corrugated*, *fibres*, *glass*, *laminated carton*, *metals*, *other*, *paper*, *plastic/polymers*, and *wood*). Based on this categorization it was then counted the mean weight in grams of the packaging material by each product group. *Glass* included colored and transparent glass materials. *Metals* included multiple metal types such as aluminum, brass, iron, metal composites, “other”, stainless steel, steel, and tin. *Paper* included paper, paperboard, and corrugated paper. *Corrugated* included multiple types of board. *Polymers/plastics* included various polymer or plastic types, except biobased polymers, which were grouped as one specific category to separate them from fossil-based polymers. *Composite, ceramic, fibres, laminated carton, other,* and *wood* were so-called single categories that did not include any sub-categories. Reusable packages were distinguished by specific fields which imply the probable application of reusable materials. Additionally, the weight and measurements were partially utilized for identification. Moreover, even though the analysis focused mainly on the mean weight, we left the median values for comparability and further information. For example, in some categories, such as bottles, packaging material (glass versus plastic) is not dominating in median values compared to the mean values. The median value may also in some cases better reflect the most common weight of a consumer package.

Second, the weight comparisons of manifold packaging materials between product groups were implemented. The focus was to identify various polymer types, thus counting the plastic share (%) used as a packaging material in all the respective product groups. Moreover, the analysis quantified the ratio between the primary packaging materials and food or beverages counted from the net and gross weight values. The former means that the weight included only the food or beverage weight, while the latter consists of the weight of both food or beverage and packaging materials. This ratio is useful to recognize the potential to decrease the amount of packaging material used.

One significant group of materials was specific polymers that are utilized for food packages. Particularly, polyvinyl chloride (PVC) and polystyrene (PS), especially expanded polystyrene (EPS), should be substituted with more sustainable alternatives [6], [41], [42]. Moreover, EPS is named by the SUP directive as a packaging material that shall not be used for single-use food and beverage packaging in the future [43]. Therefore, these materials were of special interest in the analysis. The possible effect of the SUP directive for each product group was analyzed based on the guidelines for the consumption reduction, outlined in the SUP directive Article 4, Part A [43].

RESULTS

The possibility of substituting the most detrimental packaging materials with more sustainable alternatives was assessed by first analyzing the overall packaging material usage by weight. This was followed by a more profound scanning of the primary packaging materials, such as the materials and volumes of plastic usage. The substitution potential could consist of insights like reductions of the packaging material, reuse of receptacles, replacement, or recycling of the materials. The reusable packaging materials, such as transboxes or similar containers, which can be reused several times, were excluded from the analysis if they were identifiable from the data.

Mean Weight

As reported in Table 1, and without paying any attention to the differences in packaging materials so far, the highest numbers in the mean weight in grams of the primary packaging material were found in the product group *Jams, sweet spreads, honey, and syrups* (230 grams), followed by *Alcoholic beverages (mild)* (180 g), *Fish unprepared* (161 g), *Fats and oils* (158 g), and *Sauces (ready-made)* (149 g). The smallest mean weight in grams of the primary packaging material was in the categories *Snack products* (14 g), *Nuts and seeds* (16 g), *Sausages* (19 g), *Bread* (21 g), *Grains and pasta* (22 g), and *Fruits and vegetables (fresh)* (24 g).

It is noteworthy, however, that the range of weight in grams varied between the product groups, and within the categories, the median weight could be different from that of the mean weight (Table 1). This may be due to the different volumes and measurements of the food packages (for example, family-size versus single-size packets) or different packaging material types in the product groups, thus influencing the mean and median values. A more detailed analysis revealed that in some product groups, such as *Chocolate (confectionary), Fish unprepared, Alcoholic beverages (mild), Pies, pastries (sweet), Processed meat, Seafood,* and *Unprocessed meat* the range of weight varied more than in other product groups. Furthermore, the analysis revealed single exceptionally high gram values in some categories. However, these observations could imply potential reporting or coding errors, but also unordinary packaging materials or sizes, like large buckets or barrels, chests for confectionery made of wood, or reusable materials (transboxes or alike). Nevertheless, the values were included in the analysis.

Primary Packaging Materials Used

While the various packaging materials were highly varied in terms of their densities and weight, more comprehensive comparability of the data requires information on the number of items packed and sold in separate categories. Tables 2a, *Table. 1: Descriptive statistics of the primary packaging materials in different product groups, sorted by mean weight in grams and including median weight (g) and sales volume (%).*

Product Group	**Mean weight in grams (g)**[1)]	**Median weight in grams (g)** [1)]	**Sales share (%) of total sales volume in euros** [2)]	**Number of items**
Jams, sweet spreads, honey, syrups	230	180	L	381
Alcoholic beverages (mild)	180	213	H	1 219
Fish unprepared	161	41	M	343
Fats and oils	158	82	M	306
Sauces (ready-made)	149	160	M	72
Eggs and egg products	127	47	M	110
Flavoured drinks (ready to drink)	124	40	H	579
Ketchup, mustard, mayonnaise, and other sauces/dressings	109	46	N/A	783
Fruits and vegetables (preserved)	108	45	M	959
Fish prepared /processed	107	46	M	792
Seafood	104	25	N/A	178
Fruit and vegetable juices/drinks)	102	40	M	704
Fruits and vegetables (frozen)	86	10	M	195
Pies, pastries, pizza	68	20	M	356
Chocolate (confectionary)	66	10	M	1 254
Cakes	63	40	H	406
Packaged water	61	30	M	103
Flavoured drinks (not ready to drink)	59	48	N/A	67
Nutritional supplements and dietary aids	55	25	M	549
Baby/infant food	55	33	L	468
Coffee and tea	51	30	M	573
Spices, baking/cooking additives	50	28	M	640
Meals/products (ready to eat)	46	26	H	1 310
Candies (sugar)	46	6	H	1 160
Milk and cream products & substitutes	45	27	H	475
Energy and sports drinks	42	30	H	404
Meals/products (not ready to eat)	39	22	H	198
Flour, sugar, cocoa, flakes	38	25	L	386
Unprocessed meat	37	22	H	1 456
Cereal products	36	37	L	371
Cheese & cheese substitutes	35	12	H	1 100
Desserts	34	15	N/A	124
Ice cream	33	19	M	503
Processed meat	32	20	H	1 653
Biscuits	31	15	H	548
Pies, pastries (sweet)	29	15	H	563
Yoghurts and other dairy products (drinkable)	29	17	M	790
Baking/cooking mixes (dry)	25	19	N/A	199
Fruits and vegetables (fresh)	24	20	H	117

Grains and pasta	22	15	M	429
Bread	21	8	H	968
Sausages	19	10	H	970
Nuts and seeds	16	5	M	419
Snack products	14	6	M	697

[1)] Excluding reusables = transboxes or similar packages used multiple times, like, for meat, fish, and bakery products.

[2)] Low (L) = less than 0.5%, Medium (M) = 0.5 to 2%, High (H) = over 2%. NB: Some of the figures are a combination of several similar product groups.

N/A = Not available

2b, and 2c present the results of the categories considering the three main primary packaging materials (polymers or composite materials, fiber-based materials, or glass or wood as a dominant material). In these tables (2a, 2b, and 2c) the number of items (i.e., the figure in brackets after each packaging material type) was counted based on the main packaging material of each material type. That is, the packaging material which comprises the highest amount of total material used per single item was counted. If an equal amount of different packaging material types was used, all were incorporated in figures of the number of items. However, it is also worth noting that these values consider only single items of food packages among each product group (totally the number of items were 25,877 in 44 product groups, see Table 1). That is, in general the values do not represent the total amount of packaging materials used as it would necessitate sales volume data on the number of items, which was not obtainable.

Not surprisingly, the highest mean weight of primary packaging in grams for the product groups *Alcoholic beverages (mild), Flavoured drinks (ready to drink), Fruit and vegetable juices/drinks,* and *Fruits and vegetables (preserved)* was dominated by glass counted as the number of different packaging types, not the sales volume (Tables 1, 2a, 2b, and 2c). In *Flavoured drinks (ready to drink)*, for example, the number of glass and plastic units was close to the same, but the difference in weight was nearly tenfold. However, the product group *Fish unprepared* seems to be an exception, as mainly cardboard, paper, or plastic were used as the main primary packaging material. Yet, in the product group in question, it was not always clear if the primary package was reusable or not. This has relevance particularly to some plastic receptacles, for instance.

In a few product groups, the number of items consisting of different packaging materials was close to each other, yet the weights in grams differed significantly. For example, in *Alcoholic beverages (mild)* the shares in grams between glass and aluminum were 90 and 5 percent, whereas the number of items was 61 and 36 percent, respectively. Similarly, in *Flavoured drinks (ready to drink)* the share of glass was close to 85 percent, while polyethylene terephthalate (PET) covered only 8 percent of the packaging material used. The number of items were, however, 35 and 32 percent, respectively.

In general, according to the results, glass was still the main packaging material in many product groups where bottles and jars were used for primary packaging. These product groups consisted of baby food, beverages, fats and oils, jams and marmalades, nutritional supplements, preserved fruits and vegetables, spices, baking and cooking additives, and multiple types of sauces and dressings. Metals were commonly used for cans in beverages, preserved fruits and

Table. 2a: Summary of the TOP 3 primary packaging materials by weight (outlined as a share (%) of total weight[1)]) by each product group. Polymers or composite materials as the dominant material.

Product Group	Material types (number of items)[1)]	Share in % (of total weight g)[1)]
Sausages	1. Plastic other (493)	1. 34
	2. PP (97)	2. 22
	3. LDPE (186)	3. 13
Unprocessed meat	1. Plastic other (573)	1. 32
	2. PP (453)	2. 26
	3. LDPE (180)	3. 9
Processed meat	1. Plastic other (748)	1. 32
	2. PP (247)	2. 22
	3. LDPE (256)	3. 10
Baking/cooking mixes (dry)	1. Composite (83)	1. 37
	2. HDPE (7)	2. 15
	3. LDPE (21)	3. 9
Fruits and vegetables (fresh)	1. HDPE (35)	1. 42
	2. Other (29)	2. 18
	3. LDPE (17)	3. 16
Energy and sports drinks	1. PET (110)	1. 30
	2. HDPE (50)	2. 22
	3. Metal aluminium (111)	3. 11
Candies (sugar)	1. PP (343)	1. 31
	2. Corrugated board single wall (57)	2. 22
	3. Plastic other (350)	3. 17
Flavoured drinks (not ready to drink)	1. PET (44)	1. 44
	2. Glass (14)	2. 44
	3. Paper paperboard (7)	3. 6
Ice cream	1. Plastic other (77)	1. 20
	2. Paper paperboard (127)	2. 18
	3. PP (59)	3. 17
Meals/products (ready to eat)	1. Paper paperboard (73)	1. 15
	2. PP (309)	2. 15
	3. PET (163)	3. 14
Meals/products (not ready to eat)	1. Plastic other (50)	1. 14
	2. PET (17)	2. 13
	3. Metal tin (14)	3. 12
Snack products	1. PP (250)	1. 19
	2. Glass (8)	2. 17
	3. Paper corrugated (14)	3. 12

[1)] Excluding reusables = transboxes or similar packages used multiple times, like, for meat, fish, and bakery products.

Note: The number of items (figure in brackets after the name of the product group) was counted based on the main packaging material of each material type, that is, the packaging material which comprises the highest amount of total material used per single item was counted. If an equal amount of different packaging material types was used, all were incorporated in figures of the number of items.
Note: These values take into account only single items of food packages among each product group, that is, the values do not represent the total amount of packaging materials used as it would necessitate sales volume data on the number of items, which was not obtainable.

Table. 2b: Summary of the TOP 3 primary packaging materials by weight (outlined as a share (%) of total weight[1)]) by each product group. Fiber-based materials as the dominant material.

Product Group	Material types (number of items)[1)]	Share in % (of total weight g)[1)]
Cereal products	1. Paper paperboard (194)	1. 60
	2. Paper corrugated (47)	2. 16
	3. Paper paper (20)	3. 5
Eggs and egg products	1. Corrugated board other (6)	1. 33
	2. Paper paper (13)	2. 26
	3. Fibre other (41)	3. 20
Fruits and vegetables (frozen)	1. Paper corrugated (44)	1. 67
	2. PE (16)	2. 9
	3. Corrugated board single wall (3)	3. 6
Pies, pastries, pizza	1. Paper corrugated (71)	1. 38
	2. Paper paperboard (44)	2. 19
	3. Corrugated board other (10)	3. 14
Flour, sugar, cocoa, flakes	1. Paper paperboard (132)	1. 31
	2. Paper other (15)	2. 20
	3. Paper paper (77)	3. 13
Grains and pasta	1. Paper paperboard (123)	1. 40
	2. Plastic other (129)	2. 18
	3. Paper corrugated (23)	3. 16
Bread	1. Paper corrugated (26)	1. 25
	2. Corrugated board single wall (9)	2. 15
	3. Paper paperboard (63)	3. 10
Milk and cream products & substitutes	1. Laminated carton (238)	1. 26
	2. Paper corrugated (29)	2. 19
	3. Wood other (10)	3. 14
Pies, pastries (sweet)	1. Paper corrugated (28)	1. 30
	2. Paper paperboard (82)	2. 13
	3. PET (62)	3. 9
Cakes	1. Paper paperboard (54)	1. 25
	2. PET (97)	2. 19
	3. Paper corrugated (58)	3. 17
Seafood	1. Paper corrugated (17)	1. 40
	2. HDPE (52)	2. 15
	3. PP (16)	3. 8
Fish prepared/processed	1. Paper corrugated (84)	1. 33
	2. Glass (84)	2. 16
	3. PP (133)	3. 10
Fish unprepared	1. Plastic other (43)	1. 25
	2. Paper corrugated (36)	2. 17
	3. Laminated carton (27)	3. 14

Biscuits	1. Plastic other (151) 2. Paper paperboard (99) 3. Paper corrugated (63)	1. 27 2. 14 3. 14
Chocolate (confectionery)	1. Paper paperboard (347) 2. Wood other (1) 3. Plastic other (256)	1. 25 2. 22 3. 12
Yoghurts and other dairy products (drinkable)	1. Laminated carton (159) 2. PP (192) 3. Glass (19)	1. 18 2. 17 3. 13

[1)] See the footnotes in Table 2a.

Table. 2c: Summary of the TOP 3 primary packaging materials by weight (outlined as a share (%) of total weight[1)]) by each product group. Glass or wood as the dominant material.

Product Group	**Material types (number of items)[1)]**	**Share in % (of total weight g)[1)]**
Sauces (ready-made)	1. Glass (58) 2. Plastic other (7) 3. PP (6)	1. 95 2. 1 3. 1
Alcoholic beverages (mild)	1. Glass (541) 2. Glass coloured (200) 3. Metal aluminium (443)	1. 66 2. 25 3. 5
Flavoured drinks (ready to drink)	1. Glass (189) 2. PET (185) 3. Glass coloured (15)	1. 78 2. 8 3. 6
Fats and oils	1. Glass (111) 2. Glass coloured (25) 3. Paper corrugated (14)	1. 63 2. 17 3. 3
Fruit and vegetable juices/drinks	1. Glass (202) 2. PET (173) 3. Laminated carton (108)	1. 71 2. 11 3. 4
Fruits and vegetables (preserved)	1. Glass (322) 2. Metal aluminium (55) 3. Metal other (47)	1. 68 2. 5 3. 4
Baby/infant food	1. Glass (163) 2. Paper paperboard (34) 3. Paper corrugated (20)	1. 65 2. 5 3. 5
Packaged water	1. Glass (12) 2. PET (75) 3. Metal aluminium (13)	1. 55 2. 39 3. 3
Nutritional supplements and dietary aids	1. Glass coloured (49) 2. Glass (55) 3. Plastic other (79)	1. 30 2. 25 3. 9

Jams, sweet spreads, honey, syrups	1. Glass (256) 2. Wood other (17) [2)] 3. PP (40)	1. 53 2. 21 3. 20
Ketchup, mustard, mayonnaise and other sauces/dressings	1. Glass (225) 2. Plastic other (115) 3. Paper corrugated (19)	1. 53 2. 9 3. 8
Spices, baking/cooking additives	1. Glass (99) 2. PET (121) 3. Plastic other (169)	1. 38 2. 15 3. 10
Coffee and tea	1. Glass (45) 2. Paper paperboard (163) 3. Paper paper (26)	1. 34 2. 19 3. 7
Desserts	1. Glass (6) 2. Paper corrugated (3) 3. PP (38)	1. 24 2. 17 3. 12
Nuts and seeds	1. Glass (7) 2. Plastic other (99) 3. Paper corrugated (9)	1. 21 2. 15 3. 15
Product Group		
Cheese & cheese substitutes	1. Wood other (163) 2. Paper corrugated (70) 3. Plastic other (349)	1. 29 2. 21 3. 16

[1)] See the footnotes in Table 2a and 2b.

[2)] Reported as a part of primary packaging, unresolved if pallet or alike.

vegetables, and processed meat packaging. Laminated carton was utilized for packaging juices, milk and cream products, and yogurts. Cardboard and paper were utilized to pack dry goods, like biscuits, bread, cereals, flour, grains, pasta, and chocolate. Then again, plastics and various polymer types were utilized somewhat in each one of the product groups.

In general, according to the results, glass was still the main packaging material in many product groups where bottles and jars were used for primary packaging. These product groups consisted of baby food, beverages, fats and oils, jams and marmalades, nutritional supplements, preserved fruits and vegetables, spices, baking and cooking additives, and multiple types of sauces and dressings. Metals were commonly used for cans in beverages, preserved fruits and vegetables, and processed meat packaging. Laminated carton was utilized for packaging juices, milk and cream products, and yogurts. Cardboard and paper were utilized to pack dry goods, like biscuits, bread, cereals, flour, grains, pasta, and chocolate. Then again, plastics and various polymer types were utilized somewhat in each one of the product groups.

A deeper scanning of data revealed that the most typical polymer types used were polypropylene (PP), polyethylene (PE), and polyethylene terephthalate (PET). These polymer types are defined as the most typical ones used in food packaging, also in the literature [44], [45]. The shares of polyvinyl chloride (PVC) or polystyrene (PS), which are still somewhat challenging

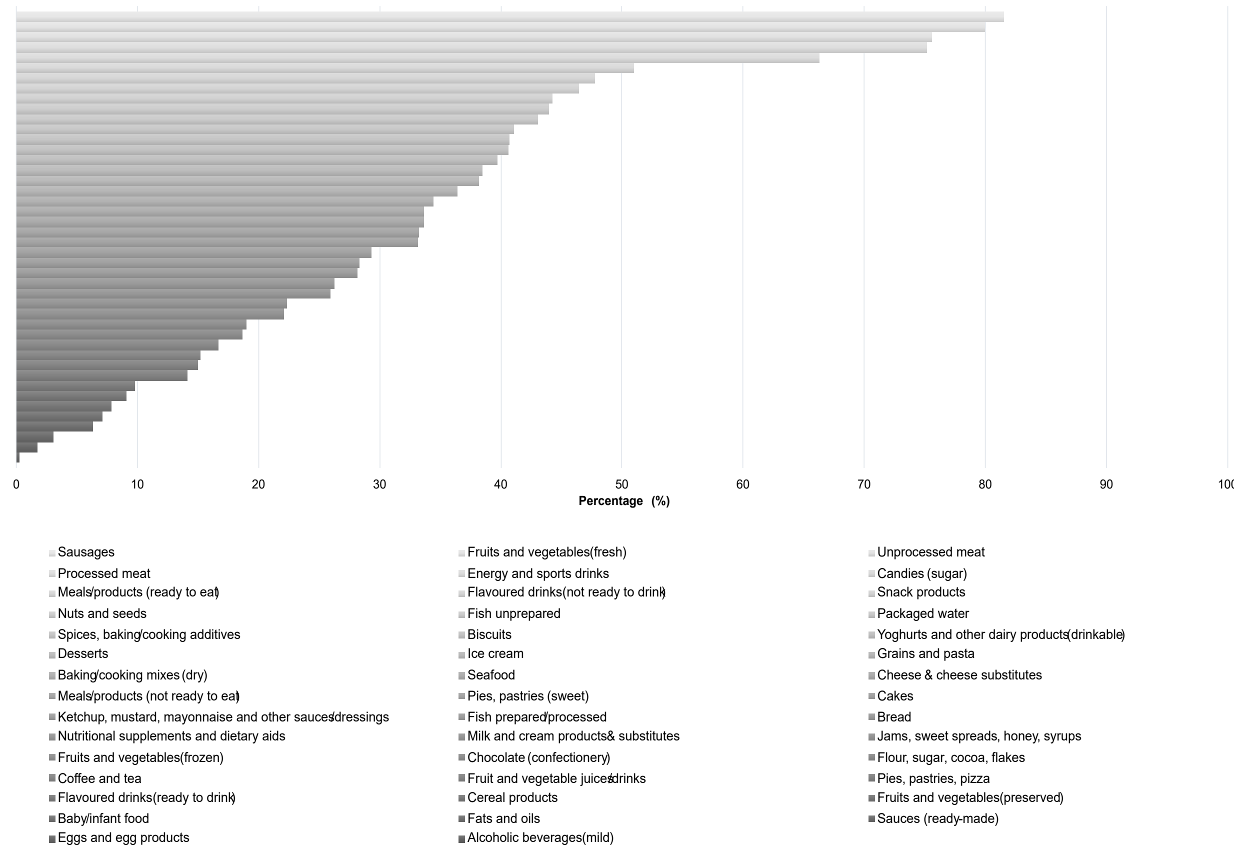

Fig 2: The percentage share of plastic as a primary packaging material (calculated according to the weight in grams, product groups listed in the legend to be read from left to right and top to down).

to recycle in current systems [41], [42], [46], [47], [48], were high in some product categories. PS is typically used as a primary packaging material with a notable amount even as the main packaging material. The highest shares of PS were found in the categories *Yoghurts and other dairy products (drinkable)* (7.1%), *Nuts and seeds* (6.5%), and *Desserts* (4.3%), and for some sweet bakery products, like cakes, sweet pies and pastries. PVC was used as the main primary packaging material for *Candies (sugar)* in a small number of cases.

The analysis also revealed that bio-based polymers were applied in a small amount, if at all, in food packages. Only about 30 percent of the product groups comprised bio-based polymers, but the amount was not more than one percent of the total weight in grams in nearly every category.

Share of Plastic

Figure 2 depicts the shares of plastic utilized as a primary packaging material in different product groups. The findings clearly describe the steep division between almost plastic-free product groups versus product groups with a high amount of plastic in use. According to the findings, product groups, like *Fruits and vegetables (fresh)*, *Processed meat, Sausages*, and *Unprocessed meat*, were almost entirely sold in

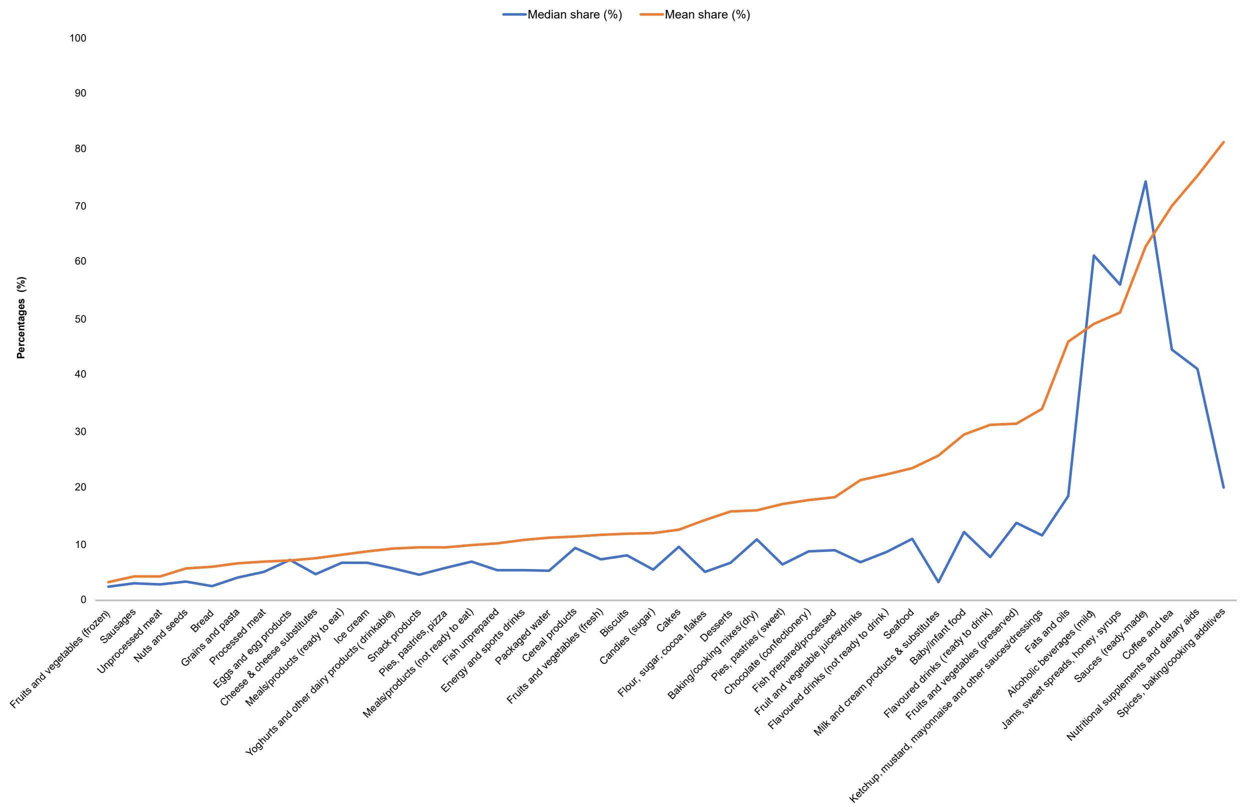

Fig 3: Percentage share of package weight from the net weight, comprising both the values of the mean and median share. Sorted by mean share.

such packages which contained mainly plastic/polymers. The share of plastic was more than 75 percent when calculated by weight in grams. In the product groups *Processed meat, Sausages,* and *Unprocessed meat* the amount of totally plastic-free packaging was quite low, less than 10 percent, and plastic was widely used as the main material, or at least as a part of the packages. In contrast, the lowest plastic share in weight was in the product group *Alcoholic beverages (mild).* Further somewhat small plastic share in primary packages was found in the product groups *Eggs and egg products* and *Sauces (ready-made).*

Ratio of Net and Gross Weight

The ratio of the net food weight with respect to the weight of primary packaging material varied significantly between the product groups. The results are shown in Figure 3 in a way that the higher the percentage, the higher share of primary packaging material utilized. The mean share values for product groups like *Spices, baking cooking additives, Nutritional supplements and dietary aids, Coffee and tea, Sauces (ready-made), Jams, honey, syrup and other sauces,* and *Alcoholic beverages* (mild) were quite significant (close to 50% or above). This indicates that the weight of the used primary packaging material is considerable compared to the packed food. The high values can be explained by the packaging material used, which in these cases is glass. However, the mean and median values could be notably different, and product groups like *Coffee and tea, Nutritional supplements and dietary aids* along with *Spices, baking/cooking additives* had mean values of 70 percent or above while the median values varied between 20 to 45 percent. The significant split of the packaging material into heavier (glass) and lighter (paper and plastics) primary packaging materials explains this division.

Product groups *Fruits and vegetables (frozen)*, *Sausages,* and *Unprocessed meat* have low mean values for the share of the primary packaging material weight from the net weight (5% or less). Once again, the mean and median values can notably differ within the product group. These product groups frequently use lighter materials, such as laminated cartons, paper-based materials, or plastics, as the main primary packaging material.

In case the minimum or maximum values vary a lot, it is typically an indicator that multiple packaging material types are utilized within the product group. In certain product groups, like *Eggs and egg products* and *Fruits and vegetables (frozen)*, the variation was somewhat small between the minimum and maximum ratio. This indicates that the used primary packaging materials were rather alike.

The Share of Sales

The share of sales as a percentage of total sales in euros indicates the best-selling product groups in retail during the first quarter of 2020 in Finnish supermarkets. The highest shares (%) were found for the product groups *Alcoholic beverages (mild), Cheese and cheese substitutes, Fruits/vegetables (fresh), Meals/products (not ready to eat), Meals/products (ready to eat), Processed meat,* and *Sausages* where, in each case, the share of sales was higher than 4 percent [39]. Additionally, for the product groups *Biscuits, Bread, Cakes,* and *Pies, pastries (sweet)*, the sales volumes were in the range of 3–4 percent [39].

Summary of the Indicators

Table 3 shows the results of several indicators which can help to identify the possible replacement potential of plastics. The cells marked with dark grey indicate the greatest potential in each column. In Table 3 is also estimated the possible effect of the SUP directive for each product group based on the guidelines for the consumption reduction, outlined in the SUP directive Article 4, Part A [43].

The product groups *Alcoholic beverages (mild), Flavoured drinks (ready to drink)*, and *Candies (sugar)* had multiple indicators for substitution; the mean weight in grams and the sales volume in euros were high. The median share of package weight from the net weight (%) was high in *Alcoholic beverages (mild)* whereas *Candies (sugar)* and *Flavoured drinks (ready to drink)* included PVC or PS as a primary packaging material. These specific polymer types in question are still somewhat challenging to recycle in current systems [41], [42], [46], [47], [48]. However, the share of plastic in general varied notably between these three product groups. For *Candies (sugar)* it was more than 50 percent, while for *Alcoholic beverages (mild)* it was less than one percent. In addition, each of these three product groups is notably influenced by the SUP directive, either through consumption reduction or other product requirements, and they constitute a significant risk for littering. The previously mentioned three product groups are followed by product groups like *Energy and sport drinks, Meals/products (ready to eat)*, and *Sausages*

Table. 3: *Analysis of the different indicators for the substitution and reduction potential of plastics in product groups. The cells marked with dark grey indicate the greatest potential in each column. Sorted primarily by if the SUP directive applies and secondary by the plastic share (%).*

Product Group	SUP directives applies (Y/N) 1)	Share of plastic (%) 2) 3)	Sales volume 4)	Mean weight (g)	Median, share of package weight from net weight (%)	Use of PVC or PS (Y/N)
Fruits and vegetables (fresh)	Y	80	H	24	7	N
Processed meat	Y	75	H	32	5	N
Candies (sugar)	Y	51	H	46	5	Y
Meals/products (ready to eat)	Y	48	H	46	7	Y
Snack products	Y	44	M	14	5	Y
Biscuits	Y	41	H	31	8	Y
Yoghurts and other dairy products (drinkable)	Y	40	M	29	6	Y
Desserts	Y	38	N/A	34	7	Y
Ice cream	Y	38	M	33	7	Y
Cheese & cheese substitutes	Y	34	H	35	5	Y
Seafood	Y	34	5)	104	11	N 6)
Cakes	Y	29	H	63	10	Y
Fish prepared /processed	Y	28	M	107	9	N 6)
Bread	Y	26	H	21	3	Y
Chocolate (confectionary)	Y	19	M	66	9	Y
Fruit and vegetable juices/drinks)	Y	15	M	102	7	Y
Fruits and vegetables (preserved)	Y	8	M	108	14	N
Sausages	N	82	H	19	3	Y
Unprocessed meat	N	76	H	37	3	Y
Energy and sports drinks	N	66	H	42	5	Y
Flavoured drinks (not ready to drink)	N	46	N/A	59	9	N
Nuts and seeds	N	44	M	16	3	Y
Fish unprepared	N	43	M	161	5	Y
Packaged water	N	41	M	61	5	N
Spices, baking/cooking additives	N	41	M	50	20	Y
Grains and pasta	N	36	M	22	4	N
Baking/cooking mixes (dry)	N	34	N/A	25	11	N
Pies, pastries (sweet)	N	33	H	29	6	Y
Meals/products (not ready to eat)	N	33	H	39	7	N
Ketchup, mustard, mayonnaise, and other sauces/dressings	N	28	N/A	109	12	Y
Nutritional supplements and dietary aids	N	26	M	55	41	Y
Milk and cream products & substitutes	N	22	H	45	3	Y
Jams, sweet spreads, honey, syrups	N	22	L	230	58	Y
Fruits and vegetables (frozen)	N	19	M	86	2	Y
Flour, sugar, cocoa, flakes	N	17	L	38	5	Y
Coffee and tea	N	15	M	51	44	N

Pies, pastries, pizza	N	14	M	68	6	N
Flavoured drinks (ready to drink)	N	10	H	124	8	Y
Cereal products	N	9	L	36	9	N
Baby/infant food	N	7	L	55	12	N
Fats and oils	N	6	M	158	18	Y
Sauces (ready-made)	N	3	M	149	74	N
Eggs and egg products	N	2	M	127	7	N
Alcoholic beverages (mild)	N	< 1	H	180	61	N

1) To be noted: The level, of how widely SUP directive applies (consumption reduction outlined in SUP directive Article 4, Part A), varies among product groups. Some product groups are affected more than others.

2) Without reusables

3) Counted in weight (g).

4) Low (L) = Sales share (%) less than 0.5%, Medium (M) = Sales share (%) 0.5 to 2%, High (H) = Sales share (%) over 2%.

5) Sales volume reported together with fish and fish products

6) Used as a reusable material.

Y = Yes; N = No; N/A = not available.

Color coding:
Dark grey: Mean weight >75g; Share of plastic >50%; Median, share of package weight from net weight >20%; Sales volume "High". Option "Yes".
Grey: Mean weight 25-75g; Share of plastic 10-49%; Median, share of package weight from net weight 5-19%; Sales volume "Medium".
Light grey: Mean weight <25g; Share of plastic <10%; Median, share of package weight from net weight <5; Sales volume "Low".

which either include multiple indicators for substitution, or are considerably influenced by the SUP directive. Furthermore, also these three product groups establish a notable risk for littering.

DISCUSSION

Food packaging is indeed in transformation. Already for some decades, fossil-based plastic has been one of the main food packaging materials offering many excellent properties and advantages. The rising concern about the impacts of plastics on humankind, flora, and fauna has created accumulative speed attempts to restrict the use of plastic, for instance, single-use plastic items [5], [49]. Especially the leakage of plastic package litter in the marine environment is a severe global environmental catastrophe. United Nations Single-use plastics roadmap [28] and Sustainable Development Goal number 12 "Sustainable consumption and production", EU directive on the reduction of the impact of certain plastic products on the environment [43], and The Plastics Roadmap for Finland [50] have been the main driving forces for this reported research work. At the same time and by the same drivers, Finnish sectoral industrial associations and Ministries made a Material Efficiency Commitment [26] including efforts to reduce plastic packaging.

Based on the results of this study, the product groups *Candies (Sugar)* and *Meals/products (ready to eat)* included multiple indicators for primary packaging material substitution. Both product groups were considerably influenced by the SUP directive, and their sales volume was high. The mean weight and share of primary packaging material (gross vs. net weight) were also at a considerable level. The share of plastic was notable, and both product groups included difficult-to-recycle polymers [41], [42], [46], [47], [48], polyvinyl chloride (PVC) or polystyrene (PS), to a small extent as a primary packaging material. Additionally, both product groups carry a well-established, significant risk of littering. Therefore, these two product groups could be a good starting point for further research on the possible primary packaging material reduction or substitution potential. In comparison to one of the few studies made in Norway [40], some differences were noticed even though the figures might not be completely comparable. Hanssen et al. brought up the same fact found in this study that ready-to-eat meals use a high share of packaging material, which can be seen as overpackaging from the consumers' viewpoint. Additionally, the need for improving the ecology of confectionery packaging has been identified by packaging brand owners, and paper-based packaging is one trend in product development, in addition to increasing the recyclability of plastic-based packaging [51]. Hence, the enhanced recycling of materials and the use of biodegradable materials are actions to prevent the negative impacts of littering.

A further product group, which also had several indicators for substitution, was the *Energy and sports drinks* category. In this product group, the sales volume (over 2%) as well as the share of plastic (66%) as a primary packaging material were high. PVC or PS was utilized in the primary packaging to some extent. The mean weight (42g) and share of primary packaging material are at a notable level (5%). Even though the consumption reductions of the SUP directive (Article 4) do not apply to beverage bottles, there are other articles of the SUP directive applying to this product group (Article 6 Product Requirements and Article 9 Separate Collection) [43]. Additionally, the risk of littering on a global level is extremely high. In Finland, the littering problem of cans and bottles has been significantly reduced because of a deposit system for empty bottles, which guarantees the systematic recycling and reuse of the bottles (see also e.g., [52], [53], [54]). Over 90 percent of empty bottles and cans are recycled in Finland [55]. The purified plastic is melted into small spheres from which new plastic products can be processed also for food packaging [56]. Rhein and Sträter [52] state that a deposit system of single-use bottles in Germany appeared to affect mitigation of the plastic pollution, hence, preventing the uncontrollable disposal of bottles. A similar recycling deposit system could be recommended for trial in other countries where littering is a particularly big problem.

In general, the results of this study must be interpreted carefully, because part of the indicators can be understood more straightforwardly than the others. For example, the primary packaging material type and the package size influenced the mean weight and the median share of package weight concerning the net weight. For beverages, the aforementioned indicators were in many cases high since the main primary packaging material for most items in the GS1 data is still glass. Naturally, those product groups that require preparation (heating, cooking) before eating do not pose a significant risk of littering. Additionally, some product groups use rather small amounts of plastic as a primary packaging material, and their sales volume is low or medium resulting in that the plastic waste streams are also lower.

The limitations of the data also complicated making unambiguous interpretations of the results for two primary reasons. First, there was no sales volume data available from the Finnish Grocery Trade Association (PTY) on the unit quantities of foodstuffs sold in different product groups. The sales volumes are therefore only indicative, so no deeper analyses can be made of the different primary packaging materials, for example, how many products are practically sold with different packaging materials. Second, there were errors and incomplete data fields in the packaging material data, for example, product grouping had not been done properly for all data producers and in some cases, it was difficult to interpreter if the package is reusable or not. Despite these shortcomings, however, the results give a reasonable overall picture of the plastic and other primary packaging materials used in the different product groups of the food supply.

While the sales share of individual food and beverage items within every product group was not accessible the actual mean weight of the primary packaging material may be notably different from the mean weight of the items in every product group. The latter discloses the mean primary packaging material weight of each one of the existing packages in the product group, however, the sales share of every item is not taken into consideration. As an example, glass is still the dominant packaging material for mild alcoholic drinks. Yet, mild alcoholic drinks are also sold in cans and plastic bottles made of polyethylene terephthalate (PET). If the sales volume and the number of sold items were accessible, the primary packaging material waste volumes might differ from these figures. For instance, it may be that the sales volumes of cans and PET bottles are significantly higher than the sales volumes of glass bottles. To make a more precise analysis and more advanced statistical analysis, better quality and more extensive data would be needed, but such does not exist.

Lahtinen et al. [57] disclosed that approximately one billion Article 4 single-use plastic products (SUPPs) were consumed in Finland in 2019 through retail or HoReCa sectors. The figure is a rough estimate for six product groups that were used as an example in their study. The plastic content in these six product groups was estimated to be 8,000 t (±25 percent). The rough estimate of the plastic content regarding the ready-to-eat meals that can be instantly consumed without any further preparation was approximately 2,000 t. This figure also includes receptacles of takeaway meals sold in restaurants. Even though the substitute potential in these six product groups is significant, the authors brought up the fact that the current substitute materials often include plastic to some extent. Thus, those still fall into the Article 4 category of the SUP directive. For instance, for liquid products such as yogurt, there is not yet a substitute package available that would be plastic-free and fulfill the shelf-life requirements. In that case, as Messner [58] points out, the wise use of the recourses, hence, increased recyclability of the material is essential until a suitable substitute material is available. On the other hand, for cherry tomatoes, several plastic-free cardboard options can substitute the traditional plastic containers without interfering with the product's shelf-life.

For ready-to-eat meal packages, Lahtinen et al. [57] proposed a few options. Either use glass or metal receptacles, which are plastic-free or use fiber-based packaging solutions, for instance. The latter option needs some kind of thin water barrier that can be either polymer-based or non-plastic materials such as waxes. For candies similar types of fiber-based packaging solutions, especially if those are biodegradable in nature, might be a viable option. Moreover, one possibility for ready-to-eat meals is the use of reusable packages with a deposit system or other type of incentive system to motivate consumers to return the packages after their use.

Although the results of this study allow some conclusions about which product groups would be suitable for substitution, in practice, substitutability is associated with numerous delays and barriers. Currently, in the product development of food and beverage packaging, efforts are being made to find alternative materials instead of plastic. For example, the aim is to change the films of drinking cups from plastic to fiber-based solutions. However, product development is slow.

As discussed in Viitanen et al. [59], (see also [60], [61]), before the start of mass production of new plastic substitutes for food and beverage packaging, the alternatives must pass numerous tests for durability, antibacterial properties, contaminant levels, and fluid permeability. At the same time, the substitute material must meet the requirements for recyclability. The recyclability could be enhanced, for instance, by using mono-materials instead of multi-layered materials, which, with current recycling systems, are difficult to recycle [62]. In addition, Viitanen et al. [59] (see also e.g., [58], [61]) note that from a business perspective, old functional plastic packaging lines are often efficient and expensive to replace, and hence, the possible investments accumulate profit in the long run [63]. Therefore, from the companies' point of view, it may be optimal to run the lines to completion before changing them to produce new and more environmentally friendly packaging materials. On the other hand, as Ambec and Lanoie [64] argue, the improvements in the company's environmental performance might not add to overall costs. Instead, by putting the environmental issues in the forefront, the company might achieve economic or financial advantages, for instance, through better risk management or improved stakeholder relations [63], [64]. Additionally, even though many consumer surveys reveal that, for example, cellulose-based packaging solutions have a positive image [60] and consumers are indicating a willingness to pay for them [60], [65], [66], [67], [68], environmentally friendly food packages should not be substantially more expensive for the consumer than the less environmentally options already on the market. Similarly, the production of new packaging materials should be cost-effective and competitive from a business perspective.

CONCLUSIONS AND RECOMMENDATIONS

Single-use plastics (SUP) are extensively utilized in food packaging for consumers, and consequently, food packages are one notable cause for the constantly growing littering issue. Hence, multiple measures, such as the EU's SUP directive have been approved to regulate the usage of SUP in the food packaging industry. Using primary packaging material summary of single items sold in Finnish supermarkets, this novel study was among the first attempts to systemically identify in which food and beverage groups there is the greatest potential to substitute the available packaging materials, especially plastics, with more environmentally friendly alternatives from the littering perspective. Even though this study concentrates on food items sold in the Finnish markets only, the study gives insights also for further discussion, for instance, at the EU level. Hence, the possible impacts are expected to be larger when considered in the EU or even at the global level.

The results indicated notable disparities among the product groups, even if calculated as single food items only and not considering the sales volume. The analysis identified *Candies (sugar)* and *Meals/products (ready to eat)* as product groups in which there is a clear need, but also the most potential, to decrease the use of plastics as a primary packaging material, focusing on the perspective of littering and its prevention. For instance, ready-to-eat meals could be packed into totally plastic-free options such as glass or metal receptacles. In this specific product category, the use of reusable packages is also a viable option. The fiber-based solutions could be either plastic-free when using e.g., wax coating or containing only a thin polymer layer against water vapor. However, the wax coating might need further studies from the recycling viewpoint. For candies similar types of fiber-based solutions, preferably biodegradable in nature, could be considered.

The obtained results can be applied to further outline strategies for a potential reduction or substitution of primary packaging materials to maximize the effect of plastic replacement with new packaging material solutions. Additionally, the analyses are connected to the recyclability of various food packaging solutions that contain plastic. Consequently, the most detrimental and difficult-to-recycle plastic types were recognized for potential substitution with more sustainable solutions from the littering perspective, for instance, by using biodegradable materials or by enhancing recycling. It is worth noting that biodegradability is always highly dependent on the environment and conditions in which the biodegradation should occur e.g., in nature or marine conditions, or if the material is home-compostable or industrially compostable [12].

Even so, sustainability is not solely accomplished by replacement of the conventional primary packaging material with a new solution. For food products, there might not even exist a suitable substituting material yet. The decisions should also be made based on the protective and preservative requirements of each product group, or even by product type, as these requirements vary notably. Therefore, it is evident that there is no single and all-inclusive solution for future food packaging. Instead, the way to achieve more environmentally friendly food packaging combines several solutions: reducing the amount of packaging material used, the use of reusable packages, the replacement of current packaging materials such as plastic with novel fiber-based solutions, and more efficient recycling [69], [70]. For instance, in Finland bottles are efficiently collected and recycled through a deposit system. Hence, more research is required to ensure that the progress of one feature does not impair any other property, like food safety, which must be always guaranteed. The amount of food waste may not increase either.

The quantity of plastic that can be substituted could not be analyzed in this work, as unit sales data in product groups were not available. The future collection of data on packaging materials sales in units will be important to comply with the proposal for a revision of EU legislation on Packaging and Packaging Waste (PPWR) (Document 52022PC0677 [71]). The PPWR regulation aims to reduce the amount of packaging placed on the market in terms of its volume and weight, and to prevent the generation of packaging waste.

This study has provided knowledge for additional research by showing which product groups have the greatest potential for reducing littering, that is, where the long-range research should concentrate. Further studies could concentrate on 1) the use of reusable packages in food packaging, especially in primary packaging, 2) the use of bio-based and biodegradable polymers in food packaging including the end-of-life process of these polymers, and 3) to a more thorough analysis of the possible effects of the SUP directive in food and beverage packaging in the future.

DECLARATION OF CONFLICTING INTERESTS

The authors declare that there are no conflicts of interests in this paper.

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LIST OF ABBREVIATIONS

4Rs Reduce, Reuse, Replace, and Recycle
CO_2 Carbon dioxide
EAN European Article Number
EU European Union
EPR Extended Producer Responsibility
EPS Expanded polystyrene
GS1 Global Standards 1. GS1 is an international standards organization having member bodies in over 100 countries globally. GS1 manages the Global Trade Item Number (GTIN) system, for the identification of the products and services used in retail.
GTIN Global Trade Item Number
HoReCa Hotels, Restaurants and Catering
MoU Memorandum of Understanding
Mt Million tonnes
PE Polyethylene
PET Polyethylene terephthalate
PLA Polylactic acid
PP Polypropylene
PS Polystyrene
PTY Finnish Grocery Trade Association (Päivittäistavarakauppa ry)
PVC Polyvinyl chloride
SUP Single-use plastics
SUPPs Single-use plastic products
t Tonnes
UNEP The United Nations Environment Programme

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