Waste Management xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Fresh, frozen, or ambient food equivalents and their impact on food waste generation in Dutch households

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ARTICLE INFO

Article history:
Received 14 October 2016
Revised 20 February 2017
Accepted 5 May 2017
Available online xxxx

Keywords:
Food preservation
Product-specific
Meal planning
Food disposal
Waste index
Freezer

ABSTRACT

In Europe, it is estimated that more than 50% of total food waste – of which most is avoidable – is generated at household level. Little attention has been paid to the impact on food waste generation of consuming food products that differ in their method of food preservation. This exploratory study surveyed product-specific possible impacts of different methods of food preservation on food waste generation in Dutch households. To this end, a food waste index was calculated to enable relative comparisons of the amounts of food waste from the same type of foods with different preservation methods on an annual basis. The results show that, for the majority of frozen food equivalents, smaller amounts were wasted compared to their fresh or ambient equivalents. The waste index (WI) proposed in the current paper confirms the hypothesis that it may be possible to reduce the amount of food waste at household level by encouraging Dutch consumers to use (certain) foods more frequently in a frozen form (instead of fresh or ambient). However, before this approach can be scaled to population level, a more detailed understanding of the underlying behavioural causes with regard to food provisioning and handling and possible interactions is required.

1. Introduction

About 25% of all food supplied for human consumption is lost or wasted during various phases in the food supply chain (Stancu et al., 2016; Secondi et al., 2015; Kummu et al., 2012). In Europe, it is estimated that more than 50% of total food waste is generated at household level (Stenmarck et al., 2016; Stancu et al., 2016; Secondi et al., 2015; Beretta et al., 2013; Kummu et al., 2012; Gustavsson et al., 2011; Parfitt et al., 2010). Most of this waste is avoidable, as at some point prior to its disposal the food was edible (Quested et al., 2013a; Parfitt et al., 2010). Food waste reduction and prevention are important strategies to increase the availability of food throughout the supply chain in order to feed the global population and to achieve necessary environmental impact savings (Stancu et al., 2016; Secondi et al., 2015).

Studies focused primarily on estimating the amount and general composition of food waste at household level (e.g. Katajajuuri et al., 2014; Silvennoinen et al., 2014; Gutiérrez-Barba and Ortega-Rubio, 2013; Griffin et al., 2009; van Westerhoven, 2010, 2013), irrespective of method of preparation, method of preservation, or way of storage. As a result, there is limited understanding of the various underlying causes with regard to consumers' food waste behaviour (Stancu et al., 2016; Abeliotis et al., 2015; Secondi et al., 2015; Stefan et al., 2013; Gustavsson et al., 2011). Attention is paid to attitudes, habits, and motivations, and to socio-economic characteristics associated with individual consumers' behaviour towards food waste generation. In several studies it has been shown that consumers' planning and shopping routines – determined mostly by their moral attitudes and perceived behavioural control – are important predictors of their food waste generation, i.e. consumers that make a shopping list, plan their meals, and check their food inventories report less food waste than those who report more frequently buying too much food or making unintended food purchases (Stancu et al., 2016; Porpino et al., 2015; Quested and Luzecka, 2014; Stefan et al., 2013; Quested et al., 2013b; Quested et al., 2011). In addition, in a Canadian sample (Parizeau et al., 2015) it was found that households that spend routinely more money per capita on groceries produced more organic waste, even though they differ in their food-related attitudes and behaviours. Aschemann-Witzel et al.'s (2015) review paper points to consumers' lack of sufficient motivation, ability, and opportunity to reduce food waste, including lack of knowledge and planning, as important factors causing food waste generation. Systematic storage practices in the refrigerator might therefore be useful to reduce food waste (Farr-Wharton

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http://dx.doi.org/10.1016/j.wasman.2017.05.010
0956-053X/

et al., 2012, 2014). Household size was found to be another factor in food waste generation, with smaller households contributing less than larger households to net food waste, whereas at the same time persons living alone were found to produce the highest amounts of waste per person (Koivupuro et al., 2012).

Surprisingly little attention has been paid so far to product-related characteristics and/or attributes that might drive consumers' food waste generation. A study on packaging attributes in relation to household food waste generation reported that too large volumes, packages that are difficult to empty, and packages that have passed the best before date were associated with higher amounts of food waste (Williams et al., 2012). Similarly, based on a supplier–retailer interface assessment, it was suggested that frozen foods were associated with lower levels of food waste, and similar cases were found for some ambient food products. These waste-reducing outcomes were attributed mainly to the extended shelf-life of ambient and frozen foods (Mena et al., 2011). The current recommendation from the Waste & Resources Action Programme (WRAP) research to use the freezer to extend the shelf-life of foods in order to decrease food waste levels is in line with this supply chain-based observation (Quested and Luzecka, 2014; Quested et al., 2013a). On should realise however, whether benefits of reduced waste exceed increased energy costs of maintaining reduced storage temperature, as recently studied by Eriksson et al. (2016) for Swedish supermarkets.

Actual consumer data at household level to support this notion of WRAP are currently scarce. On the basis mainly of food waste data over a relatively short period of time (i.e. a week), Martindale (2014) suggests that food wastage at home was significantly lower for frozen food products compared to their fresh equivalents. However, in this study, neither the actual amounts of the specific foods wasted nor their consumption frequencies were reported. Thus, a relative comparison between fresh, frozen, and ambient food equivalents – taking consumption frequency, disposal frequency, and amounts of food usually wasted into account over a longer period of time (i.e. a year) – is needed to further our understanding.

The aim of the current study is to explore possible impacts of different preservation methods on food waste generation in Dutch households taking both concurrency of frequency and habitual amounts into account. An extended survey on self-reported food waste is performed in a Dutch consumer sample. In addition to general information gathered with regard to Dutch household's routines and general food waste generation, product-specific information is collected for food equivalents with different methods of preservation at the point of sale, namely, fresh, frozen, and/or ambient. It is hypothesized that the use of frozen foods is associated with lower food waste generation in Dutch households than the use of fresh and/or ambient food equivalents.

2. Methods

2.1. Participants and survey

An online survey was developed and implemented in the NIPO Odin software of TNS NIPO. All participants were recruited by TNS NIPO. Data were collected by TNS NIPO in October 2015 in the Netherlands. Filling out the survey took about 20 min.

A total of 1167 households representative of the Dutch population according to age (18–75 years), sex, household size and type, education level, income, and employment status were invited via e-mail to participate in the survey, of which 701 households responded (response rate of 60%). Storage of foods in a freezer was defined as an inclusion criterion as well as disposing of food at least once per year. Sixty households (9%) indicated that they never stored foods in a freezer and were consequently excluded from partaking further in the survey. Another 125 households (20%) indicated that they never threw food away, and they were also excluded (except from analyses in Table 2 in question C1 on frequency of general food waste generation). Table 1 provides a summary of the socio-demographic characteristics of the households participating in the survey as compared to the general Dutch population.

Participating respondents received a monetary reward.

2.2. Measures

2.2.1. Household routines and general food waste generation

First, some general household routines regarding shopping for groceries and hot meal planning were ascertained (questions A and B in Table 2). Then, the survey requested self-reported measures on general food waste generation (C): (1) how routinely foods were disposed of in the household; (2) food waste generation in relation to the way products were stored at home (in the refrigerator or freezer or at ambient temperature; (3) food product categories into which disposed foods fall; and (4) the main reasons for disposal per way of storage. The first two of these latter four questions are visible in Table 2. Per way of storage, food categories from which respondents could choose were (question C3): meat, poultry (such as chicken), meat substitutes; fish, fish products; vegetables; fruit; potatoes, potato products; pasta; rice; soups; sauces, oils, fats; milk, dairy products; bread, bakery products; sweet spreads; savoury spreads; candy, snacks, ice; readymade meals; (leftover) homemade meal. All options that applied could be indicated. Reasons for disposal from which respondents could choose were

Table 1
Socio-demographic background characteristics of respondents (sample of the study) compared to the Dutch population in 2015. Source: TNS-NIPO

Characteristic	Sample of the study (%)	Dutch households in 2015 (%)
Sex		
Male	45.8	49.9
Female	54.2	50.1
Age		
18–34 years	23.3	28.6
35–54 years	41.5	39.6
55^{+} years	35.2	31.8
Household size		
1–2 persons	57.7	54.5
3–4 persons	36.4	31.7
≥5 persons	5.9	5.8
Household type		
1 person	17.1	18.9
Adult household	50.6	48.7
Households with children ≤17 year	32.4	32.3
Education		
No, basic	1.4	3.8
Low	12.6	13.9
Middle	47.1	46.2
High	38.8	35.9
Occupation		
Full/part-time work	61.8	58.9
Retired	14.8	15.8
Unemployed	19.0	18.2
Pupil, student	4.3	7.1
Income		
≤26,200 €	16.7	20.3
26,200–38,800 €	14.2	15.0
38,800–65,000 €	34.4	29.2
65,000–77,500 €	11.7	10.9
≥77,500 €	23.1	24.6

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Table 2
Results for general household routines regarding shopping for groceries, hot meal planning, and food disposal; percentages of Dutch households are indicated.

A - General household shopping routines (% of n = 506[1])

How often are groceries bought within your household?		Is a shopping list prepared in advance?		Is the food inventory checked before the groceries are bought?	
≤1 time per week	15	Never	6	Never	2
2–3 times per week	58	Seldom	10	Seldom	4
4–5 times per week	21	Sometimes	18	Sometimes	24
>5 times per week	7	Often	34	Often	50
		Always	32	Always	21

B - Household hot meal planning routines (% of n=506)

How many times per week is a hot meal usually prepared in your household?[2]		To what extent is it known in advance which hot meals are on the menu in your household?	
0–1 time per week	2	Usually, on the day itself	40
2–3 times per week	6	A few hot meals per week	37
4–5 times per week	26	Most hot meals per week	13
6–7 times per week	65	Almost all hot meals per week	10
> 7 times per week	1	I don't know	0

C - General food waste generation

C1 - How often is food disposed of in your household?

	% of n = 641[3]	% of n = 506
Daily	12	14
Weekly	35	44
Monthly	24	31
Yearly	9	12
Never	20	0

C2 - How regularly are foods that are stored in the refrigerator/ freezer/at ambient temperature disposed of in your household?

	Refrigerator	Freezer	Ambient
Daily	2	0	2
Weekly	36	1	16
Monthly	43	10	24
Yearly	11	47	34
Never	8	41	24

[1] Households that indicated that they stored foods in a freezer and disposed of food at least annually.
[2] Readymade meals are not counted here.
[3] All households that responded (i.e. 701), excluding 60 households that never store foods in a freezer.

(question C4): too much bought; forgot it was there; no time to eat it, does not fit the schedule; too much prepared; too little left; the product has gone off; the expiry date has passed. All options that applied could be indicated.

2.2.2. Product-specific food waste generation

The main part of the survey was about waste generation for specific food products in relation to their form of preservation at the point of sale in Dutch supermarkets, namely, for fresh, frozen and/or canned or glass-jarred (ambient) variants. Three measures are taken: (1) annual consumption frequencies (CF); (2) annual disposal frequencies (DF); and (3) actual amount usually wasted per wasting event (fraction of purchased volume, FPV). Based on these measures, a food waste index (WI) is calculated, enabling a relative comparison of the amounts of food waste between food equivalents with different preservation methods on an annual basis.

Twelve different food products were surveyed in two (fresh and frozen or ambient and frozen) or three (fresh, frozen, and ambient) methods of preservation at the point of sale: seven types of vegetables, potato products (excluding French fries), readymade meals, and red berry fruit. The food product 'fish' was subdivided into unbattered fish, battered fish, and fish fingers (surveyed only for frozen). In total, 28 food product-preservation method combinations (Table 3) were surveyed.

In the survey, product-specific frequencies of consumption and of wasting, and product-specific usual amount of waste per wasting event was quantified as follows. Food products were organized in a matrix table per method of preservation, first fresh, then frozen, and finally ambient food products. All questions per matrix table, so per method of preservation, were answered before switching to the next method of preservation. First, the frequency with which the food product is consumed, followed by the frequency with which it is disposed of in the household were ascertained. Frequencies had to be filled out on a seven-item scale, except for fresh seasonal food products, which were scored on a five-item scale (Table 4). Subsequently, respondents were asked to indicate on a five-item scale the amount of food product usually disposed of per wasting event in relation to the amount bought (Table 4). Lastly, the form in which the food product is usually disposed of had to be indicated. Options from which to choose were: still unprepared; prepared, immediately after eating; prepared and after storage in the refrigerator; prepared and after storage in the freezer; none of these options. All options that applied could be indicated. Note: If the option 'never' was indicated for the frequency of consumption of a specific food product, this household was deemed a non-consumer of this product, and the survey continued with the next food product. When a consumer of a specific food product indicated that he/she never wasted this food product, the survey continued with the next food product.

2.3. Data analyses

Ten households were omitted from the analyses because of their erroneous scoring behaviour. These respondents indicated for four or more food product-preservation method combinations that they disposed of the specific food product more frequently than they consumed it. Furthermore, for 24 of the total 28 food product-preservation combinations surveyed, a few extra respondents were excluded from the data analyses, namely, those who indicated a higher frequency of disposal than frequency of consumption; in most cases, one to three respondents were excluded. The data analyses for household routines and general food waste generation results are therefore based on a sample of 506 households (46% men; 54% women; 47 ± 15 year), and for product-specific food waste generation, on 501–506 households. Thus surveyed households (HH) all generally dispose of foods at least annually, as this was an exclusion criterion.

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Table 3
Overview of the categorization of the surveyed foods into fresh, frozen, and ambient according to differences in their form of preservation at the point of sale in Dutch supermarkets.

	Spinach	Peas	Peas + carrots	Broccoli	Green beans	Curly kale[1]	Red cabbage[1]	Potato products[2]	Fish, unbattered	Fish, battered	Fish fingers[3]	Readymade meals	Red berry fruit[1,4]
Fresh													
Purchased non-chilled; whole product	x			x	x	x	x						x
Purchased chilled; pre-cut and/or pre-processed						x	x	x	x	x		x	
Frozen	x	x	x	x	x	x	x	x	x	x	x	x	x
Ambient[5]		x	x		x	x	x						

[1] Fresh seasonal product.
[2] Such as potato slices, baby potatoes, so no unpeeled potatoes; for frozen, French fries were excluded.
[3] Fish fingers were surveyed only for the frozen preservation method.
[4] Such as strawberries, blackberries, raspberries.
[5] In the survey, ambient referred to canned and glass-jarred.

Table 4
Conversion of descriptive values as used in the survey for frequency of eating and disposal of food products into annual frequency, and of the amount of food usually disposed of per wasting event into fraction of purchased volume (FPV).

Frequency of eating/disposal[1]		Amount of food usually disposed of per wasting event	
Scale in survey	Annual frequency	Scale in survey	Fraction of Purchased Volume (FPV)
≥2–3 times per week	130	(Almost) all bought	1
1 time per week	52	Half of the purchase	0.5
2–3 times per month	30	A quarter of the purchase	0.25
1 time per month	12	2–3 tablespoons	0.1
2–3 times per year	2.5	Practically nothing	0.05
1 time per year	1		
Never	0		

[1] For seasonal food products, a five-item scale was used; options 2–3 times per year and 1 time per year were omitted.

2.3.1. Household routines and general food waste generation

The data on household routines and general food waste generation were analysed using Excel and with descriptive statistical analysis using software SPSS (IBM SPSS Statistics 22 release 22.0.0.1).

2.3.2. Product-specific food waste generation

Product-specific food waste generation was analysed using R (R i386 version 3.2.3).

First, descriptive frequencies of consumption and disposal of the specific food products (Table 3) were converted into annual consumption frequencies (CF) and annual disposing frequencies (DF), as indicated in Table 4. Next, per food product-preservation method combination, the number (n_C) and percentage of HH consuming the specific food product at least once per year were calculated. These consumers are referred to as HH-Con, i.e. households that consume the specific food product (Table 5). Next, for HH-Con only, the number (n_D) and percentage of households that throw away the food product at least once per year was calculated. These consumers are referred to as HH-Dsp, i.e. households that dispose of the specific food product (Table 5). Thus, HH-Dsp form a subgroup of HH-Con (see Fig. 1 for a schematic of the different groups). To test for significant differences between numbers of HH-Dsp for food products with different preservation methods, a generalized linear model with a binomial link function and a tukey posthoc test was applied. A significance level of 0.05 was used.

To further explore the data, means ± standard deviations were calculated for the annual CF of HH-Con, and for annual DF of HH-Dsp (Table 6). Means ± standard deviations were also calculated for the FPV (Table 6). To this end, for HH-Dsp the descriptive usual amounts of disposed food product per wasting event were calculated into amounts disposed in arbitrary units, namely, fraction of purchased volume (FPV), as indicated in Table 4. To assess significant differences between means of food products with different preservation methods, a Wilcoxon rank sum test comparing two preservation methods was applied; and for the three methods of preservation a Kruskal-Wallis rank sum test, with a pairwise comparison using Nemenyi-test with Chi-squared approximation, was applied. A significance level of 0.05 was used.

To calculate the WI, i.e. the amount of waste per consumption event of a specific food product-preservation method combination (for HH-Con), the following approach was taken. First, the total number consumption events (NCE) at which a food product is consumed per year by all HH-Con (n_C) was calculated by summation of the HH-Cons' values of annual CF.

$$NCE_{HH\text{-}Con} = \sum_{i}^{n_C} CF_i \quad (\text{in times} \cdot \text{yr}^{-1})$$

Then, for each food product-preservation method combination, the amount wasted per year as generated by all HH-Dsp was calculated: for each HH-Dsp, firstly the HH-DSP's annual DF was multiplied by the amount of which the household usually disposes per wasting event in FPV. This results in the amount of waste generated per year per HH-Dsp and is defined in units of purchased volume (UPV) per year. Next, for all HH-Dsp (n_D), their UPV values were summed, resulting in the total amount of waste in units of purchased volume (WUPV) generated per year for the specific food product-preservation method combination.

$$UPV_{perHH-Dsp} = DF * FPV \ (\text{per year})$$

$$WUPV_{HH\text{-}Dsp} = \sum_{i}^{n_D} UPV_i \ (\text{per year})$$

Finally, the amount of waste per consumption event, the WI for consumers of the specific food product (HH-Con) was calculated for each method of preservation (Table 6): the WUPV per year was divided by the NCE per year.

$$WI_{HH\text{-}Con} = \frac{WUPV_{HH\text{-}Dsp}}{NCE_{HH\text{-}Con}} \ (\text{in UPV per consumption event})$$

Also, the ratio of the WI (RWI) of frozen (WI_{Frozen}) over WI fresh (WI_{Fresh}), and/or WI_{Frozen} over WI ambient ($WI_{Ambient}$), was calculated (Fig. 2).

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Table 5
The number (n_C) and percentage (%) of Dutch households consuming a specific food product (HH-Con), and the number (n_D) and percentage of households thereof that dispose of the food product (HH-Dsp), for different methods of preservation at the point of sale of the food product.

Product	HH-Con		HH-Dsp	
	n_C	%	n_D	%
Spinach				
Fresh	455	91	115	25
Frozen	381	75	75	20
Peas				
Ambient	274	54	78	28
Frozen	220	43	51	23
Peas + Carrots				
Ambient	295	59	84	28
Frozen	116	23	27	23
Broccoli				
Fresh	437	87	146[a]	33[a]
Frozen	85	17	17[b]	20[b]
Green beans				
Fresh	480	95	133	28
Frozen	180	36	40	22
Ambient	230	46	61	26
Curly kale				
Fresh	374	74	73	19
Frozen	155	31	31	20
Ambient	43	8	9	21
Red cabbage				
Fresh	241	48	44[b]	18[b]
Frozen	174	35	31[b]	18[b]
Ambient	273	54	79[a]	29[a]
Potato products				
Fresh	490	97	217[a]	44[a]
Frozen	296	59	68[b]	23[b]
Fish, unbattered				
Fresh	430	85	43	10
Frozen	322	64	32	10
Fish, battered				
Fresh	374	74	36	10
Frozen	260	51	31	12
Fish fingers				
Frozen	319	63	34	11
Readymade meals				
Fresh	320	63	82	26
Frozen	206	41	54	26
Red berry fruit				
Fresh	465	92	146[a]	31[a]
Frozen	217	43	35[b]	16[b]

Note: Different letters refer to statistical differences ($\alpha = 0.05$).

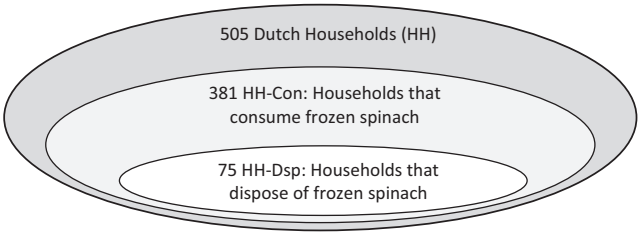

Fig. 1. Schematic representation of the number of Dutch households (HH) that generally dispose of foods at least annually, the number of households thereof that consume – as an example – frozen spinach (HH-Con), and the number of households that consume frozen spinach and dispose of frozen spinach at least once per year (HH-Dsp).

$$RWI_{Frozen/Fresh} = \frac{WI_{Frozen}}{WI_{Fresh}}$$

$$RWI_{Frozen/Ambient} = \frac{WI_{Frozen}}{WI_{Ambient}}$$

3. Results

3.1. Household routines and general food waste generation

Table 2 shows results for the questions on Dutch household routines. Almost three-quarters of Dutch households shop for groceries up to three times per week. The majority (66%) generally use a shopping list that is prepared in advance. Also, most Dutch households (71%) check their food inventories before buying the groceries. More than 90% of Dutch households prepare a hot meal four to seven times per week (readymade meals are excluded). Only about one quarter of the Dutch households plan in advance the hot meal that is on the menu.

Of the Dutch households that store foods in a freezer, 9% indicated that they disposed of food in general only on a yearly basis (Table 2). When asked about general food waste generation in relation to the way of storage of products at home, almost no Dutch households indicated that they disposed of food from the freezer on a daily or weekly basis. Most Dutch households indicated that

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Table 6
For different methods of preservation at the point of sale of the food product, means ± SD for annual consumption frequencies (CF) of Dutch households that consume the food product (HH-Con), and for annual disposal frequencies (DF) and amounts wasted per wasting event (in FPV) of households that dispose of the food product (HH-Dsp); waste index (WI) of Dutch households that consume the food product (HH-Con).

Product	HH-Con	HH-Dsp		HH-Con
	CF (times/year)	DF (times/year)	Waste per event (FPV)	WI ($\cdot 10^{-3}$ UPV)
Spinach				
Fresh	24 ± 20[a]	7 ± 11	0.15 ± 0.20	10
Frozen	17 ± 16[b]	6 ± 9	0.09 ± 0.06	6
Peas				
Ambient	16 ± 15	7 ± 9	0.10 ± 0.08	13
Frozen	15 ± 18	6 ± 8	0.10 ± 0.05	10
Peas + Carrots				
Ambient	16 ± 19	7 ± 9	0.11 ± 0.08	12
Frozen	13 ± 14	6 ± 7	0.11 ± 0.05	12
Broccoli				
Fresh	29 ± 23[a]	9 ± 12	0.17 ± 0.21	15
Frozen	18 ± 20[b]	8 ± 8	0.11 ± 0.06	9
Green beans				
Fresh	32 ± 18[a]	10 ± 13	0.13 ± 0.15	10
Frozen	18 ± 20[b]	6 ± 6	0.12 ± 0.07	8
Ambient	21 ± 22[b]	10 ± 13	0.11 ± 0.08	16
Curly kale				
Fresh	28 ± 19[a]	15 ± 7[a]	0.11 ± 0.07	11
Frozen	14 ± 15[b]	6 ± 7[b]	0.11 ± 0.06	8
Ambient	15 ± 15[b]	9 ± 9[b]	0.15 ± 0.08	26
Red cabbage				
Fresh	24 ± 15[a]	14 ± 6[a]	0.13 ± 0.10	13
Frozen	12 ± 13[b]	6 ± 8[b]	0.12 ± 0.07	10
Ambient	14 ± 16[b]	6 ± 10[b]	0.12 ± 0.07	17
Potato products				
Fresh	73 ± 47[a]	14 ± 25	0.17 ± 0.20	13
Frozen	31 ± 36[b]	10 ± 14	0.13 ± 0.17	8
Fish, unbattered				
Fresh	35 ± 32[a]	6 ± 12	0.17 ± 0.24	3
Frozen	21 ± 23[b]	4 ± 6	0.22 ± 0.31	3
Fish, battered				
Fresh	19 ± 17[a]	5 ± 8	0.17 ± 0.27	7
Frozen	13 ± 14[b]	4 ± 6	0.17 ± 0.23	5
Fish fingers				
Frozen	12 ± 14[b][1]	8 ± 23	0.19 ± 0.26	14
Readymade meals				
Fresh	22 ± 30[a]	5 ± 7	0.20 ± 0.28	10
Frozen	17 ± 23[b]	4 ± 8	0.24 ± 0.33	16
Red berry fruit				
Fresh	64 ± 47[a]	20 ± 15[a]	0.12 ± 0.08	11
Frozen	24 ± 35[b]	6 ± 8[b]	0.12 ± 0.09	5

Note: Different letters refer to statistical differences ($\alpha = 0.05$).
[1] Frozen fish fingers were compared to fresh battered fish.

they disposed of food stored in the freezer yearly, or never disposed of their frozen foods. In contrast, foods from the refrigerator are disposed of on a weekly or monthly basis by more than 80% of Dutch households. The timeframe of disposal of food stored at ambient temperatures in Dutch households is in between that of frozen and refrigerated foods. On average, Dutch households dispose of food products from the refrigerator 46 ± 45 times per year, whereas from the freezer, food products are disposed of only six ± 15 times per year, and food products from ambient storage are disposed of 27 ± 8 times per year.

The most frequently mentioned food products disposed of from the refrigerator were: (leftover) homemade meal (mentioned by 61% of Dutch households); vegetables (60%); milk and dairy products (56%); savoury spreads (44%); meat, poultry, and meat substitutes (39%). For frozen food products, these were: meat, poultry, and meat substitutes (71%); (leftover) homemade meal (54%); bread and bakery products (38%); fish and fish products (38%); candy, snacks, and ice (36%). For food products stored at ambient temperature, these were: fruit (48%); bread and bakery products (38%); potato and potato products (32%); sauces, oils, and fats (31%). All other food categories were indicated by a proportion lower than or equal to 27% of Dutch households.

The main reasons for disposal of food products from the refrigerator were: 'too much was prepared' (44%), 'the food product was forgotten' (40%), and/or the food product was no longer edible, i.e. 'the product had gone off' (51%), or 'the expiry date had passed' (55%). Food products from the freezer were disposed of because 'the expiry date had passed' (38%) and/or 'the product was forgotten' (32%). Foods from ambient storage were disposed of mainly because 'too much was prepared' (24%). All other reasons for disposal of all three ways of storage at home were indicated by a lower proportion than 27% of Dutch households.

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3.2. Product-specific food waste generation

3.2.1. Numbers and percentages of households

Table 5 shows the numbers and percentages of Dutch households consuming a specific food product (HH-Con), and the number and percentage of households thereof that dispose of the food product (HH-Dsp), for different methods of preservation at the point of sale of the food product.

For all food products, more Dutch households consume (i.e. HH-Con) the fresh food product than the frozen and/or ambient equivalents. An exception is red cabbage, which is consumed from cans or glass jars by more households compared to the fresh and frozen equivalents.

For most of the twelve product types, there are no significant differences between the number of Dutch households that dispose of (HH-Dsp) the fresh, frozen, and/or ambient product equivalents (generalized linear model with binomial link function and tukey posthoc test). The four exceptions are broccoli, red cabbage, potato products, and red berry fruit. For these product types, significantly lower numbers of Dutch households dispose of the frozen food products compared to the households making use of the fresh counterparts. For red cabbage, both the frozen and the fresh equivalents are wasted by significantly fewer Dutch households compared to canned or glass-jarred red cabbage.

3.2.2. Waste index

3.2.2.1. Annual consumption and disposal frequencies, and amount wasted per event. Table 6 shows the mean annual consumption frequencies of Dutch households that consume the food product (HH-Con), for different methods of preservation at the point of sale of the food product. Also, the mean annual disposal frequencies and mean amounts usually wasted per wasting event (in relation to the purchased amount), expressed as FPV, for households that dispose of the food product (HH-Dsp) are indicated.

Statistical analysis of the data (Wilcoxon rank sum test when comparing two preservation methods; Kruskal-Wallis rank sum test with a pairwise comparison using Nemenyi-test with Chi-squared approximation when comparing three methods of preservation) shows the following differences. The mean annual consumption frequencies (CF of HH-Con) of all fresh food product variants are significantly higher than those of the frozen and/or ambient equivalents, except for peas and peas with carrots. The annual disposal frequencies (DF of HH-Dsp) for most of the food products studied did not vary significantly with preservation method. Only the annual disposal frequencies of frozen (and ambient) curly kale and red cabbage and of frozen red berry fruit are significantly lower than those of their fresh counterparts. It should be noted that the number of Dutch households consuming (HH-Con) ambient curly kale is very low, i.e. 8% (Table 5). For all food products, amounts usually wasted per wasting event (FPV) by Dutch households that dispose of the food product (HH-Dsp) are not significantly different for the two and/or three methods of preservation.

3.2.2.2. Waste index. The WI for Dutch households that consume the specific food product (HH-Con) is also indicated in Table 6 per food product-preservation method combination. Fig. 2 presents the ratios of the waste index (RWI) of frozen over fresh and/or frozen over ambient. For almost all studied frozen vegetables, the ratio is below one (the dashed line in Fig. 2). This indicates that, for these food products, when households use the frozen food product compared to the fresh and/or ambient equivalent, per consumption event a lower amount is wasted. For peas with carrots and for unbattered fish, the amount wasted per consumption event is similar. The only food products where the amounts wasted per consumption event are higher for frozen than for fresh are ready-made meals.

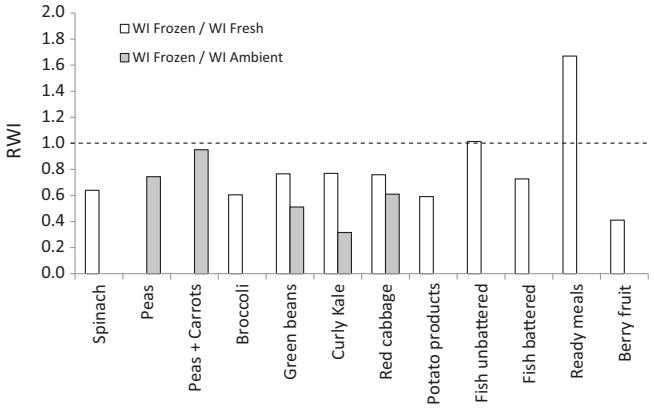

Fig. 2. Ratios of the waste index (RWI) of frozen over fresh and/or frozen over ambient for households that consume the food product (HH-Con); the dashed line indicates the value where both WIs are equal to each other.

3.2.3. Form of disposed food product

Visual inspection of Table 7 – presenting the form of food disposal – shows that Dutch households mostly dispose of food products directly after meal consumption, independent of the method of preservation at the point of sale of the food product. An exception is fresh and frozen red berry fruit; fresh red berry fruit is mostly disposed of 'still unprepared'. Furthermore, regarding the different food preservation methods, clearly more households indicated that they disposed of ambient prepared food products immediately after consumption compared to their fresh and frozen equivalents. Furthermore, it is notable that the second most often indicated form in which food products were disposed of was 'prepared and after storage in the refrigerator', and this was particularly true for the fresh food products.

4. Discussion

This study explored both general and food product-specific waste generation in Dutch households. For the latter, a WI was calculated per specific food and preservation method combination. The majority of Dutch households generally reported disposing less routinely of foods from the freezer ('never' or 'yearly'), than foods from the refrigerator ('weekly' or 'monthly'), or from ambient storage ('monthly' or 'yearly'). The main reasons given by the consumers for disposing of foods from the freezer were that 'the expiry date had passed' and/or that 'the product was forgotten', whereas the main reasons for disposing of foods from the refrigerator were that the products had actually gone off ('the product had gone off', 'the expiry date had passed') or that 'too much was prepared'. The product-specific part of the study showed that, with the exception of peas and peas with carrots, Dutch households consume fresh food products more often than their frozen and/or ambient equivalents. Taken together, the annual consumption frequencies and disposal frequencies of specific foods, and also taking their total amounts wasted per year into account, the RWIs demonstrate some product-specific variation in their net outcomes. For most of the foods studied, the usage of the frozen equivalent was associated in the Netherlands with lower food waste generation.

The results observed in the current study with regard to food household routines and general food waste generation are in line with previous research. For example, the most regularly disposed of food products in this study correspond with observations in another recent Dutch survey, namely, vegetables, dairy products, and bread (Temminghoff and van Helden, 2015); and this holds true also for the reported shopping and mealtime planning-related behaviours. The distinctly different timeframes observed

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Table 7
The form in which the food product is usually disposed of for fresh, frozen, and ambient purchased food products; for each option, the percentage of households is indicated.

Product	Still unprepared %	Prepared, immediately after eating %	Prepared, after storage in refrigerator %	Prepared, after storage in freezer %	None of these %
Spinach					
Fresh	20	51	20	4	6
Frozen	7	69	15	4	6
Peas					
Ambient	5	69	21	1	3
Frozen	10	53	22	7	8
Peas + Carrots					
Ambient	5	66	23	0	6
Frozen	6	38	32	9	15
Broccoli					
Fresh	29	45	22	2	2
Frozen	8	42	23	15	12
Green beans					
Fresh	19	47	28	4	3
Frozen	14	44	24	10	8
Ambient	4	72	20	0	4
Curly kale					
Fresh	8	61	23	3	5
Frozen	5	46	26	15	8
Ambient[1]	[0	67	33	0	0]
Red cabbage					
Fresh	9	55	27	4	5
Frozen	7	55	24	10	5
Ambient	9	67	22	0	1
Potato products					
Fresh	28	46	19	3	4
Frozen	14	58	13	8	8
Fish, unbattered					
Fresh	11	45	27	7	11
Frozen	19	40	19	17	5
Fish, battered					
Fresh	13	48	19	6	13
Frozen	19	48	14	12	7
Fish fingers					
Frozen	29	44	11	11	4
Readymade meals					
Fresh	14	40	31	7	8
Frozen	17	46	23	12	2
Red berry fruit					
Fresh	62	6	22	1	9
Frozen	29	21	29	10	12

Note: As all options that applied could be indicated, the total percentages were standardized according to the total number of households that indicated the options per food.
[1] Disposed of by only a very small number of households.

in the current study within which foods are disposed of from refrigerator, freezer, and ambient storage are in agreement with Temminghoff and van Helden (2015) and Martindale (2014), and also highly interesting in themselves because of the stated reasons for disposal. The reasons given clearly point to infrequent and insufficient screening of existing stocks so that stored food products remain overlooked when new purchases are planned, similar to other studies (Temminghoff and van Helden, 2015; Quested and Luzecka, 2014; Stefan et al., 2013; Stancu et al., 2016). This indicates that consumers need assistance in their domestic management of stored foods in order to prevent avoidable food waste generation. This might be facilitated by a smart phone app (Woolley et al., 2016) or via smart kitchen appliances (Surie et al., 2013), providing consumers with supporting information about foods still in stock and foods that are close to their expiry date. We expect that this might be especially beneficial for foods stored in the freezer, since here the 'window of action' is the longest because of these foods' extended shelf-life. Also, there is another reason why reminding consumers of foods in their freezers probably is very important. Eriksson et al. (2016) claim that at the supermarket level, even though waste is reduced by lower storage temperature, there might be a net cost due to the increased need for electricity, and therefore prolonging shelf-life might just shift waste of food to waste of electricity. Similar to the supermarket level, at the household level this might also play a role, because too long storage in the freezer possibly also might have a negative environmental impact. However, research on resource efficiency analysis of fresh and processed food chains still is scarce. Thus, storing foods more often in the freezer just as suggested by Mena et al. (2011) and WRAP (Quested and Luzecka, 2014; Quested et al., 2013a), in combination with effective storage management tools, might indeed decrease food waste generation at household level. This might be an successful approach, as the research of Temminghoff and van Helden (2015) and of Quested et al. (2011) showed that consumers themselves mentioned that they might be more successful in reducing their food waste if they used a better way of storing food products, namely freezing.

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In relation to the RWIs, for the majority of frozen food equivalents, smaller amounts were wasted compared to their fresh or ambient equivalents. However, no difference seems to exist between the fresh and frozen unbattered fish equivalents, and between the ambient and frozen peas with carrots equivalents, whereas more food is wasted from frozen readymade meals than from their fresh equivalents. We hypothesize that these differences in the net food waste outcome can be attributed to underlying behavioural causes, such as differences in the management of food provisioning and handling between types of foods and/or their preservation method (Aschemann-Witzel et al., 2015). For example, one could hypothesize that leftovers of frozen readymade meals are habitually disposed of immediately after consumption because they are not seen by consumers as a fresh product, whereas leftovers resulting from fresh readymade meals might are treated more like a home-cooked meal and therefore leftovers are stored to consume at a later stage. This is supported by the observation in the current study that, in general, fresh products were more likely to be stored in the fridge prior to disposal than their frozen or ambient equivalents. Another explanation for the observed differences might be more related to dosing issues. For ambient foods in particular, this seems currently very relevant, as leftovers of these foods are often disposed of immediately after meal consumption. A possible explanation could be that because of the rather fixed packing sizes and short shelf-life of small leftovers, consumers prepare too much when using ambient foods. To be able to gain a systematic understanding of underlying behavioural causes, further experimental explorations in specific food waste contexts are required, that also take possible interactions into account.

WI analyses was based on data comprising a period of one year. This long timeframe is essential in order to achieve a valid relative comparison of households' differences in their food waste generation for food products that vary widely in their shelf-life (from fresh products with a short shelf-life to frozen and ambient products with a much longer shelf-life). This is in contrast to Martindale (2014), where data was analysed from a retrospective view of UK households' fresh and frozen food use over one week. Because of this short measuring period in this research, the less frequently occurring food waste events of frozen or ambient foods might not have picked up. Furthermore, in order to estimate food waste reduction potentials of specific products, only assessing their regular (i.e. daily, weekly, monthly, yearly) disposal frequency is not enough, since this measure does not take the usually wasted amounts into account. For example, very small amounts of a product might be wasted on a monthly basis, whereas a complete unused package might be thrown away only once a year; as a consequence, this latter occurrence might lead to a much higher net impact on food waste generation than the monthly disposal frequency might cause. Consequently, the current survey was designed in such a way that households that dispose of the specific food product indicated not only the frequency of the wasting event but also the amount usually disposed of per event. This was done by relating the usual amount wasted to the amount that was bought, using a scale with consumer-relevant wording indicative of disposed amounts, elaborating further on the lessons learned in earlier studies (Stefan et al., 2013; Quested et al., 2011). The WI proposed here represents the amount of waste per consumption event for each specific product-preservation method combination. It takes the total number of consumption events of the specific food product and accordingly also the number of consumers of the food product into account. In turn, the ratio of two different WIs is a relative measure and a comprehensible way, that allows direct comparisons of yearly relative food waste generation from very different numbers of households consuming and possibly also disposing of specific frozen, fresh, and/or ambient food products. In future research, it is recommended to measure also absolute amounts of waste to be able to calculate impacts on consumers' total yearly food waste amounts. The high frequencies of fresh produce consumption and low frequencies of frozen produce consumption observed in the current study are typical for the Netherlands (personal communication H. van Hassel, GfK, The Netherlands). Consequently, a replication of the study in a country with traditionally high frozen food use frequency might enlarge the observed actual beneficial effects.

Quantifying actual food waste generated by households is complex, and there are very many different approaches (Møller et al., 2014; Quested et al., 2011; Parfitt et al., 2010): amongst others, self-reported food waste via a survey, questionnaire, or interview (e.g. Stancu et al., 2016; Abeliotis et al., 2015; Martindale, 2014); food waste-sorting analyses of waste in garbage bins (e.g. Van Westerhoven, 2010, 2013; Parizeau et al., 2015); weighing by the researchers of waste provided by households (Gutiérrez-Barba and Ortega-Rubio, 2013); or participating households keeping a diary of food waste weighed by the households themselves (e.g. Katajajuuri et al., 2014; Williams et al., 2012). All methods have advantages and disadvantages (Zorpas and Lasaridi, 2013), and, to be able to prevent food waste, it is probably necessary to combine different methodologies (Møller et al., 2014; Zorpas and Lasaridi, 2013). In the current study a survey was used, and we realise that a drawback of self-reporting is that intended attitudes and recalled behaviour is measured, rather than actual behaviour. Also, results obtained are more reflective of relative frequencies and/or amounts than of absolute frequencies and/or amounts. Therefore, we believe that it is a suitable approach aiming at relative comparisons between amounts wasted of differently preserved foods. There has been a call for more direct observation of consumer behaviour (Walker and Gur, 2016; Baumeister et al., 2007). For example, immersive virtual reality (IVR) environments are promising tools for immersing people into an almost real environment that provides many similarities to the complexity of the real world and at the same time allows experimenters to constrain experimental parameters to obtain empirical data (Ischer et al., 2014). We believe that these emerging new technologies might prove to be very useful in further unravelling the underlying behavioural drivers of the currently observed product-specific differences in consumers' food waste generation patterns.

5. Conclusions

In conclusion, differences in food preservation method were observed to impact on food waste generation at Dutch household level. The waste index (WI) proposed in the current paper confirms the hypothesis that it may be possible to reduce the amount of food waste at household level by encouraging Dutch consumers to use (certain) foods more frequently in a frozen form (instead of fresh or ambient). However, before this approach can be scaled to population level, a more detailed understanding of the underlying behavioural causes with regard to food provisioning and handling and possible interactions is required.

6. Conflict of interest

The authors state that there is no conflict of interest.

7. Role of funding source

Neither funding sources had any role in the design, analysis, or writing of this article.

Acknowledgements

We would like to thank Anna Maaskant and Wayne Martindale for their valuable help in designing the survey and in the data analyses. This work received financial support from Iglo Group – Nomads Foods and the Ministry of Economic Affairs of the Netherlands (grant number TKI-AF-14318).

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