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Food Safety Risk Perceptions in the Dumpster Diving Community and Analysis of Bacterial Burden in Discarded Foods

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Abstract

The main topic of this study was dumpster diving (the act of retrieving discarded goods, in this case especially food, from waste containers) and the exploration of this activity from the infection biology viewpoint. Dumpster diving is a common way of accessing goods without spending economic resources, as well as an expression of anti-consumerism or civil disobedience. A biomedical perspective on this subject is novel, as it has mostly been studied and documented through the lens of socioeconomics. No substantial research has been done on the risks of contracting foodborne diseases through the consumption of discarded foods. A better understanding of the potential impact of dumpster diving on public health could better prevent infectious diseases.

A laboratory investigation into microbial development in discarded foods has been performed based on a background of information gathered through interviews with supermarket operators and answers to an online questionnaire designed to explore the thoughts, habits, risk awareness, and risk mitigation techniques in the dumpster diving community.

No increase in bacterial burden was recorded within the scope of this study. An increase, as well as a decrease of total aerobic bacterial count in food items was observed. It has also been shown that dumpster divers follow different procedures to reduce their risk of contracting a foodborne disease or poisoning, though those actions are not always evidence-based. Future studies are needed to map out all potential risks in connection with dumpster diving, as well as solutions for risk mitigation techniques.

Popular scientific summary

Dumpster diving is an activity present, for example, among the poor or those who view it as a way of gaining an economic upper hand, and even those who see themselves as a part of the anti-consumerism movement. Some even do it for the thrill of it.

Retrieval and consumption of foods that retailers once discarded equal a cheap and sustainable way of accessing goods. Persons gathering and consuming thrown away food may be stigmatized as unhygienic. However, there is limited research on the actual conditions of the discarded foods upon their retrieval.

This study aimed to contribute to this knowledge with the help of an online questionnaire distributed in the dumpster diving community and a '*dive*' into the microbiology of discarded foods. Through following the bacterial development in some of the most popularly foraged foods gathered from supermarkets and analyzed upon" best before" or" use by" date, it aimed to answer whether there is an actual increase in the risk of foodborne disease in the dumpster diving community. This potential risk was weighed and compared to what an everyday mainstream consumer would expose themselves to in their ordinary supermarket.

Understanding this from the biomedical perspective could help create fact-based sources on how to dive safely and safely treat the food if a person turns to dumpster diving for one reason or the other.

The sample size of the microbiological study was small; however, the results suggested no increased risk of contracting a foodborne disease from discarded foods. The responses to the online questionnaire show existing processes and tools for risk mitigation techniques amongst the dumpster divers, although most of these actions are based on 'old wives' tales' and require fact-checking and a scientific evaluation.

Keywords and abbreviations

C	Number of times a food product is allowed to exceed m (the lower limit of CFU/g)
B	Blood agar
BP	Baird-Parker agar
CFU	Colony-forming units
DALY	Disability-adjusted life year
DD	Dumpster diving
(The) divers	Persons engaging in dumpster diving
ED	Expiry (" best before" or" use by") date sample
ESRD	End-stage renal disease
FAO	Food and Agricultural Organization
FCM	Flow cytometry
HUS	Hemolytic uremic syndrome
m	The lower limit for microbiological criterion that can be exceeded by a food product a certain number of times (c)
M	The upper limit for microbiological criterion which a food product cannot exceed.
MALDI-TOF	Matrix-assisted laser desorption/ionization – Time of Flight
PI	24h post-incubation in 15°C sample
RTE	Ready-to-eat
SPW	Saline peptone water
TAC	Total aerobic count
WHO	World Health Organization

Introduction

Dumpster diving

According to a report compiled by the Food and Agricultural Organization of the United Nations (FAO) in 2014, as much as a third of food produced globally each year becomes waste (1). In Sweden, the vast majority (75%) of annual food waste is produced by singular households, accounting for over 900 000 tons. Around half of Sweden's food waste is sorted as combustible waste, and a quarter is discarded in the sewage systems (40% of which is coffee). In comparison, supermarkets account only for around 30 000 tons of food waste. However, this number is an understatement of supermarkets' total food waste since packaged foods (sorted as combustible waste) are not accounted for (2). Most of the food waste produced by supermarkets happens due to reached "best before" date or "use by" date, the substandard appearance of the product (discolored or pulpy fruits or vegetables), damage to the packaging, or dissonance between inventory and demand (2,3). In this article, and per the FAO legislation, the "best before" date refers to foods whose quality may deteriorate after a specific date without affecting the safety of the food. The "use by" date will refer to foods that should not be consumed after a specific date as it might become a health risk (1).

Dumpster diving (DD) is the act of retrieving foods, clothes, and other items from dumpsters or other containers. These have been discarded by the manufacturer, retailer, or a private person or household. It is often done by the poor in our society or in the context of the anti-consumerism movement (4,5). It is viewed by the *divers* (persons engaging in dumpster diving) themselves as a sustainable way of accessing goods. Still, the consumption of foraged foods is stigmatized today as unhygienic and dirty, leading to ostracizing individuals who engage in this activity (6). There are several different perspectives through which this topic can be discussed, including environmental impact and social and economic impact. A perspective that has yet to be studied extensively is the possible risks carried with the consumption of discarded foods on public health and the health of the dumpster diving community. There are currently minimal resources of evidence-based knowledge on the safety of this conduct. While searching for the terms "dumpster diving", "totting" (here: hand-sorting waste (7)) or "skipping" (here: retrieving waste from containers (8)) in the PubMed database (9), only one relevant result turns up; the article by J. Tibbetts from 2013 highlights the lack of research on the health-related consequences that this phenomenon may have (10).

Laws and regulations

European Commission regulation 178/2002 states that food business operators are obligated to only place food on the market that is safe (11). Another commission regulation, 2073/2005, states the microbiological criteria established to protect the public health through food safety criteria that apply during foods' entire shelf life and process hygiene criteria that describe an acceptable food production chain. The regulation includes information on which organisms should be included in controls during food production and which levels they may not exceed. The manufacturer's responsibility is to perform controls of the concentrations of contaminants, metabolites, and toxins in the product and ensure that these meet the standards formulated in the criteria (12).

During the food's shelf life, food business operators are required to upkeep the correct storage temperature for the foods. Certain foods require cold storage to preserve their quality for a more extended period of time and slow down bacterial growth. This is known as the "cold chain". Once the food is discarded, the requirement to keep the cold chain intact ceases, increasing the

deterioration rate of the food and affecting the bacterial burden contained within. This poses the hypothesis that there is a potential risk of contracting a foodborne bacterial infection or food poisoning upon ingestion of discarded foods (13).

As the food passes its" best before" or" use by" date or otherwise no longer meets the retailer's standards, some regulations apply to how the food should be disposed of. The food waste is to be kept in a way that hinders it from contaminating the surrounding environment. There is no requirement for lockable containers if the supermarket operator can prove that the containers are appropriately formed for easy cleaning, disinfection, and keeping away pests and vermin. (13). Waste that risks leaking is required to be stored in leak-proof containers or rooms equipped with a floor drainage system. There are no requirements for specific temperature intervals in the spaces where the food waste is stored. The supermarket operator is responsible for deciding if cold storage or suitable ventilation should be installed based on the needs of the business. If such measures affect the surrounding environment, other types of legislation, like The Environmental Code, might come into play (14). In the same legislation, no part is assigned responsibility when a person who chooses to consume foods discarded by the supermarket falls ill due to consumption of the food. The focus lies solely on how the discarded foods affect the environment, and not how the environment might affect the food or how the food might further affect potential divers.

The legal status of dumpster diving

The attitude around DD legal status in Sweden has been fluctuating over the years. In early 2011 there were simultaneously two different opinions present in the judiciary system. One stated that diving for food in an unlocked container in which food is disposed of is legal if no littering occurs. Another one stated that diving for food in a supermarket's containers equals theft since supermarkets placing food in the container is only another way for the supermarket to store it (15). Later in the same year, two people were accused of *criminal conversion* in connection to DD (16), which has become the general offense to charge the divers with. It incorporates the act of misplacing or misusing an item for purposes other than intended – which is a lesser crime than theft (17). According to Ann Lundgren, a Swedish lawyer and educator on criminal law at Umeå University, the reasoning behind it is that once the supermarket disposes of the food, it becomes the property of the company that transports the waste to its destination (18). Supermarket owners usually do not view DD as an issue unless accompanied by littering or property damage. When that occurs, it becomes the supermarket's issue, as there are laws in place enforcing a clean environment surrounding the waste containers (19).

Infectious diseases and food

More than 200 diseases are caused by foodborne bacteria, viruses, or parasites every year, leading to personal suffering, economic burden, and strain on local healthcare. One way of calculating disease burden is in "disability-adjusted life year" (DALY), which normalizes worldwide disease burden. It is most often used based on the prevalence or incidence of the causative agent, the number of years lost due to mortality, and the number of years lost to living with a disability after recovery (otherwise known as sequelae). Based on 2010 data, the World Health Organization (WHO) calculated that the burden of bacterial foodborne agents was equal to 14,5 million DALYs. Children below the age of 5 are the most negatively impacted by these diseases, with many suffering deaths (20).

Bacillus cereus

A frequent causative agent of acute food poisoning is *Bacillus cereus*, a spore-forming, ubiquitous bacterium. Residual amounts of *B. cereus* are found on almost all kinds of raw food ingredients, often dry pantry goods such as spices, rice, and pasta. Dairy products and vegetables can also become contaminated with *B. cereus*. The bacteria can persist even during heat treatment due to their ability to form durable spores. During slow cooling, bacteria reactivate and begin to increase in numbers, and produce toxins. The heat-stable emetic toxin produced by the bacteria causes severe poisoning symptoms accompanied by predominantly vomiting, cramping, and nausea. Alternatively, *B. cereus* can multiply and infect the digestive tract once ingested, producing an enterotoxin causing watery diarrhea and nausea (21,22). In 2019, 1636 cases of poisoning with *B. cereus* toxins were recorded in Europe, seven resulting in death (23).

Escherichia coli / coliform bacteria

Escherichia coli and other coliform bacteria are traditional markers of fecal contamination of the food. These bacteria should not be present in food unless handled with poor hygiene or rinsed or irrigated with contaminated water. The finding of *E. coli* in food does not always carry the risk of disease, although properly heat-treated products and drinking water should be completely free from it (24). Recontamination is a common culprit in heat-treated foods. Testing for *E. coli* is recommended for specific food items (ready-to-eat foods (RTE) and some meat preparations) as a process hygiene criterium (12). Most *E. coli* strains are harmless to healthy humans. They are a part of natural intestinal flora. Sequelae of infection with pathogenic *E. coli* strains, e.g., Shiga toxin-producing *E. coli*, include hemolytic uremic syndrome (HUS) and end-stage renal disease (ESRD). While HUS is usually curable, ESRD leads to life-long disability. There were 8313 cases of highly pathogenic *E.coli* infections recorded in Europe during 2019, out of which 756 cases were reported in Sweden (25). The overall trend of incidences for pathogenic *E. coli* seems to be on the rise (20,26).

Coagulase positive Staphylococcus aureus

Another toxin-producing pathogen that occurs naturally in human microbiota is coagulase-positive *Staphylococcus aureus*. It is one of the few indicator organisms whose burden is wholly attributed to foodborne contamination (20). It is a prevalent human skin bacteria used to measure possible contamination during manual handling of the food in such foods as RTE sandwiches and salads. Certain strains of *S. aureus* produce heat-stable enterotoxin. Upon contamination of food and during storage at an inaccurate temperature, the bacteria begins production of the toxin, which, once ingested, can cause acute gastroenteritis and even death (27). In 2019, 1400 cases of food poisoning were attributed to *S. aureus* toxins in Europe (23).

Listeria Monocytogenes

Listeria monocytogenes is a pathogen associated exclusively with the foodborne disease (20). It is usually found in foods that have been handled with contaminated equipment or insufficient hygiene. It survives and grows in a wide range of temperatures (0-45°C, with an optimum at 30-37°C) and pH (pH4,5-9)(28). Its analysis is most valuable in cold-stored products with long shelf life (e.g., sliced cheeses and meats, cured fish). If the pathogen is present in a food product that allows its growth, it can multiply to a concentration that might constitute a health hazard before the" use by" date. There are different limits for *L. monocytogenes* found in foods depending on the food type (12). Exposure to *L. monocytogenes* can cause a condition known as listeriosis, possibly leading to severe complications (sepsis, meningitis, encephalitis,

spontaneous abortion, death) in risk groups such as pregnant women, infants, the elderly, and immunocompromised people. *Listeria monocytogenes* is associated with high case-fatality ratios. In healthy humans, the bacteria can cause self-limiting gastroenteritis (29). During 2019, 2621 confirmed cases of listeriosis were recorded in Europe, out of which 81 were reported in Sweden (23,30).

Total aerobic count

The total aerobic count (TAC) could be used as a measure of food quality. It is recommended to be measured during different steps in meat manufacturing to ensure correct process hygiene is being applied (12). It cannot by itself indicate or contraindicate the presence of pathogens or their concentration. However, if measured outside of the scope of what is deemed within the norm for a particular food product, it can alert the manufacturer about insufficient process hygiene. Abnormally high TAC is seen in products nearing expiry, either due to natural processes of spoilage or in case of improper handling (slow refrigeration, inaccurate storage temperature) or substandard raw materials (31). Food manufacturers can follow the trends in TAC to observe compliance with manufacturing practices and standards. For certain foods, such as yogurt or fermented meats, high TAC is a natural occurrence. Intrinsic factors such as food's pH, water activity, oxygen levels, and nutrient availability affect TAC (32–34). Once exponential growth and stationary phase have been observed, the visible spoilage of the food steps in (32).

Aims

Considering the above topics, several questions need to be contemplated surrounding the potential health impact of the consumption of discarded foods. Does consuming foods from dumpsters carry a higher than the regular risk of contracting foodborne diseases? Is the bacterial burden of discarded foods indeed higher than in store-bought foods? Are the divers aware of the potential risks, and do they apply appropriate techniques to mitigate that risk?

To address these questions, the first aim of this study was to assess some of the reasons for DD, behaviors, and habits surrounding the retrieving of foods, as well as current awareness of risks of foodborne diseases in the community and resources that are being used to mitigate that risk.

The second aim was to assess how the food is being discarded and determine the temperature and type of enclosure where the discarded food is stored. These conditions were simulated in a laboratory setting to assess the microbial load of the food that a potential dumpster diver may expose themselves to, focusing on the total aerobic count, *E. coli*, *L. monocytogenes*, *B. cereus*, and *S. aureus*.

Materials and methods

Questionnaire and data collection

An online questionnaire was designed with 24 questions in Swedish in Google Forms (Google Ireland Limited, Gordon House, Barrow Street, Dublin 4, Ireland). Eight of the questions were open (the respondents could add their own answers), the remaining questions were closed. The link to the questionnaire was distributed in four Swedish social media groups ("Dumpstra med oss", "Downshifting Sweden", "Zero Waste lifestyle i Sverige", "DDT (Dumpster Diver Troop)"), one page for a soup kitchen active in Uppsala ("Bruised Food Club Uppsala"), and one Swedish blog whose focus is DD (https://dumpstringslyx.com/). The questionnaire would potentially reach 26 000 members and 6 700 followers of these social media gatherings [as of March 2021]. A reminder to respond to the questionnaire was sent halfway through the response time.

Participation in the study was voluntary, and no compensation for contribution was offered. An introduction was given in the questionnaire that stated the general aim of the questionnaire (to investigate behaviors, thoughts, and habits surrounding diving for food) and target group (individuals that are or have been retrieving food through DD). The answers were registered for 63 days (28th Jan – 31st Mar 2021). Upon receiving interest from English-speaking persons, an English version of the questionnaire was published a few days later and registered answers for 59 days (1st Feb – 31st Mar 2021) utilizing the same channels as for the Swedish version. Only persons engaging in DD in Sweden were asked to answer the questions on specific supermarkets where they were picking up discarded foods due to the supermarkets being country-specific to Sweden.

The first four questions captured the participants' background such as sex, age, occupation, and highest completed level of education. One of the questions examined the participants' awareness of the term "dumpster diving." The remaining questions focused on the reasons for DD, habits surrounding it, values attributed to DD, awareness of risks of foodborne diseases, and risk mitigation techniques. The respondents were asked some questions to which they could choose several pre-written options or write down their answers, as well as choose alternatives such as "I do not wish to disclose", "Not applicable" or "I don't know", depending on the type of the question. The respondents were able to choose more than one answer to some of the questions. For the complete list of questions, see ***Supplementary Data, Appendix 1***.

Interviews with supermarkets

Three different supermarkets from three different supermarket chains were contacted, and two of these were interviewed on current routines surrounding the discarding of foods. No selection of the supermarkets of interest was applied other than choosing supermarkets in Uppsala, Sweden. The supermarkets were contacted through the general contact form on their websites. The supermarket managers were asked about the routines and processes around food waste disposal: how the decision to discard food was made, how the food was being discarded, how long it was kept at other-than-recommended temperatures, and whether the disposal container was located indoor or outdoor. The managers were also asked about the supermarket's strategy for minimizing food waste.

Collection of food samples

Based on the online questionnaire, items of the most popular foodstuff to retrieve through dumpster diving (excluding foods with little importance regarding bacterial growth, such as dry pantry goods or canned goods) were bought from three different retailers in Uppsala, Sweden. Two items of the same batch were bought and subjected to laboratory analysis. A few of these were bought and analyzed twice.

The foods were collected between 2-30 days before the" best before" date, transported by bus for a maximum of 30 minutes, and stored in a household fridge at 4 degrees Celsius until reaching the" best before"/" use by" date. At that point, the foods were once again transported by bus to the microbiology laboratory at the Department of Biomedical Sciences and Veterinary Public Health (Swedish University of Agricultural Sciences). The foods were bought as close to the "best before" date as possible.

Foods that did not have an assigned" best before" date (vegetables and strawberries) or were sold at room temperature in the supermarket were left resting at room temperature in a household kitchen until their quality worsened visibly and signs of spoilage (black spots, soft spots, or mold) started to appear. At this point, they were subjected to the same matter of transportation as the items mentioned above.

The wrapping of packaged foods was unbroken until the moment of bacteriological sampling.

The collected food items included the items listed in ***Table 1*** (for a complete list of ingredients, see ***Supplementary data, Appendix 4***).

Table 1 *Food items collected for the investigation of bacterial burden in discarded foods.*

Food item	N (# items tested)	RTE?	Shelf life	Packaging	Storage instructions
Chicken wrap (packaged)	4	Yes	No information	Paper wrapping	+4°C - +8°C
RTE small leaf mixture (packaged)	4	Yes	No information	Plastic bag	+2°C - +6°C
Minced meat (packaged)	4	No	Two days	Styrofoam tray, plastic wrapping	Below +4°C
Whole grilled chicken (packaged)	4	Yes	One day	Paper bag with plastic coating	Above 60°C (in the supermarket)
Cured salmon (packaged)	2	Yes	No information	Vacuum packaged in plastic on a paper tray	0°C - +4°C
Cabbage (unpackaged)	4	Yes	No information	Unpackaged	No information
Strawberries (packaged)	2	Yes	No information	Plastic box with holes	No information
Lettuce (Packaged)	2	Yes	Nine days	Thin plastic wrapping	No information
Pre-diced melon mix (Packaged)	4	Yes	No information	Plastic cup with plastic, air-tight seal	+2°C - +6°C, max +8°C

Enumeration of bacteria in the food samples

All samples were handled with sterile equipment using an aseptic technique. The different food items were tested for appropriate indicator organisms and pathogens (*L. monocytogenes*, total aerobic count, *E. coli*/coliforms, coagulase-positive *S. aureus*, *B. cereus*) at" best before" or" use by" date, or the date at which their condition worsened visibly (ED, "expiry date"), and after 24h incubation in 15°C (PI, "post-incubation"). The incubation parameters were based in part on information collected from the interviews with supermarket managers and field study—another reason being that the incubation was to simulate Swedish temperatures during spring.

For all methods except *L. monocytogenes*, 10g of food was weighed in a stomacher bag and diluted 1:10 with saline peptone water (SPW). The samples were homogenized using EasyMix lab blender (AES Laboratories Pvt. Ltd.) for one minute. A serial dilution of the suspension was performed in SPW. Suitable dilutions were used to cultivate the different bacteria (See **Supplementary Data, Appendix 3** for table depicting dilutions, foods, and pathogens analyzed). Following final incubations, the bacterial burden was calculated as log CFU/g.

Total aerobic count

The total aerobic count was enumerated for all foods, both in ED and PI samples. For each appropriate dilution (see **Supplementary Data, Appendix 3**), 1mL was pipetted on 3M™

Petrifilm™ Aerobic Count Plate (3M Canada). The samples were incubated at 30°C for 48 +/- 2h. The results were interpreted according to the 3M Petrifilm™ Interpretation Guide for Aerobic Count Plate. Pink to reddish pink colonies were accounted for as CFU.

Escherichia coli/Coliforms
Enumeration of *E. coli* was performed on the chicken wrap, leaf mixture, minced meat, whole grilled chicken, unpackaged cabbage, packaged strawberries, packaged lettuce, and melon mix. For each sample, 1mL was pipetted on 3M™ Petrifilm™ *E. coli* /Coliform Count Plate (3M Canada, Canada). The samples were incubated at 44°C for 48 +/- 4h, and the results were interpreted according to the 3M Petrifilm™ Interpretation Guide for *E. coli* /Coliform Count Plate.

Coagulase-positive Staphylococcus aureus
Analysis of *S. aureus* burden was performed using NMKL 66 (35) method on the chicken wrap, whole grilled chicken, leaf mixture, and melon mix (see **Supplementary Data, Appendix 3** for dilutions used). For each of the samples, 0.1mL was spread on the surface of Baird-Parker agar (BP, Oxoid PO5014) and incubated at 37°C for 48 +/- 4h.

Bacillus cereus
Enumeration of *B. cereus* was performed with NMKL 67 (36) method on the chicken wrap, leaf mixture, and melon mix (see **Supplementary Data, Appendix 3** for dilutions used). For each of the samples, 0.1mL was spread on the surface of blood agar (B, 5% bovine blood, SVA) and incubated at 30°C for 24 +/- 3h.

Listeria monocytogenes
Detection of *L. monocytogenes* was performed applying a modified NMKL 136 (37) method on the chicken wrap, leaf mixture, whole grilled chicken, cured salmon, unpackaged cabbage, packaged lettuce, and melon mix. For each food item, 25g was diluted in Half Fraser broth (Oxoid Ltd. Thermo Fisher Scientific Inc.) to a dilution of 1:10 and stomached for one minute. The suspension was then incubated at 37°C for 24 +/- 3h. For each of the samples, 10μL was then streaked on Chromogenic Listeria medium (Oxoid, PO5183) agar and B and incubated at 37°C for 48 +/- 4h.

Biotyping
Matrix-assisted laser desorption/ionization – Time of Flight (MALDI-TOF) method was applied to biotype the unidentified colonies produced on Chromogenic Listeria medium, BP, or B agar and some atypical colonies on the AC petrifilm. The unidentified colonies were purified on B agar and incubated at 37°C for 24h. Purified colony material was then plated on a polished steel 96-well target plate (Burker Daltonik GmbH), dried, and coated with 1μL HCCA matrix (Matrix for MALDI-TOF MS. [10mg/ml]: ultra-pure water, trifluoroacetic acid, acetonitrile. Burker Daltonik GmbH.). The plate was then analyzed using Microflex ® LT/SH instrument (Burker Daltonik GmbH). Only the hits with score values >2.0 indicating reliable identities were included in the results.

Data processing
All data from the online questionnaire was processed using the software Microsoft ® Excel for Mac v16.48 (Microsoft). Graphs were rendered using the same software. Flow charts were

created using the online tool Lucidchart (Lucidchart Software Inc). MALDI-TOF results were analyzed using software Compass for flexSeries 1.4, v3.4 (Burker Daltonik GmbH).

Ethical approval

No ethical approval was deemed necessary for this study. The responses to the online questionnaire were collected anonymously without any measures of identification applied. No sensitive information was handled during this study, and the responses cannot be attributed to any individuals. No testing was performed on biological material originating from a physical person.

Results

Epidemiological assessment of behaviors, habits, and perceptions of dumpster diving and foodborne disease

General information

A total of 92 completed questionnaires were registered for the Swedish (n=89) and English (n=3) versions. Most respondents were female (70%, n=64) and aged 18-29 years (53%, n=49) (***Table 2***).

Table 2 *Distribution of gender, age, occupation, and highest completed level of education among the respondents of the online questionnaire. Organized from highest value to lowest.*

		(n)	(%)
Gender	Female	64	70%
	Male	23	25%
	Non-binary	4	4%
	I wish not to disclose that information	1	1%
Age	18-29 years	49	53%
	30-39 years	16	17%
	50-59 years	12	13%
	40-49 years	9	10%
	60-69 years	6	7%
Occupation	Student / postgraduate student	32	35%
	Full-time employee	21	23%
	Part-time employee	14	15%
	Unemployed	10	11%
	None of the above	5	5%
	Full-time sick leave	5	5%
	Retired	4	4%
	I wish not to disclose that information	1	1%
Highest completed level of education	College / university 1-3 years	26	28%
	High school	23	25%
	College / university 4-5 years	23	25%
	College / university >5 years	11	12%
	Other vocational training	6	7%
	Primary school	2	2%
	None of the above	1	1%

All the respondents (100%, n=92) were aware of the definition of DD. Most of them (60%, n=55) engaged in DD with motivation to reduce food waste and reduce their environmental impact. Another popular reason for DD was to save money (27%, n=25).

The food was usually consumed by the household of the person retrieving the food (39%, n=36), the household and its guests (35%, n=32), or only the person retrieving the food (22%, n=20). A few gave away or sold the food (2%, n=2).

The most popular foodstuff to dive from the alternatives given in the questionnaire are listed in ***Figure 1***. More than 50% of respondents were positively inclined to retrieve most of the listed foods except for unpackaged bread. The respondents also had the opportunity to fill out any other foods they dive for that were not mentioned in the multiple choices. These mainly included candy, frozen goods, spices, pet food, and herbs.

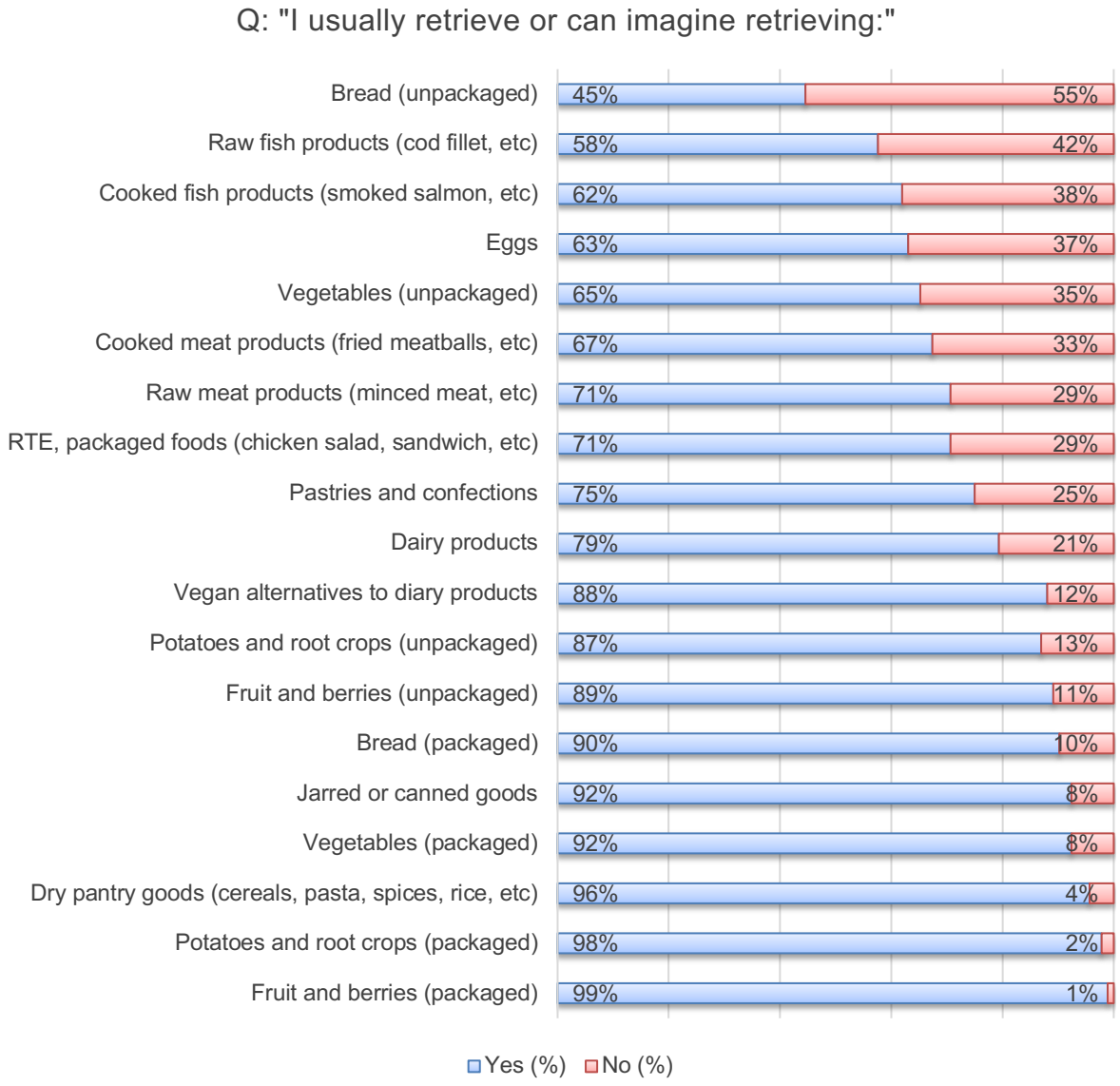

Figure 1 *Answers to the question "I usually retrieve or can imagine retrieving:". The answers are depicted as percentages of "yes" (blue) to "no" (red) answers among the 92 respondents.*

Most of the respondents (54%, n=50) estimated discarded foods to constitute between 0-25% of the food they consume during the year, meaning they usually bought groceries at a supermarket but engaged in DD from time to time. Some of the respondents (21%, n=19) estimated that between a quarter to a half of the food they consumed throughout a year came from DD. A few of the respondents (12%, n=11) estimated that more than half of the food they consumed during a year came from DD. A similar proportion of the respondents (13%, n=12) estimated that majority of the food they consumed during the year came from DD.

Risk awareness
Most of the respondents (96%, n=88) answered that they were aware of the difference between "best before" and "use by" date. A few of the respondents (3%, n=3) answered that they did not know the difference, and one (1%) responded that there was no difference between the two dates.

A majority (82%, n=75) of the respondents disclosed to others around them their habit of DD, and almost half of them (47%, n=43) had not experienced any negative response to it. Those who had experienced a negative response to DD habits (53%, n=49) mentioned the following:

> "*My parents became worried that I would end up in jail.*"
> (Female, 18-29 years old)

> "*You do not talk about it with those you expect to get a negative reply from*"
> (Female, 50-59 years old)

> "*Many believe that I cannot afford food and therefore feel sorry for me. I do not like them assuming things about me or feeling sorry for me.*"
> (Female, 18-29 years old)

> "*People have an initial idea that it is disgusting, I think, but I would not say I have gotten any negative replies, rather skepticism, but curious. As soon as I explain it, or even better, show a photo of my kitchen table set with all the fresh vegetables, that is when they stop thinking that it's disgusting.*"
> (Male, 18-29 years old)

Most of the respondents (93%, n=86) declared they had never become ill from the foods retrieved from DD. Two persons (2%, n=2) reported becoming ill in connection to the consumption of discarded food, and four persons (4%, n=4) were unsure if they had become ill from the picked-up food. Out of those six, two (2%, n=2) reported having mild symptoms. None of the respondents had sought medical advice for their symptoms.

When asked about perceptions of risk of disease in connection with the consumption of discarded foods, half of the respondents (52%, n=48) reported believing that there is a risk of falling ill after consuming the food, and five of these (5%) believed there was a risk of contracting a severe infection. One of the respondents wrote:

> "*(…) I believe that the probability of getting hit by a car on the way to/from the pick-up spots is higher than the probability of getting food poisoning after heating*

> *the food. There is always a small risk of getting a foodborne illness no matter if the food is picked up from a dumpster or not.*"
> (Male, 30-39 years old)

The respondents were asked to provide names of bacteria they knew to be foodborne (***Figure 2***). Mostly repeated by the respondents were *Salmonella* (35%, n=32) and/or *Listeria* (18%, n=17). A tenth (11%, n=10) answered that they were aware of foodborne bacteria but could not mention any at the time. Subsequently, a fifth (22%, n=20) said they did not know of any such bacteria. Twenty-five respondents reported more than one bacterial agent. Other than bacterial agents – chemicals, mold, nematodes, toxins – were reported by seven respondents. Two persons reported "*Typhus from wet hay*". The nine responses that consisted of other than bacterial agents were regarded as "other".

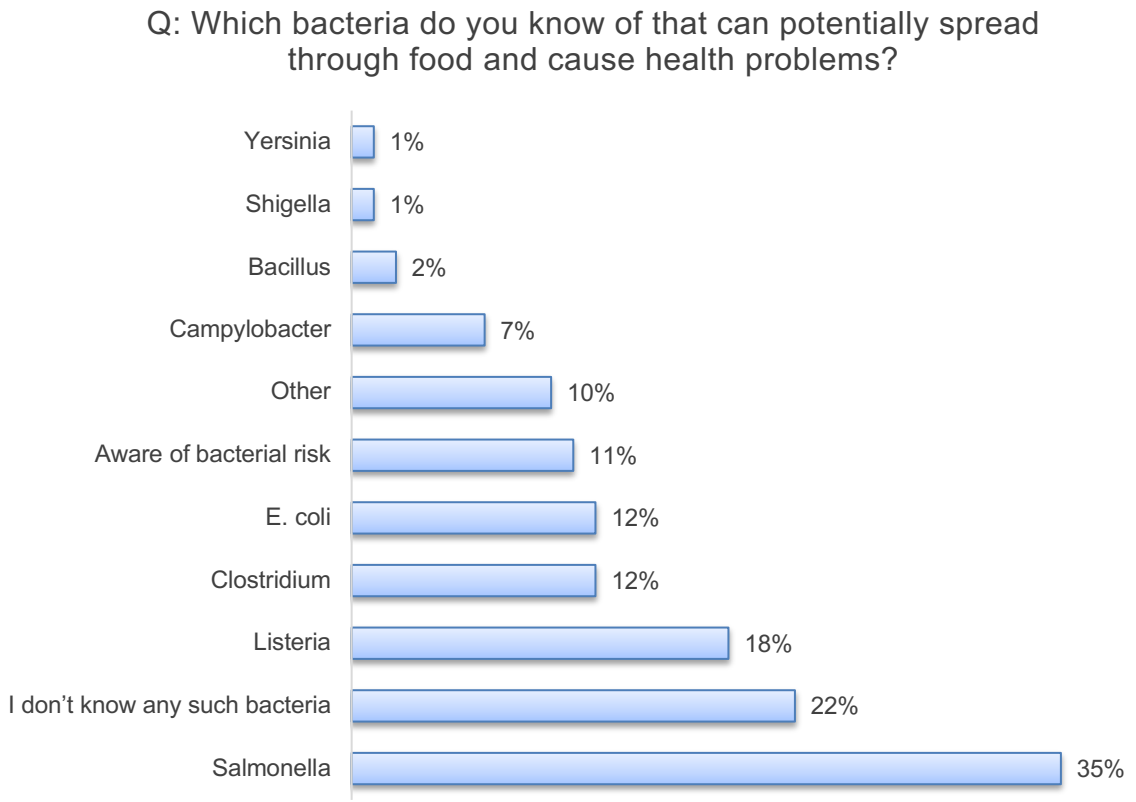

Figure 2 *Answers to the question "Which bacteria do you know of that can potentially spread through food and cause health problems?". Other than bacterial agents – chemicals, mold, nematodes, toxins – are denoted as "Other".*

The respondents wrote the following to complete their answers to the question:

> *"Fruits and vegetables that have not been mixed with other foods do not carry more bacteria in the container than in the store. The highest risk is carried with the molds, or if there are chemicals that have been poured over the goods.*"
> (Female, 50-59 years old)

> *"There is a lot [of bacteria] mostly in dairy and meat produce, which I don't consume, then there is, of course, a risk with other products too, but I use my brain a little, and it's usually fine!"*
> *(*Male, 18-29 years old)
>
> *"I can't recall any names, but I know the risk is higher with certain foods and those I avoid ☺"*
> (Female, 18-29 years old)

Risk mitigation techniques
The majority (83%, n=76) of the respondents used personal protective equipment when diving for food. Most of these items were gloves (79%, n=73) and special or protective clothing (34%, n=31). Some used flashlights (5%, n=5) or facemasks (4%, n=4). Other equipment used included reacher-grabber (3%, n=3) and stool (1%, n=1). One person chose not to answer this question.

Several different actions can be applied during the process of picking up discarded foods to mitigate the risks of foodborne disease. These include, for instance, controlling the" best before" or" use by" dates on the packaging of the food. Most of the respondents agreed with the statement "*I pick up food that is unpackaged as well as packaged*" (70%, n=64). The second most agreed-on statement has been "*I check the news and other sources for information on recalls before I pick up the food*" (49%, n=45). These sources included, for instance, "aktuella återkallanden"/" current recalls" accessed through the website of the Swedish Food Agency (Livsmedelsverket) (38). Half of the respondents (54%, n=50) answered that they were willing to pick up unpackaged foods. Some respondents were aware of when their containers of choice are being refilled (30%, n=28) and adjusted the pick-up times accordingly (36%, n=33) (**Figure 3**).

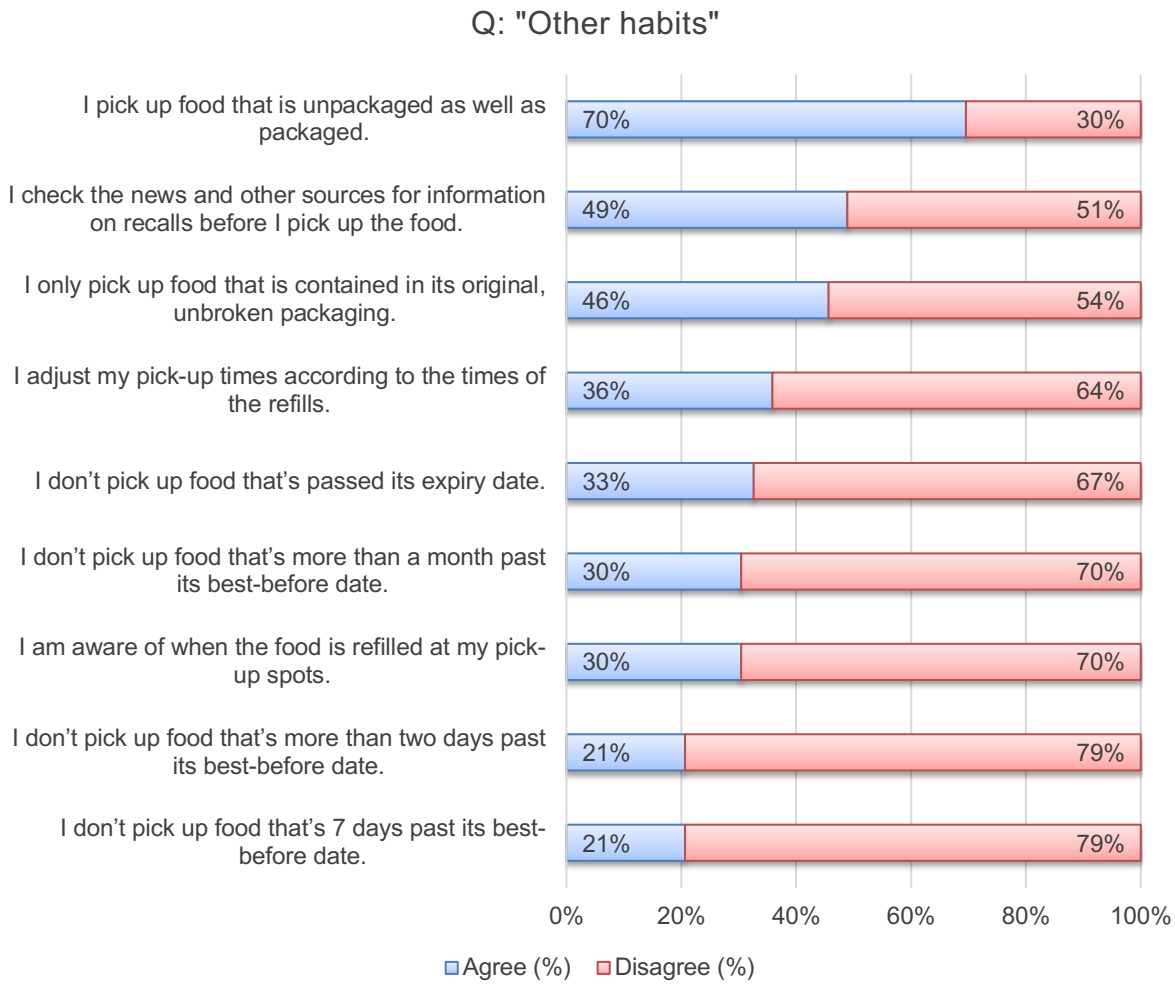

Figure 3 *Answers to the question regarding other habits applied during dumpster diving. The answers are depicted as a percentage of the 92 respondents who found a statement agreeable (shown in blue) or not agreeable (shown in red).*

Most of the respondents (84%, n=77) treated the food in one or more ways to minimize the risk of contracting a foodborne disease after consumption. In comparison, 16% (n=15) stated that they were not treating the food in any way before consumption.

The most popular treatment included discarding foods that smelled bad or did not look fresh (93%, n=86) and rinsing fruits and vegetables (93%, n=86). Many respondents avoided eating moldy foods (80%, n=74), and a similarly large proportion made sure to keep thorough hand hygiene when handling the food (82%, n=75). More than half would cut away the mold if they found it on cheese (60%, n=55). The majority of those who said they were willing to pick up raw meat said they handled it and other foods separately (72%, n=47/65) (***Figure 4***).

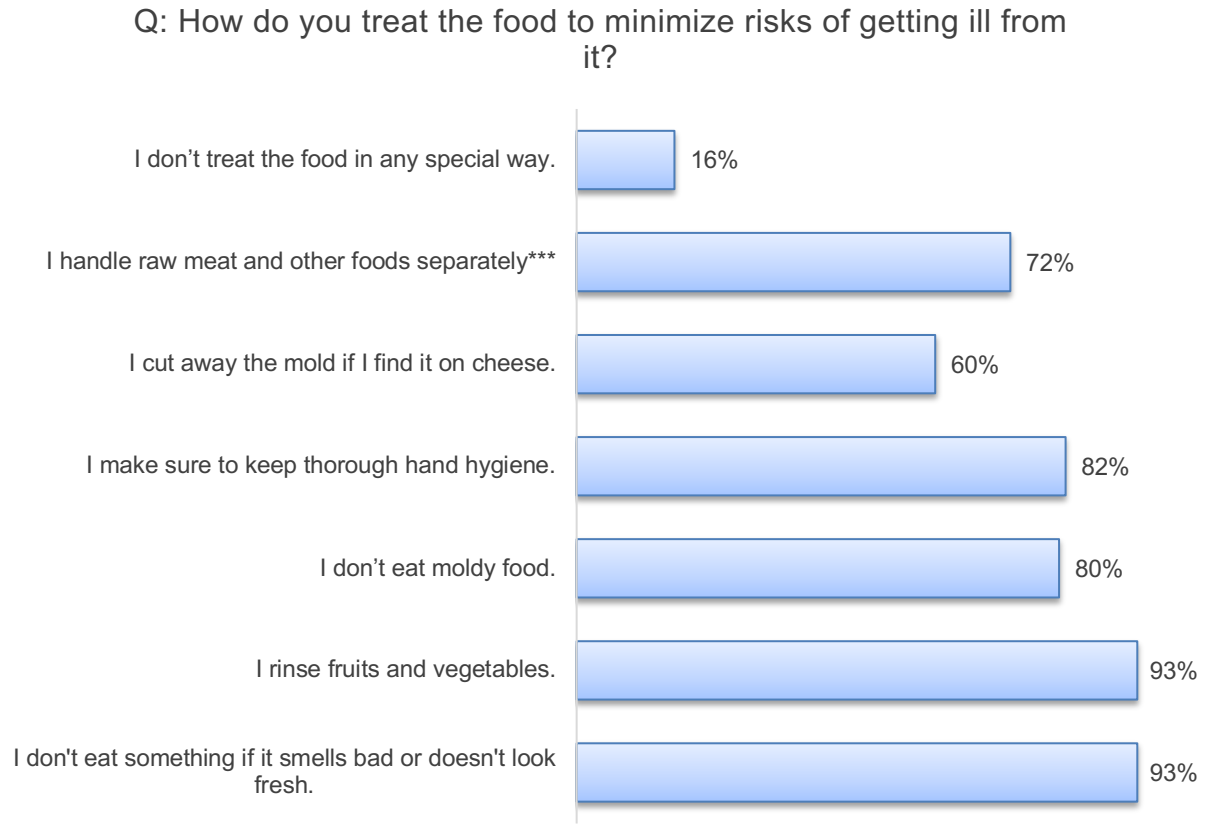

Figure 4 *Answers to the question "How do you treat the food to minimize the risk of getting ill from it?". Respondents were allowed to check one or more of the alternatives. *** number is based on the 65 respondents who admitted picking up raw meat from containers. The remaining numbers are based on the 92 respondents who completed the questionnaire.*

The question "How do you treat the food to minimize risks of getting ill from it?", which offered the possibility to add own answers, generated much input. Seven respondents mentioned evaluating the food's smell, texture, and consistency before consuming it to estimate its quality. Six of the respondents mentioned making sure to heat-treat the food, often straight away after picking it up, then freezing the prepared food. None mentioned any specific temperatures at which they prepared or stored the food.

One respondent wrote:

> *"If I pick up flour/similar, I isolate it in a plastic bag/freezer to secure myself from insects."*
> (Female, 18-29 years old)

Seven respondents mentioned rinsing the food or packages. One of them mentioned water being used for rinsing of the food. Others wrote the following:

> *"[I] clean fruits & packaging with dish soap/vinegar."*
> (Female, 50-59)

> *"[I] put some vegetables in a bath with water and vinegar, that stops the development of fungal spores, especially on berries."*
> (Female, 18-29)

> *"I usually put fruits and greens in a water bath with vinegar; I put bread in the freezer. But what I'm most careful about is if the store poured out rat poison or cleaning agents in the containers, it's important to have a sharp sense of smell. When I ate meat, I used to take only that which was still cold, and I avoided meat during the warm time of the year. If something tastes or smells weird, it's gone straight away."*
> (Female, 18-29)

Four respondents repeated that they would not pick up unpackaged foods or foods with broken packaging. Two persons mentioned avoiding diving in containers in which they had discovered rat poison. The notion of "risk foods" and animal products being considered as such was brought up by six respondents. Another five respondents said they would not engage in DD during the warmer months, believing it is too hot to do so at that point. One person mentioned explicitly not picking up raw or pre-cooked meat if the outside temperature exceeded 6-8°C. Meats that were picked up in these or higher temperatures were instead given to that individual's pet.

Interviews with the supermarkets' representatives

General overview

The interviews performed with the operators of the two supermarkets provided a general overview of the food waste disposal process (***Figure 5***). It was reported that they would usually reduce the price of a food item that was to expire within a few days. Once the" best before" date was passed, the food would be removed from the shelf in the morning and placed in indoor storage. During the field study, the air temperature of such storage measured with an on-site infrared thermometer was 16-17°C.

At a later point during the day, workers would deduct the value of the expired food from the inventory value and later place the food in a disposal container that was placed outdoors. When measured with the previously mentioned method on a sunny day in February in Uppsala, Sweden, the air inside of such container reached 10°C at noon, while the outdoor temperature was 9°C.

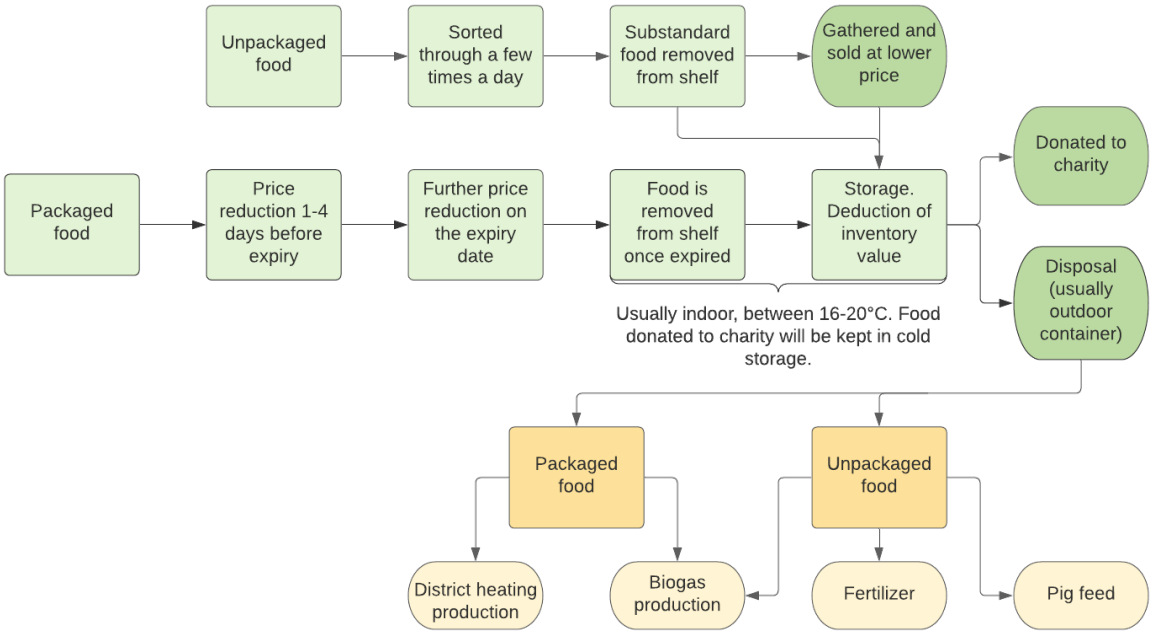

Figure 5 *General overview of the packaged food waste disposal process. Based on short interviews with operators of two different supermarkets in Uppsala, Sweden.*

Packaged food waste handling

Two separate ways of handling packaged food waste came to light during the interviews (***Figure 5***). One supermarket sorted packaged foods in a separate container from the unpackaged food waste and combustible waste. This packaged food waste was later picked up by a company that used a modern technique of separating the packaging from the food and utilized food for biogas production. Another supermarket stored their packaged food waste and combustible waste together, which a different company later used to produce district heating.

Unpackaged food waste handling

According to the interviews performed, unpackaged food waste was also used in two different ways by the two supermarkets. One sorted the food into containers picked up by a company that later used the waste for biogas production. In contrast, the other supermarket sorted the food in containers that were later picked up by a company that utilized the waste for fertilizer and pig feed, according to the supermarket operators.

The unpackaged fruits and vegetables were usually visually inspected a few times a day, and items that no longer met the supermarket's standard for appearance, smell, or firmness, were discarded.

Strategies for minimizing food waste

Both supermarkets applied several strategies for minimizing food waste. They would reduce the food price a few days before the" best before" date (mainly applied for packaged foods, such as RTE, juice, and snacks) or" use by" date (mainly applied for fresh foods with short shelf life, such as fresh fish and seafood). Another strategy would be further reducing the price of the food on the" best before" or" use by" date. Substandard fruits and vegetables that were earlier sorted out during the day were packed into bags of 1-3kg and sold at a much lower price the

day after. Dry foods, fruits, and vegetables that could no longer be sold were donated to charity. These foods were stored in a cold room by the supermarket until picked up by the charity. It then became the charity's responsibility to decide whether to distribute the food further or discard it.

The bacterial enumeration in collected samples

Based on the questionnaire, the most popular foodstuffs to retrieve through DD were analyzed by applying quantitative or qualitative laboratory methods to assess the level of deterioration and the potential increase in bacterial burden during storage in a simulated "waste container" at 15°C for 24h. In total, 30 food items were tested. There was no detection of *S. aureus*, *E. coli, L. monocytogenes,* or *B. cereus* in any of the food items tested for these parameters (***Table 3***).

Most of the items (8/13) displayed an increase in the total aerobic count during the 24h storage in the simulated waste container, for example, the packaged lettuce and chicken wrap. A few items (5/13) displayed a decrease in the total aerobic count, for example, unpackaged cabbage and pre-diced packaged melon mix. A few items were analyzed twice for the total aerobic count, *E. coli* or *L. monocytogenes*.

Table 3 *Bacterial load as log CFU/g for ED and PI. The table includes the description of the food item, type of parameter tested, results of enumeration, and the difference between ED and PI where such could be estimated.*

Food item (n= # items tested)	Parameters	(ED) log CFU/g	(PI) log CFU/g	Difference
Packaged strawberries (n=2)	Total aerobic count	3,3	3	-0,3
	E. coli	<1,0	<1,0	
Packaged lettuce (n=2)	Total aerobic count	5,4	6,4	+1
	L. monocytogenes	Absent in 25g	Absent in 25g	
	E. coli	<1,0	<1,0	
Pre-diced packaged melon mix (n=4)	Total aerobic count	6,5	6,1	-0,4
	Total aerobic count (re-run)	6,3	5,4	-0,9
	L. monocytogenes	Absent in 25g	Absent in 25g	
	E. coli	<1,0	<1,0	
	B. cereus	<2,0	<2,0	
	S. aureus	<2,0	<2,0	
Chicken wrap (n=4)	Total aerobic count	9,0	9,0	
	Total aerobic count (re-run)	9,2	9,4	+0,2
	L. monocytogenes	Absent in 25g	Absent in 25g	
	E. coli	<1,0	<1,0	
	B. cereus	<2,0	<2,0	
	S. aureus	<2,0	<2,0	
Small leaf mixture (n=4)	Total aerobic count	8,8	9,5	+0,7

	Total aerobic count (re-run)	7,7	8	-0,3
	L. monocytogenes	Absent in 25g	Absent in 25g	
	E. coli	<1,0	<1,0	
	B. cereus	<2,0	<2,0	
	S. aureus	<2,0	<2,0	
Minced meat (n=4)	Total aerobic count	<3,0	5,6	
	Total aerobic count (re-run)	5,4	7,6	+2,2
	E. coli	<1,0	<1,0	
	E. coli (re-run)	<1,0	<1,0	
Whole grilled chicken (n=4)	Total aerobic count	<4,0	<4,0	
	Total aerobic count (re-run)	1,8	3,3	+1,5
	L. monocytogenes	Absent in 25g	Absent in 25g	
	E. coli	<1,0	<1,0	
Cured salmon (n=2)	Total aerobic count	<3,0	5,2	
	L. monocytogenes	Absent in 25g	Absent in 25g	
Unpackaged cabbage (n=4)	Total aerobic count	6,2	4,6	-1,6
	Total aerobic count (re-run)	2,7	4,7	+2,0
	L. monocytogenes	Absent in 25g	Absent in 25g	
	E. coli	<1,0	<1,0	

Biotyping

The growth of other bacteria than *S. aureus*, *L. monocytogenes*, *B. cereus,* and *E. coli* were recorded on the different media used in the previously mentioned tests. Biotyping was performed on a total of 54 unidentified colonies, resulting in reliable identities for 11 of the colonies (***Table 4***).

Table 4 *The results from MALDI-TOF biotyping of unidentified colonies*. The table includes information on the type of sample (ED/PI), food item tested, and the organism identified by MALDI-TOF.

Food item	ED / PI	Organism (best match)
Small leaf mixture	ED	*Shewanella baltica*
	PI	*Pantoea agglomerans*
		Serratia fonticola
Packaged lettuce	PI	*Pseudomonas flavescens*
Chicken wrap	ED	*Enterococcus thailandicus*
	PI	*Pantoea agglomerans*
Pre-diced packaged melon mix	ED	*Pseudomonas aeruginosa*
		Leuconostoc citreum
		Leuconostoc mesenteroides
		Pseudomonas guariconencis
	PI	*Leuconostoc mesenteroides*

Discussion

The main topic of this study has been dumpster diving and the exploration of this activity from the infection biology viewpoint. A biomedical perspective on this subject is novel, as it has to this day mostly been discovered and documented through the lens of socioeconomics. A red thread has been created to scientifically follow the microbial development in discarded foods, based on the stories provided by supermarket operators through interviews and dumpster divers themselves. An insight into the risk awareness and risk mitigation techniques has been provided through an online questionnaire distributed among communities engaged in DD.

Epidemiological assessment of behaviors, habits, and perceptions of dumpster diving and foodborne disease

The questionnaire was distributed via social media, possibly creating an age bias leading to over half of respondents being young (between 18-29 years of age). However, a study from 2014 reported similar age distribution, with an average age of 28 among divers in Montréal, Quebec (39). In similarity with this study, the divers observed in Montréal were a heterogeneous group of persons of all sorts of academic and work backgrounds, with varying reasons for diving.

Almost half of the respondents did not experience any negative response once talking openly about their habit of DD with their contacts. Others reported either negative or ambiguous responses to their habit. It requires consideration how this type of response from society might affect the already existing bottlenecks in healthcare when recording new instances of foodborne disease or poisoning (40).

There seems to be a general notion of "risk food" among the divers and that these should be avoided; what type of food they refer to has seldom been explained by the respondents. The only type of food that has openly been mentioned in the context of "risk food" by the respondents is meat and dairy. The assumption that avoidance of meat or dairy dramatically reduces the risk of foodborne disease is not correct. Pathogenic bacteria have been recorded in different mixtures of purely vegetarian or vegan foods. They can be carried with spices, herbs, water, or contaminate foods through contact with handlers (23,41–43). When handling meat, most of the bacterial burden can easily be reduced through heat treatment (44), which is seldom applicable to RTE foods, salads, fruits, or vegetables.

Many of the respondents mentioned using their senses of sight, smell, and touch during their pick-ups, which is a common way of estimating the quality of fruits and vegetables. It is applied by consumers in supermarkets, as well as supermarket employees, to determine whether an item meets the standards set by the consumer or the supermarket chain. During 2017 one environmental campaign in Sweden marketed the phrase "*look, smell, taste*" under the hashtag *#BästFöre2017* ("#BestBefore2017")(45). A few years later, the company Too Good To Go coined the catchphrase "*Look, smell, taste, do not waste!*" (46,47) aimed to encourage consumers to evaluate the food quality rather than rely solely on the" best before" date.

A problem with these kinds of campaigns and statements is that some people do not know the difference between" best before" and" use by" date. In this study, 4% of the respondents to the online questionnaire reported not knowing what the difference between" best before" or" use by" date was (3%) or thinking that there was no difference between the two (1%). There were no further questions included in the questionnaire to explore whether those who believed

themselves to know the difference between the two dates really knew what it was or if they were mistaken in their conviction.

Another risk mitigation technique applied by some respondents included washing/rinsing the food with or without washing/rinsing the packaging. Some of the respondents mentioned the different solutions they applied to rinse their food and the thought process behind it. Many of these solutions seemed to be 'old wives' tales', including household chemicals and items as vinegar, bicarbonate, and dish soap. It has been recorded that only vinegar with an acetic acid concentration of 10% and citric acid of 1.5% can reduce some of the common pathogens found in food. This can be challenging because usual household vinegar only reaches 5-7% acetic acid concentration (48,49), and the divers sometimes dilute it further in the water. The greatest risk with using household chemicals may be that once combined with other chemicals, toxic reactions can occur, jeopardizing consumers' health (50). Applying dish soap to rinse foods is not recommended, as this process carries the risk of accumulating detergents in the food, which can cause health problems upon consumption (51).

Interviews with the supermarkets' representatives

During the interviews with the supermarkets' representatives, it became apparent that the food being discarded in Sweden does not go to "waste", as consumers may assume. In Sweden, the unpackaged food waste produced by supermarkets is used for composting and biofertilizer or anaerobic digestion and biogas production. The packaged food that is discarded as residual waste produces district heating through combustion (52,53). The emissions produced in the process are purified before they are released into the atmosphere (54–56). Since the packaged food waste constitutes the unknown but assumed majority of food waste produced by the supermarkets, it could be argued that the divers take an important part in the valorization of this waste. By sequestering food waste from a supermarket's waste chain and putting it to use further, they repurpose food waste to food and later to household bio-waste, which can be used directly in fertilizer production and biogas formation.

In countries where the food waste created by supermarkets is not directly contributing to energy production, the role of a dumpster diver could be viewed as an even more essential step to valorizing waste by turning it into a resource.

Laboratory results

The sampling of food was performed directly from the supermarket before it reached the waste containers of the supermarket. This creates a risk that the results were not representative of a true-case scenario that applies to a discarded food from a supermarket. The simulations were performed in conditions assumed to represent a supermarket's storage space and inside an outdoor container during spring in Uppsala, Sweden. Considering the seasonal variations in outside temperature, moisture, and sunlight, the results from this study can only be inferred on the conditions the tests were performed in. It should also be noted that the sample size for this study was small, following limited resources. The laboratory results should be viewed as a pilot study for further studies on a larger scale.

In the present study, 30% of questionnaire respondents confirmed that they know when their containers of choice are being refilled, and 36% adjust their pick-up times accordingly. The remaining 64% may pick up food that has been stored in the container for longer or shorter than 24h. It should be mentioned that many of the foods carrying a higher risk of foodborne diseases,

such as RTE foods (57), usually decay quickly and noticeably and seldom risk being picked up by the divers once a certain level of deterioration is surpassed. This was the case for packaged strawberries and pre-diced packaged melon in this study. Their quality worsened either visibly (mold found on strawberries after 24h storage in 15°C) or their smell became a tell-tale of ongoing spoilage process (pre-diced, packaged melon).

Only a few of the tested items were covered by the microbiological criteria, such as pre-diced packaged melon mix (under the 2.5.2 Pre-cut fruit and vegetables (Ready to eat) EG 2073/2005) and minced meat (under the 2.1.6 Minced meat EG 2073/2005) (12). Neither the lower nor the upper limit of *E. coli* levels and total aerobic counts was exceeded by either of the items presented in this study. It should be noted that the limits set by these criteria should be applied during or at the end of the manufacturing process. Even though the" best before" or" use by" date has been passed and temperature abuse was applied, the laboratory results show that the food items tested in this study still did not exceed the limits set by the legislation at the production stage.

Many of the food items included in the study consisted of a mixture of different sourced produce. It is impossible to tell if these multi-compound foods carry a more significant risk of foodborne infection based on this study. However, it is noteworthy that the food items exhibiting the highest concentration of total aerobic count are the chicken wrap and small leaf mixture. They both consist of products sourced from multiple ingredients that don't require any heat treatment and have high water activity. With plenty of nutrients accessible, these foods create a suitable environment for the bacteria to thrive (57,58).

Since some of the food items lacked a" best before"/" use by" date (packaged strawberries, unpackaged cabbage), they were sampled only once their condition worsened visibly, which was based on subjective rather than objective judgment. Sampling these items a day before or after what's been perceived as the" best before" date could have rendered different total aerobic counts, although these would most likely not change the study's outcome.

A decrease in the total aerobic count was observed for food items such as packaged strawberries and unpackaged cabbage, with the most prominent decrease in the latter. There may be several different explanations for why this occurs. There is a naturally occurring decrease in total aerobic count in deteriorating foods once the nutrients are depleted and bacteria enter the death phase (59). Another plausible explanation for the decline in the aerobic count is an overgrowth of fungi, as in the case of packaged strawberries. *Ascomycetes spp* growing on these fruits may very well be capable of producing antibiotics or outcompeting bacterial growth (60). Yet another possible reason for the drop in aerobic count on cabbage leaves might be attributed to a compound known for antimicrobial properties, isothiocyanate (61). This metabolite is present in cruciferous vegetables (e.g., cabbage, cauliflower) and is produced readily upon damage to the leaves. Once visible deterioration of the vegetable sets in, it is not unlikely that this metabolite is released and causes the deterioration of the bacterial flora.

The results from biotyping identified mostly ubiquitous, non-pathogenic, or opportunistic growth on agar plates. One of the samples from chicken wrap produced *Enterococci spp*, which could be attributed to fecal contamination and lacking process hygiene during food production, although Enterococci may also originate from environmental reservoirs (62). Findings of Enterococci in manually prepared food is not uncommon, as contamination from handlers may

occur (63). *Pseudomonas aeruginosa* is an opportunistic pathogen that was identified in the pre-diced packaged melon mix. Infection and colonization by *P. aeruginosa* doesn't pose a danger to immunocompetent individuals, but it is a common issue for immunocompromised individuals and a known cause of nosocomial infections (64,65).

Prospects and studies

A lot of exciting development is happening on the front of sustainable food packaging. One possible future way of reducing bacterial burden in food and slowing down the clock on the" best before" or" use by" dates can be utilizing the novel compound known as chitosan. It's a saccharide extracted from the shells of crustaceans, which carries antimicrobial properties against several species of bacteria. It is biodegradable and can be used to produce food packaging (66,67), prolonging the shelf life of food. A packaging with potentially bacteriocidic properties could offer even more safety to dumpster divers.

It would be interesting to perform the current study with the help of flow cytometry (FCM) to achieve higher accuracy in CFU/g since studies show that bacterial chains lead to the understatement of CFU on plate counts. Specific staining procedures allow for differentiation between viable and non-viable cells. FCM also allows for cell sorting and purification of the sample as specific antibodies can be used against pathogens (68,69). It would also be worthy to look at other types of food items and food categories within the scope of foods that have been deemed attractive by the online questionnaire. Furthermore, a study conducted in a similar matter but with items retrieved directly from waste containers would give a valuable insight into potential contaminants that may affect the food's microbial burden after it's been discarded.

Many interesting questions remain to be addressed in the future considering the role of infection biology in dumpster diving. Which pathogens can be found in the environments that the divers encounter? Could there exist a risk of contracting a potentially dangerous infectious disease from these environments? Do persons engaging in DD become more or less frequently ill with foodborne or other types of infection due to their potentially increased contact with "unclean" surfaces? How might their immune system differ from that of a person complying with societal norms surrounding food consumption?

Conclusions

The concept of food safety in one's kitchen is an interplay between several aspects. These include the temperature, individual knowledge of the consumer, time, and pathogens in the food. These could be present in the raw material, remain due to failed manufacturing processes, or contaminate food due to substandard hygiene routines. It is known that bacterial burden in food can increase or decrease over time and that temperature is an important factor. It is, however, not known what types of microbiological contaminants food may encounter once discarded. This study has shown a gap in the knowledge of the exact nature that all these aspects come into play in discarded foods. It also shone a light on the separation between evidence-based science and the convictions of the divers, especially on the subject of how to safely remove pathogens from their food. It's crucial for science to seal that gap to avoid raising possible public health problematic in the future. Although no significant increase in bacterial burden was observed in this study, the public's answers to the online questionnaire leave much room for discussion and further exploration into the subject of dumpster diving.

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Supplementary data

Appendix 1:

Questionnaire on dumpster diving, the complete list of questions.
Swedish/English.
"…" answer corresponds to free text, where the respondent was allowed to add their options or elaborate.

Introduktion/Introduction:
Hej och välkommen till en kort enkät om dumpster diving!

"Dumpster diving", "containerdykning" eller "sopdykning" är benämningar som används för att beskriva hämtning och användning av kasserade kläder, möbler, mat med mera. Syftet med den här enkäten är undersöka beteenden, tankar och vanor som förekommer i samband med 'dumpstring' av mat. Den riktar sig framför allt till personer som har hämtat eller hämtar delar eller majoriteten av sin mat via dumpster diving.

Det är helt frivilligt och anonymt att svara på den här enkäten. Svaren kommer att användas i ett examensarbete som undersöker eventuella hälsorisker med att äta kasserad mat. Arbetet utförs på mastersnivå inom programmet infektionsbiologi vid Uppsala universitet, i samarbete med Sveriges Lantbruksuniversitet.

Svaren kommer att registreras till och med 31:a mars 2021.

Tack för din medverkan och hjälp!
Vänligen,
Allyson

Vid frågor kring frågeformuläret kontakta mig via mail på XXX

/

Hi and welcome to a short questionnaire on dumpster diving!

"Dumpster diving", "totting", "skipping" is the act of salvaging discarded goods such as clothes, furniture, or food. This questionnaire aims to investigate the behaviors, thoughts, and habits exhibited in connection to diving for food specifically.

It's voluntary and anonymous to submit an answer via this form. The answers will be used in a master's degree thesis that investigates the potential impact of dumpster diving on public health. The project is performed in cooperation between Uppsala University and the Swedish University of Agricultural Sciences.

Answers will be registered until the end of March 2021.

Thank you for your participation and help!
Cheers!
/Allyson

If you'd like to contact me, please do so through my UU mail: XXX

Formulär/Form:
1. Kön/Gender:
    a) Kvinna/Female
    b) Man/Male
    c) Icke-binär/Non-binary
    d) Vill ej ange/I'd rather not disclose that information

2. Ålder/Age:
    a) <18 år/years

b) 18-29 år/years
c) 30-39 år/years
d) 40-49 år/years
e) 50-59 år/years
f) 60-69 år/years
g) 70-79 år/years
h) Vill ej ange/I'd rather not disclose that information

3. Sysselsättning/Occupation:
a) Elev (grundskola, gymnasieskola)/Student (primary school, high school)
b) Student / doktorand/Student / postgraduate student
c) Arbetslös/Unemployed
d) Arbetar deltid/Part-time employee
e) Arbetar heltid/Full-time employee
f) Pensionär/Retired
g) Sjukskriven heltid/Full-time sick leave
h) Inget av ovannämnda/None of the above
i) Vill ej ange/I'd rather not disclose that information

4. Högsta avklarad utbildningsnivå/Highest completed level of education:
a) Grundskola/Primary school
b) Gymnasieskola/High school
c) Högskola / Universitet 1-3 år/College / university 1-3 years
d) Högskola / Universitet 4-5 år/College / university 4-5 years
e) Högskola / Universitet >5 år/College / university >5 years
f) Annan yrkesutbildning/Other vocational training
g) Inget av ovannämnda/None of the above
h) Vill ej ange/I'd rather not disclose that information

5. Jag är bekant med termen' dumpster diving'/I am familiar with the term' dumpster diving':
a) Ja/Yes
b) Nej, det här är första gången jag är i kontakt med den termen, men jag har deltagit i liknande aktiviteter/No, I'm not familiar with the term but I have participated in similar activities.

6. Främsta anledning till dumpster diving/Leading reason for dumpster diving:
a) Sparar pengar och förbättrar den egna ekonomin/To save money and improve my economy
b) På grund av dålig ekonomi (hade min ekonomi varit bättre skulle jag handla i butik)/Due to poor economy (I would buy my groceries in a supermarket, had my economic situation been better)
c) Med miljön/djur i åtanke/To reduce food waste/make a contribution to the environment
d) Vill ej ange/I'd rather not disclose that information
e) …

7. Maten du hämtar äts oftast upp av/The food you obtain is usually consumed by:
a) Endast dig själv/You alone
b) Ditt hushåll (fler personer)/Your household (more than one person)
c) Ditt hushåll och gäster/Your household and guests
d) Ges/säljs vidare till andra/Food is given away or sold to others
e) Husdjur/Pets
f) Inget av ovannämnda/None of the above

8. Jag brukar eller kan tänka mig att hämta/I usually dive for or could imagine diving for:
a) Frukt och bär (i förpackning)/Fruit and berries (packaged)
b) Frukt och bär (utan förpackning)/Fruit and berries (unpackaged)
c) Grönsaker (i förpackning)/Vegetables (packaged)
d) Grönsaker (utan förpackning)/Vegetables (unpackaged)
e) Potatis och rotfrukter (i förpackning)/Potatoes and root crops (packaged)
f) Potatis och rotfrukter (utan förpackning)/Potatoes and root crops (unpackaged)
g) Bröd (i förpackning)/Bread (packaged)

h) Bröd (utan förpackning)/Bread (unpackaged)
i) Torra skafferivaror (ex. flingor, gryn, pasta, kryddor, ris, mm)/Dry pantry goods (cereals, groats, pasta, spices, rice, etc)
j) Mjölkprodukter/Dairy products
k) Veganska alternativ till mjölkprodukter/Vegan alternatives to diary products
l) Råa fiskprodukter (ex. torskfilé, gravad lax, mm)/Raw fish products (cod fillet, etc)
m) Tillagade fiskprodukter (ex. fiskpinnar, mm)/Cooked fish products (fish sticks, smoked salmon, etc)
n) Råa köttprodukter (ex. nötfärs, mm)/Raw meat products (minced meat, etc)
o) Tillagade köttprodukter (ex. stekta köttbullar, mm)/Cooked meat products (fried meatballs, etc)
p) Ägg/Eggs
q) Burkar, konserv, mm/Jarred, or canned goods
r) Ätfärdig mat i förpackning (ex. kycklingsallad, sandwich, mm)/Ready-to-eat, packaged foods (chicken salad, sandwich, etc)
s) Bakverk och konditoriprodukter/Pastries and confections

9. Finns det någon mer matprodukt som du brukar hämta som saknas i listan ovanför? (ej obligatorisk fråga)/Is there any other kind of foodstuff that you tend to obtain through dumpster diving that is missing in the previous question?
a) …

10. Hur mycket hämtad mat konsumerar du per år/How much retrieved food do you consume in a year?:
b) 0-25% (Jag handlar för det mesta och då och då äter mat jag hämtat via dumpstring)/0-25% (I usually buy my food but sometimes I get food via dumpster diving)
c) 25-50% (En del av mat jag äter kommer från dumpstring, men jag handlar minst lika mycket)/25-50% (A part of the food I eat comes from dumpster diving, but I buy just as much food in a supermarket)
d) 50-75% (Mer än hälften av mat jag äter kommer från dumpstring)/50-75% (More than half of the food I consume originates from dumpster diving)
e) 75-100% (Jag lever till absolut största delen, eller helt på dumpstring)/75-100% (Most or all of the food I consume comes from dumpster diving)

11. Jag hämtar majoriteten av maten från (välj ett alternativ)/I pick up majority of my food primarily at (pick one. If you're diving outside of Sweden, chose option "NA"):
a) Coop
b) Hemköp
c) Lidl
d) ICA
e) Willys
f) Vill ej ange/I'd rather not disclose that information
g) Not applicable
h) …

12. Jag hämtar även maten från (flera alternativ kan väljas här)/I also pick up food from supermarkets such as (several options can be chosen. If you dive outside of Sweden chose "NA"):
a) Coop
b) Hemköp
c) Lidl
d) ICA
e) Willys
f) Vill ej ange/I'd rather not disclose that information
g) Not applicable
h) …

13. Fler vanor/Other habits:
a) Jag har koll på när ny mat fylls på där jag hämtar varor./I am aware of when food is refilled at my pick-up spots
b) Jag anpassar tiden för hämtning av varor till strax efter påfyllning./I adjust my pick-up times according to the refills

c) Jag hämtar inte maten som är äldre än 2 dagar efter bäst före datum./I don't pick up food that's more than two days past its best before date.
d) Jag hämtar inte maten som är äldre än 7 dagar efter bäst före datum./I don't pick up food that's 7 days past its best before date.
e) Jag hämtar inte maten som är äldre än 1 månad efter bäst före datum./I don't pick up food that's more than a month past its best before date.
f) Jag hämtar inte maten som har passerat sista förbrukningsdatum./I don't pick up food that's passed its use by date date.
g) Jag hämtar endast mat som finns i sin obrutna originalförpackning./I only pick up food that is contained in its original, unbroken packaging.
h) Jag hämtar även mat som inte har någon förpackning./I pick up food that is unpackaged as well as packaged.
i) Jag kontrollerar livsmedelsverkets aktuella återkallanden innan jag hämtar maten./I check the news and other sources for information on recalls before I pick up the food.

14. Jag känner till skillnaden mellan "bäst före datum" och "sista förbrukningsdag"./I know the difference between "best before date" and "use by date date".
a) Det finns ingen skillnad/There is no difference
b) Ja/Yes
c) Nej/No

15. Berättar du för andra att du håller på med dumpster diving?/Do you disclose to others that you are dumpster diving?
a) Ja/Yes
b) Nej/No

16. Har du upplevt negativt bemötande från andra när du berättat om att du konsumerat mat som du hämtat via dumpstring? Beskriv gärna kortfattat vad du upplevt (vi undersöker möjliga förutfattade meningar och stigman om dumpster diving)./Have you experienced negative response from others once they know that you're consuming food obtained through dumpster diving? Describe your experience briefly (we're looking into possible preconceptions and stigma associated with dumpster diving):
a) Vill ej ange/I'd rather not disclose that information
b) …

17. Har du blivit sjuk eller mått dåligt p.g.a. maten du hämtat?/Have you ever become ill from the food you've picked up?
a) Ja/Yes
b) Nej/No
c) Vet ej/I do not know

18. Hur allvarligt sjuk har du blivit då?/How seriously ill were you?
Jag har inte blivit sjuk från mat jag hämtat via dumpster diving./I have not been ill from the food I have picked up.
a) Milt (illamående, lätt feber, lätt diarré, symptom varade i timmar till någon dag)/Mild (nausea, mild fever, mild diarrhea, the symptoms lasted for a few hours up to a day)
b) Måttligt (illamående, kräkningar, feber, diarré, symptom varade i timmar till några dagar)/Moderately (nausea, vomiting, fever, diarrea, the symptoms lasted for hours up to a few days)
c) Allvarligt (illamående, svåra kräkningar och/eller diarré, vätskebrist, symptom varade mellan en och flera dagar. Sjukvården kontaktades (1177, vårdcentral)/Severely (nausea, severe vomiting and/or diarrhea, dehydration, the symptoms lasted between one to several days. I sought professional healthcare advice)
d) Akut (allvarlig sjukdom med sjukhusvistelse)/Acutely (hospital stay was necessary)

19. Om du sökt sjukvård, fick du svar på vilken smitta du drabbats av, och vilken smitta var det i så fall (Om du inte drabbats av någon smitta eller inte sökt sjukvård välj "ej applicerbart")?/If you sought medical advice or were admitted to a hospital, did you find out what microbiological agent caused your symptoms? Please write it below. (If you haven't been ill or sought medical advice, please chose "Not applicable").
a) Ej applicerbart/Not applicable
b) …

20. Vad är din uppfattning kring risker med dumpstring av mat och bakteriella sjukdomar som sprids via mat?/What are your thoughts on risks with dumpster diving and food-borne bacterial diseases?

a) Jag tror inte att jag kan bli smittad med något från den maten jag hämtar./I don't think I risk getting a foodborne infection or poisoning from the food I pick up.
b) Jag tror att det finns en risk att jag kan bli smittad med något från maten jag hämtar./I think there is a risk that I could potentially get a foodborne infection or poisoning from the food I pick up.
c) Jag tror att det finns en risk att jag kan bli smittad och allvarligt sjuk i något från maten jag hämtar./I think there is a risk that I could potentially get a food-borne infection or poisoning and become seriously ill from the food I pick up.

21. Använder du några verktyg eller skyddsutrustning när du hämtar maten? (fler alternativ kan väljas, lägg gärna till egna alternativ)/Do you use any tools or safety equipment when you dive for food? (several options can be chosen, please add own options)

a) Vill ej ange/ I'd rather not disclose that information
b) Använder inte några verktyg eller skyddsutrustning/I don't use any tools or protective equipment
c) Skyddsglasögon/Safety goggles
d) Andningsmask/Face mask
e) Handskar/Gloves
f) Speciella eller skyddande kläder/Protective clothing or other special clothing
g) …

22. Hur behandlar du maten för att minska risken att bli sjuk från den? Lägg gärna till egna alternativ./How do you treat the food to minimize risks of getting ill from it? Please add own alternatives.

a) Om något luktar illa eller inte ser fräscht ut äter jag det inte. /I don't eat something if it smells bad or doesn't look fresh.
b) Jag äter inte mat som är möglig./I don't eat mouldy food.
c) Jag skär bort mögel om jag hittar det på t.ex. ost./I cut away the mold if I find it on cheese.
d) Jag sköljer frukt och grönsaker./I rinse fruits and vegetables.
e) Jag är noga med att tvätta händerna efter hantering av maten./I make sure to keep thorough hand hygiene.
f) Jag behandlar inte maten på något speciellt sätt, utan tillagar den som vanligt./I don't treat the food in any special way. I prepare it as usuall.
g) Jag hanterar rå kött och annan mat separat./I handle raw meat and other foods separately.
h) …

23. Vilka bakterier känner du till som potentiellt kan spridas via mat och orsaka hälsoproblem?/Which bacteria do you know of that can potentially spread through food and cause foodborne infections or poisoning?

a) Jag känner inte till någon bakterie som kan spridas via maten/I don't know any such bacteria
b) …

24. ÖVRIG fråga: har du några övriga synpunkter du vill dela med dig? (ej obligatorisk fråga)/ADDITIONAL (non-compulsory) question: other viewpoints that you would like to share?

a) …

Appendix 2:

The microbiological criteria for microorganisms mentioned in this study. For the complete list of microbiological criteria, see Commission Regulation (EC) no 2073/2005 (12).

Abbreviations:
n = number of samples that a sample set consists of
C = number of samples allowed to exceed the lower limit m
m = the lower limit
M = the upper limit

Food category	Sampling plan		Limits		The stage where the criterion applies
	n	C	m	M	
L. monocytogenes					
Ready-to-eat foods intended for infants and ready-to-eat foods for special medical purposes	10	0	Absence in 25g		Products placed on the market during their shelf life
Ready-to-eat foods able to support the growth of *L. monocytogenes*, other than those intended for infants and for special medical purposes	5	0	100 CFU/g		
	5	0	Absence in 25g		Before the food has left the immediate control of the food business operator, who has produced it
Ready-to-eat foods unable to support the growth of *L. monocytogenes*, other than those intended for infants and for special medical purposes	5	0	100 CFU/g		Products placed on the market during their shelf life
S. aureus					
Cheeses made from raw milk	5	2	10^4 CFU/g	10^5 CFU/g	At the time during the manufacturing process when the number of *Staphylococci* is expected to be the highest
Cheeses made from milk that has lococcal enterotoxins. undergone a lower heat treatment than pasteurization and ripened cheeses made from milk	5	2	100 CFU/g	1000 CFU/g	

or whey that has undergone pasteurization or a stronger heat treatment					
Unripe soft cheeses (fresh cheeses) made from milk or whey that has undergone pasteurization or a stronger heat treatment	5	2	10 CFU/g	100 CFU/g	End of the manufacturing process
Milk powder and whey powder	5	2	10 CFU/g	100 CFU/g	End of the manufacturing process
E. coli					
Live bivalve mollusks and live echinoderms, tunicates and gastropods	5	1	230 MPN/100g of flesh and intravalvular liquid	700 MPN/100g of flesh and intravalvular liquid	Products placed on the market during their shelf life
Minced meat	5	2	50 CFU/g	500 CFU/g	End of the manufacturing process
Mechanically separated meat	5	2	50 CFU/g	500 CFU/g	End of the manufacturing process
Meat preparations	5	2	500 CFU/g or cm^2	5000 CFU/g or cm^2	End of the manufacturing process
Cheeses made from milk or whey that has undergone heat treatment	5	2	100 CFU/g	1000 CFU/g	At the time during the manufacturing process when the *E. coli* count is expected to be highest
Butter and cream made from raw milk or milk that has undergone a lower heat treatment than pasteurization	5	2	10 CFU/g	100 CFU/g	End of the manufacturing process

Pre-cut fruit and vegetables (ready to eat)	5	2	100 CFU/g	1000 CFU/g	Manufacturing process
Unpasteurized fruit and vegetable juices (ready-to-eat)	5	2	100 CFU/g	1000 CFU/g	Manufacturing process
Total aerobic count					
Minced meat	5	2	$5x10^5$ CFU/g	$5x10^6$ CFU/g	End of the manufacturing process
Mechanically separated meat	5	2	$5x10^5$ CFU/g	$5x10^6$ CFU/g	End of the manufacturing process
B. cereus					
Powdered infant formula and dietary foods for special medical purposes intended for infants under six months	5	1	50 CFU/g	500 CFU/g	End of the manufacturing process

Appendix 3

Food categories, food items, pathogens, and sample dilutions that were used in the study.

Food category	Food item	Criterion	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}
Fruits and berries (packaged)	**Strawberries**	Total aerobic count				X	X	X	X	
		E. coli	X	X	X					
Vegetables (packaged)	**Lettuce**	Total aerobic count				X	X	X	X	
		L. monocytogenes	Qualitative, either present or absent in 25g							
		E. coli	X	X	X					
Ready-to-eat	**Pre-cut melon**	Total aerobic count			X	X	X	X		
		Total aerobic count 2			X	X	X	X	X	
		L. monocytogenes	Qualitative, either present or absent in 25g							
		E. coli	X	X	X					
		B. cereus				X	X	X	X	
		S. aureus	X	X	X					
	Wrap	Total aerobic count					X	X	X	
		Total aerobic count 2					X	X	X	X
		L. monocytogenes	Qualitative, either present or absent in 25g							
		E. coli	X	X	X					
		B. cereus					X	X	X	
		S. aureus	X	X	X	X				
	Mixed salads	Total aerobic count				X	X	X	X	
		Total aerobic count 2					X	X	X	X
		L. monocytogenes	Qualitative, either present or absent in 25g							
		E. coli	X	X	X					
		B. cereus			X	X	X	X		
		S. aureus	X	X	X					
Raw meat	**Minced meat**	Total aerobic count				X	X	X	X	
		Total aerobic count 2	X	X	X	X	X			
		E. coli	X	X	X					
		E. coli 2	X	X						
Cooked meat	**Whole grilled chicken**	Total aerobic count				X	X	X	X	
		Total aerobic count 2	X	X	X	X				
		L. monocytogenes	Qualitative, either present or absent in 25g							
		E. coli	X	X	X					
Raw fish		Total aerobic count			X	X	X	X		

	Cured salmon	*L. monocytogenes*	Qualitative, either present or absent in 25g							
Vegetables (unpackaged)	**Cabbage**	Total aerobic count				X	X	X	X	
		Total aerobic count 2	X	X	X	X	X	X	X	
		L. monocytogenes	Qualitative, either present or absent in 25g							
		E. coli	X	X	X					

Appendix 4

Complete list of food items, RTE status, weight, packaging, ingredients, country of origin, storage instructions, and shelf life for the samples used in this study.

Food item	RTE?	Weight	Packaging	Ingredients	Country of origin	Storage instructions	Shelf life
Chicken wrap (Packaged)	Yes	300g	Paper wrapping	Tortilla wheat (flour, spinach, water), vegetable oil (rapeseed), sugar, emulsifier (E471), baking powder (E500, E450), salt, acid (malic acid), diced chicken 24% (chicken breast fillet, salt, spices (paprika, chili, fennel, white pepper), potato flour, dextrose, stabilizers (E451), onion powder, antioxidants (E301), Provence mix 21% (fries salad, rose salad, mache salad), mayonnaise green hill (rapeseed oil, water, egg yolk, sugar, salt, mustard seeds, vinegar essence, cayenne pepper, preservative (E202, E211, E270), thickener (E412, E415), cabbage/carrot mix, curry (turmeric, coriander, buckhorn clover,	No information	+4°C - +8°C	No information

				cayenne pepper, fennel, cumin, black pepper, cinnamon, paprika), salt (NaCl), anti-caking agent (E535)			
RTE small leaf mixture (Packaged)	Yes	65g	Plastic bag	Rucola, spinach, red leaves, red chard	Italy	+2°C - +6°C	No information
Minced meat (Packaged)	No	746g-758g	Styrofoam tray, plastic wrapping	Beef, less than 20% fat, the ratio of collagen to meat protein below 15%.	Sweden	Below +4°C	2 days
Whole grilled chicken (Packaged)	Yes	1026g	Paper bag with plastic coating	Whole chicken (97%), salt, spices (paprika, garlic, black pepper, cayenne pepper, chili pepper, rosemary, cumin), onion, dextrose, starch syrup, sugar, paprika extract, acidity regulator (E330).	Sweden	Above 60°C	1 day
Cured salmon (Packaged)	Yes	150g	Vacuum packaged in plastic on a paper tray	Salmon, salt, sugar, dill, natural aroma (Salmo salar).	Farmed in Norway, produced in Germany, ACS certified	0°C - +4°C	No information
Cabbage (Unpackaged)	Yes	Whole head	No information	No information	Produced in Sweden, KRAV-certified	No information	No information
Strawberries (Packaged)	Yes	250g	Plastic box with holes	No information	Spain	No information	No information
Lettuce (Packaged)	Yes	Whole head	Thin plastic wrapping	No information	Spain	No information	9 days
Pre-diced melon mix (Packaged)	Yes	125g	Plastic cup with plastic, air-tight seal	Honeydew melon, watermelon, cantaloupe	Brazil, Honduras, Costa Rica	+2°C - +6°C, below +8°C	No information