

## Article

# A Multifaceted Evaluation of Food Waste in a Polish Supermarket—Case Study

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**Abstract:** The objective of this paper is to evaluate the food waste generated in one Polish supermarket in terms of its mass, financial value, and wasted caloric value, and to specify ways in which to manage food that can help contribute to reducing the phenomenon of food waste in commercial facilities. The research material was a list of unsold food items in one supermarket over two weeks. The evaluation shows that in one supermarket, approximately 3.3 tonnes of food was wasted over two weeks, with a total value of €5500. The groups of products with the highest percentage share in the structure of waste were fruits and vegetables, as well as meat, cold meats, and fish. The estimated caloric value of dairy products wasted over two weeks amounts to approximately 243.8 kcal. The estimated mass of dairy products appropriated for social purposes would feed from 72 to 174 persons a day (depending on the daily reference value). As various types of food products for social purposes may be sourced from the retail sector, it constitutes an important link in the chain “from the field to the table”, from which food should be redistributed to people in need.

**Keywords:** food waste; supermarket; food redistribution; losses of caloric value; monetary losses

## 1. Introduction

A sustainable food system is defined as a system which ensures food and nutrition security in a way (economic, social, and environmental) which does not endanger the food and nutrition security of future generations [1].

One of 17 new development goals (known as the Sustainable Development Goals) for the years 2015–2030 is ensuring sustainable consumption and production. It involves halving food waste at the retail and consumer levels and food losses at the production and post-harvest stages [2].

Due to an increasing global population, society faces a greater challenge for sustainable food production, quality, distribution, and food safety in the food supply chain. Adopting green supply chain management elements is essential for utilizing the food supply chain in an environmentally benign way [3].

Worldwide, about 4.5 trillion tonnes of food are produced every year, which is nearly twice as much as the amount required to satisfy the food needs of the world. In spite of this, 870 million of the inhabitants of the Earth starve and 2 million are undernourished (accounting for 12.5% of the population) [4]. By 2050, an additional 2.4 billion people will exist on the planet. This is equal to an increase of around 30%. Due to increasing per capita incomes and changing diets, global food production will need to grow by 70–100% in order to ensure global food security [5].

Major constraints on food production are the shortage of land and water, and the effects of climate change and natural disasters. Reduction of food waste and more efficient organization of food marketing systems are especially effective instruments for lowering the pressure on food production [6].

There is consensus that food losses and waste must be reduced and numerous action plans have been announced [7]. Each step of the entire food chain has the capacity to play a significant role in preventing and reducing food waste [8]. As noted by Smith [9], the reduction of food losses and waste has been identified as an essential means to enhance food security while reducing pressure on natural resources.

According to Food and Agriculture Organization of the United Nations (FAO), “food losses and food waste” mean any processed, partly processed, or non-processed food intended or supposed to be intended for human consumption, which, despite that, was not used according to its purpose. This definition refers to each link in the food supply chain from agricultural production through processing, distribution, and, finally, consumption. This loss, however, does not refer to raw materials and products that were originally meant for purposes other than human consumption, e.g., processed for bio-components, feed, bioenergy, etc., and inedible parts of food, such as eggshells, bones, or peels [10]. Food losses occurring at the end of the food chain (retail and final consumption) are rather called “food waste”, which relates to the behavior of retailers and consumers [11].

According to the European Commission, the majority of total food waste in the EU 27 is produced by households, i.e., 38 Mt (on average 76 kg per capita). The manufacturing sector comes in second place with 35 Mt of loss per year (70 kg per capita). Food service and catering produce approximately 25 kg of food waste per capita, which amounts to approximately 12.3 Mt. The retail and distribution sectors have the smallest share in the structure of loss at 8 kg per capita, i.e., 4.4 Mt per year. Households have the largest share of EU 27 food waste (42%), followed by agriculture/ food processing (39%), food service/catering (14%), and retail/wholesale (5%) [12].

On the one hand, food is wasted and on the other hand, the production of food has to be expanded to feed the world [13].

From a scientific point of view, reliable data are needed in order to quantify the contribution of each stage of the supply chain (e.g., agriculture, production and processing, retail, consumers) to overall food loss quantities, as a basis for planning and evaluation and identification of well-founded waste prevention measures [14].

As noted by Kliugaitė and Kruopienė [15], the retail sector is one of the actors of the supply chain where there is still a gap in data and information regarding the state of the problem of food waste, especially in the Central and Eastern European region. Better understanding of food wastage within retail stores is necessary in order to assess the actual scale of the problem and to determine efficient waste prevention measures. It is not only the amounts of waste that make the retail sector important, but also the link between producers and consumers.

It is important to note that results of different studies usually cannot be exactly compared due to different definitions, methodologies, and reference bases [14].

The exact amounts of food waste in the retail sector are not exactly clear. According to Swedish Methodology for Environmental Data, only 4% of food waste can be attributed to grocery stores [16]. One large retail chain, Tesco, claims that in Central Europe, unsold food in the financial year 2016/2017 made up 1.8% in relation to total sales (in Poland, 1.5%) [17]. Approximately 500,000 tonnes of food waste from U.K. retailers are disposed of annually, largely to landfills [18]. In Italy, distribution wastes 238,000 tonnes of food per year [16]. According to Cicatiello et al. [19], in one year, the total in-store (hypermarket) waste was 70.6 tonnes of food. The retail sector in Denmark produces more than 45 tonnes of food waste per year. On average, a retailer creates approximately 165 to 562 kg of food waste per every €130,000 of turnover [20]. Katajajuuri et al. [21] estimated the total food waste of the Finnish wholesale and retail business to be 65–75 million kilograms annually.

Selected causes and effects of food waste in retail are presented in Table 1.

**Table 1.** Selected causes and effects of food waste in the retail sector.

Causes	Effects
Non-compliance with marketing standards (size, color, shape, etc.)	Product is suitable for consumption, but there are problems with their sale
Overestimation the order	
Short shelf life	
Inadequate quality of packaging (mechanical damage to bulk containers)	
Damage of sensitive products like fruits and vegetables	Product is not suitable for sale and consumption
Excess of product shelf life	
Inadequate storage and exposure conditions (e.g., interruption of the cold chain)	
Inadequate quality of packaging (mechanical damage to unit packages)	

The high level of waste in the retail sector stems from the applicable retail standards specifying the size, shape, and color of fruits and vegetables, due to which many of them are rejected despite them being edible.

Overstocking due to inaccurate demand forecasting can lead to exceeding product shelf life, which may lead to wastage. At this stage (for both wholesale and retail distribution), waste is generally the consequence of inappropriate ordering and incorrect projections of demand for food products, resulting in enormous quantities of merchandise which are not sold before the expiration date and/or natural deterioration (which is mainly a concern for fruits and vegetables). Estimating demand for food products, in fact, is highly complex and is influenced by multiple factors, such as climate, season, specific marketing campaigns, new product launches, promotions, and holidays [16]. Food retailers must generally keep surplus quantities of food to ensure that they do not run out of any particular product, which would cost them both sales and the trust of their customers [22].

Another important factor driving food waste at the sale and distribution stages is the damage to bulk containers which affects the appearance of unit packages. The products contained therein pose no threat to human health, and can be consumed.

The cause of waste in retail is the industry standards which impose the obligation to keep “full shelves”, especially in supermarkets. It is applied to give the impression of a continuous rotation of stock. In most retail outlets, piles of fresh-looking produce on display are seen as a means to attract buyers, who then have the luxury to choose by rummaging through the pile. Products such as fruits at different ripening stages are piled together to give the buyer a choice [1]. As a result of this practice preceded by extensive replenishment of stock, products and their packaging may become damaged. Sometimes retailers mix different expiry dates for the same product; items close to their expiry dates are ignored by consumers, who prefer products with a longer shelf life.

Conditions within the retail outlet (temperature, humidity, lighting, etc.) and handling practices, especially hygiene, have an effect on food safety, quality, and acceptability of the product.

Sustainable cold chain management is a strategic tool for achieving social, ecological, and economic goals in managing supply chain activities that deal with perishable products like meat, dairy, and vegetables, which must be stored and distributed under special time and environmental conditions [23].

As noted by Shashi et al. [24], the supply of high-quality raw products, less lead time, low price, and use of cold storage at the supplier stage may reduce wastage.

Marketing strategies, such as  $2 \times 1$  (buy one, get one free) or  $3 \times 2$  (buy two, get one free) options, are intended to promote the sale of products close to their expiration date and solve overstock problems, but result in transfer of the risk of waste from distribution to final consumption [16]. The strategy was

indicated in The High Level Panel of Experts (HLPE) report [1] as the reason for the waste, because of how it lures consumers to buy produce they may not use and then throw it away after its “best before” or “use by” date. In accordance with Polish law [25], food after the expiration date (use by) or after the date of minimum durability (best by) cannot be put on the market, and therefore cannot be donated to charity. Many consumers are not aware that exceeding the date of minimum durability (best by) does not, in fact, imply that the product is harmful to one’s health, but that it may have partially lost taste and flavor. As noted by Kowalewska and Kołtajtis-Dołowy [26], effective education is an important factor in preventing food waste.

Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives [27] sets out the waste hierarchy, in which the first and the most important activity is prevention. Other desirable activities are preparing food for reuse, recycling, or other recovery, e.g., energy recovery. The last link is the disposal of food waste; however, the preceding activities should make this stage a last resort. According to the U.S. Department of Agriculture, the manners of mitigating waste in retail are an enhanced ordering system, more frequent and smaller deliveries, shop staff training, and improved temperature monitoring [28]. The unsold products in retail (which are safe but, e.g., short-dated) can be transferred to people with low income and those who cannot afford them. As showed by Giuseppe et al. [29], if food is not properly recovered for human consumption or recycled for animal feeding, it represents an inefficiency in the supply chain.

An analysis carried out in April 2015 in Philadelphia showed that 11 stores donated 68,039 pounds (about 30,862 kg) of food over one month, of which 51.25% was fresh fruits and vegetables [30]. Buchner et al. [16] estimated that food wasted in Italian distribution could cover the daily consumption needs (breakfast, lunch, supper) of about 620,000 adults. The Tesco retail chain donated for social purposes in the financial year 2016/2017 in Poland 25.8% of its unsold food, suitable for consumption [17].

The cost of waste management, i.e., storage or incineration, should be relatively high in order to discourage its use and consequently prevent food waste. Moreover, the regulations concerning the support and subsidizing of renewable sources of energy should be reviewed. The objective of such a review is to eliminate contradictory economic incentives, e.g., the case in which on one hand, the waste treatment is subject to tax, and on the other, the production of energy from waste is subsidized [31].

It is worth emphasizing that food waste, apart from the obvious problem of food loss, is linked with further waste management, namely, waste stocking, sorting, and treatment. Many of these activities negatively affect the environment [32]. Moreover, the irrational use of food is a waste of money, workforce, raw materials, health and security systems, exploitation of machines, and consumption of natural resources [33]. Extensive food waste and its far-reaching consequences should be a stimulus for each link of the food supply chain “from the field to the table” to use and distribute food reasonably. It is essential to follow the recommendations, which could help to mitigate the problem.

The objective of this paper is to evaluate food waste generated in a Polish supermarket (as a case study) in terms of its mass, financial value, and wasted caloric value. The research material was a list of unsold food items in one Polish supermarket over two weeks. Focus was laid on the losses of 14 food groups.

This paper is organized into five sections. The research material and methodology are described in Section 2. Section 3 reveals study findings which are then discussed according to the body of literature in Section 4. Finally, Section 5 contains the conclusions.

## 2. Materials and Methods

### 2.1. Research Material

The research material was a list of unsold food items in one commercial facility (supermarket) over two weeks in April 2016. The store is one of the 150 supermarkets (sales area of about 2000 m<sup>2</sup>) belonging to a large retail chain, located in a large city (about 1,744,351 residents). Average monthly net

turnover was 0.2 million euro. A supermarket was chosen for the study because this type of store is very popular among residents of big cities; evidence of this comes from Statistics Poland (GUS) data [34]. In 2016, the estimated share of the total value of sales realized by supermarkets and hypermarkets in retail sales in stores and at service stations accounted for 25.0% of the total [34]. Although this study was based on the data from a single retail store, the schedule of product management is similar in each supermarket.

The database included 1245 items showing the digital code, product name (with the mass of the packaged product), quantity (number of unsold unit packages or kilograms for unpackaged products), and net purchase price (without trade margin) expressed in PLN. The store's employees during the 14 days recorded handwritten information in detail. Prices in PLN were then converted into EUR, assuming the middle exchange rate of the National Bank of Poland (for the session day), which was 4.1739 PLN/1 EUR on 30 May 2017 [35].

Within the available database, the food products were divided into the following groups: milk and milk products, vegetables, fruits, meat, cold meats and fish (and fish products), sweets, beverages, grains, bread, legumes and nuts, fats, eggs, mushrooms, ready meals, other (e.g., spices, sauces). This classification allowed for the determination of the percentage structure of waste and the estimation of the financial losses incurred by the commercial facility under study. For that purpose, the mass of products wasted over two weeks was summed up for each product group. (It is assumed that 1 L of fluid corresponds to 1 kg.)

## 2.2. Evaluation of Food Waste Generated in a Polish Supermarket in Terms of Wasted Caloric Value and Calcium Content

The assumption was made that two-thirds of total wasted food at retail could be used for consumption purposes. The remaining amount (one-third) could not be consumed due to the lack of food safety. Based on the daily model food intake for selected age groups [36], the potential number of people whose daily requirements for bread, cereal products, milk and dairy products, meat, cold meats and fish, vegetables, fruits, and fats would be met was estimated, thanks to the mass of wasted food (two-thirds) over two weeks.

To estimate the lost caloric value and calcium content, one product group was selected, namely milk and milk products, constituting a significant component of the human diet. Based on the data from the Central Statistical Office [37]), it was stated that the selected assortment group represented 12.5% in the structure of products consumed in Poland. Moreover, cow's milk and its products have a high caloric value. They are rich in proteins (casein, lactalbumin), calcium, potassium, magnesium, phosphorus, polyunsaturated fatty acids, lactose, fat-soluble vitamins (A, D, E, and K) and many other components [38]. Based on the Ingredients and Nutrition Facts Table by Jarosz [38], the average caloric value and average calcium content in 100 g of dairy product was calculated. Then, based on the recorded food waste, the total caloric value and calcium content that was wasted with these products, which were not allocated to consumption, was estimated. The last phase of the analysis was the comparison of the total caloric value and calcium content wasted with the daily reference value in the given age groups. The result of the analysis was used for calculation of the potential number of people who could be fed if the wasted milk products had been redistributed.

Moreover, an estimation of the caloric value of waste generated by vegetables, fruits, meat, cold meats, and fish over two weeks in the supermarket was made. Based on the Ingredients and Nutrition Facts Table by Jarosz [38], the caloric value in 100 g of products was obtained. Then, the total caloric value for wasted products or the average caloric value for the group of wasted products was calculated. Included in the cold meat category were smoked and boiled meats (e.g., ham, bacon, sausage). A graphical scheme of the research system is presented in Figure 1.



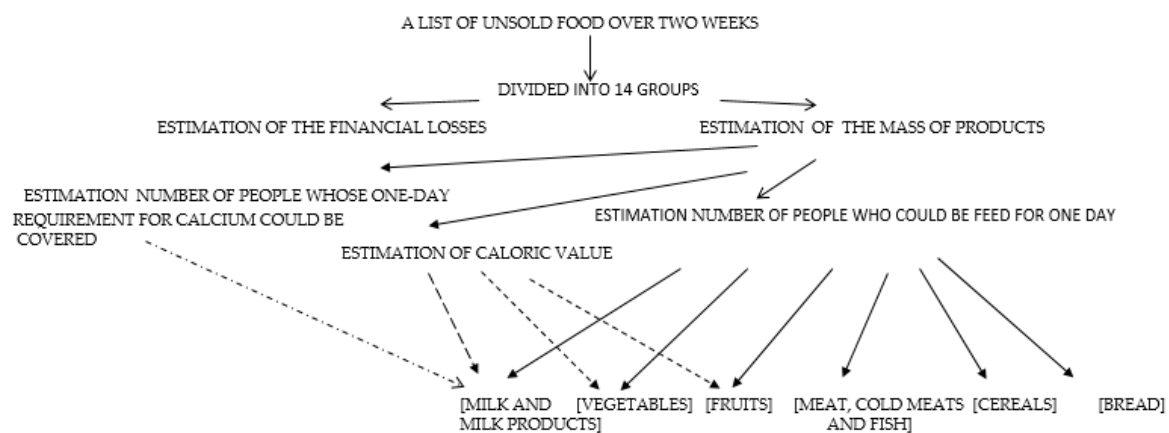


Figure 1. Graphical scheme of research system.

The statistical data analysis was carried out using the program Excel 2013.

The adopted research model is based on the list of unsold products recorded by the employees of the supermarket every day. A similar methodology was presented by Cicatiello et al. [19] and by Lebersorger and Schneider [14]. Within the majority of studies, questionnaires were used as a research tool and focused only on individual food product groups. The advantage of this study is that it covered a very detailed database and analyzed all types of food. The information was recorded during a daily process which allowed the avoidance of gaps. The weak point of this research system is the fact that seasonal variations of food waste amounts generated were not analyzed.

### 3. Results

#### 3.1. Mass, Caloric Value, and Percentage Share of Food Waste Generated by One Supermarket

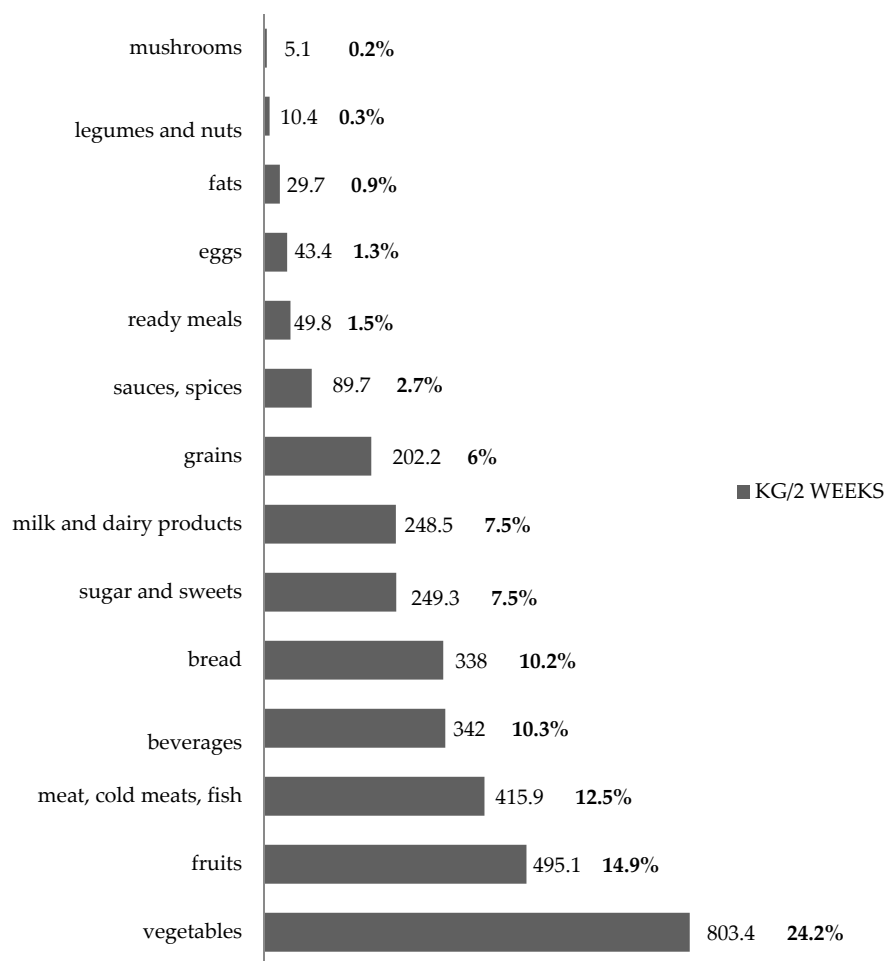
The total quantity of food waste produced over two weeks in the supermarket under study was 3.3 tonnes. The percentage share of waste in the selected food groups was the following: vegetables, fruits, meat, cold meats, and fish (in total more than 50%) (Figure 2). These were followed by bread and beverages. Fats, legumes and nuts, and mushrooms had the smallest share in retail food waste (i.e., below 1%).

This study showed the largest waste of cold meats (Figure 3a). Among the types of meat, there is significant waste of pork and poultry (Figure 3b).

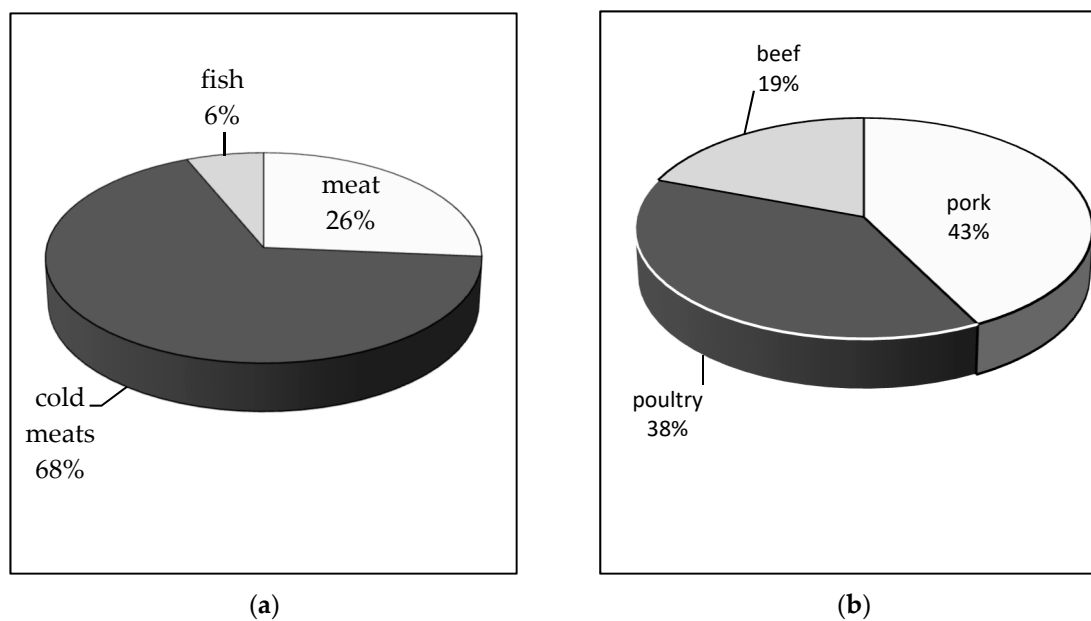
In the structure of the wasted milk and milk products, rennet cheese and homogenized cheese were dominant (Figure 4). These were followed by sour cream, yoghurt, and milk.

As shown by our own study, wasted vegetables, the weight of which was twice that of meat products, delivered about 3.7 times less kcal. The waste of fruits was about 19% larger than that of meat, cold meats, and fish in terms of weight, but they differed significantly in terms of caloric value (the caloric value of fruits was 4 times less) (Table 2).

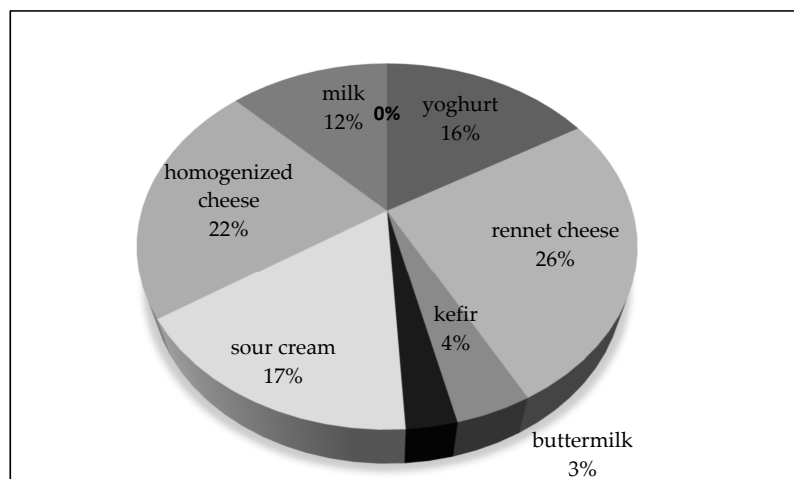
Although the ongoing processes of globalization make consumption patterns more and more similar in different countries, non-economic factors, cultural and social, still have a strong influence. Therefore, it is to be expected that the presented waste structure in this study is correlated with Polish consumption patterns.



**Figure 2.** The mass (kg) and percentage value (%) of waste generated under selected assortment groups in two weeks in the supermarket under study.



**Figure 3.** (a) The percentage structure of the wasted meat, cold meats, and fish; (b) The percentage structure of the types of wasted meat.



**Figure 4.** The percentage structure of the wasted milk and milk products.

**Table 2.** The estimation of the mass (kg), percentage value (%), and caloric value (kcal) of waste generated in terms of vegetables, fruits, and meat, cold meats, and fish over two weeks in the supermarket under study.

	Mass (kg)	Percentage Value (%)	Caloric Value * (kcal)
<b>Vegetables</b>			
carrot	145	18.0	47.9
tomatoes	99	12.3	19.8
cabbage	90	11.2	22.1
onion	81.5	10.1	34.2
pepper	79	9.8	50.6
cucumbers	76	9.5	10.6
lettuce	71	8.8	9.9
potatoes	60	7.5	46.2
radish	35	4.4	4.9
beetroot	20	2.5	8.6
asparagus	9	1.1	1.8
parsley	7	0.9	2.5
cauliflower	6.5	0.8	1.8
garlic	5.5	0.7	3.6
broccoli	4	0.5	1.4
chives	3.9	0.5	1.0
spinach	3.5	0.4	805.0
leek	3	0.4	1.8
bean sprouts	2.5	0.3	675.0
celery	2	0.2	420.0
<b>TOTAL</b>	<b>803.4</b>	<b>100</b>	<b>270.7</b>
<b>Fruits</b>			
apples	68	13.7	32.00
watermelon	67	13.5	24.8
grapes	48.5	9.8	33.9
melons	39	7.9	13.7
grapefruit	38	7.7	14.0
oranges	37	7.5	18.1
peaches	33.5	6.8	15.7
lemons	32	6.5	11.8
bananas	31.5	6.4	30.2
pears	25.5	5.2	14.0
strawberries	13	2.6	3.8
raspberry	11	2.2	3.3



Table 2. Cont.

	Mass (kg)	Percentage Value (%)	Caloric Value * (kcal)
avocado	11	2.2	177.1
tangerine	9	1.8	3.8
kiwifruits	6	1.2	3.4
mango	5.5	1.1	3.3
pineapples	5	1.0	2.7
plums	4	0.8	1.8
passion fruit	3.5	0.7	1.0
pomegranate	2.6	0.5	2.2
gooseberry	1	0.2	410.00
cherries	1	0.2	610.00
dates	1	0.2	2.8
apricots	1	0.2	470.00
figs	0.5	0.1	1.5
TOTAL	495.1	100.0	257.1
<b>Meat, Cold Meats, Fish</b>			
pork	47	11.3	141.0
poultry	41.6	10.0	56.2
beef	20.8	5.0	31.6
cold meats	280.3	67.2	734.4
fish	26.2	6.3	44.5
TOTAL	416.9	100.0	1007.7

\* The caloric value in 100 g of products was retrieved from the Ingredients and Nutrition Facts Table in [38].

### 3.2. Financial Value of Food Waste Generated by One Supermarket

Another issue regarding the food waste in retail is the money lost. According to our own research, the total value of financial losses in the supermarket under analysis resulting from food waste was €5523/2 weeks (Table 3).

**Table 3.** The estimation of percentage share (%) of financial losses and value (€) generated by selected assortment groups over two weeks in the supermarket under research.

	Percentage Share (%)	Value * (€)
vegetables	15.2	863.8
fruits	13.1	740.3
meat, cold meats, fish	23.9	1357.7
beverages	2.9	163.5
bread	9.4	532.5
sugar and sweets	13.2	745.8
milk and dairy products	10.5	596.4
grains	2.3	124.8
saucers, spices	3.7	212.6
ready meals	2.9	164.0
eggs	1.1	64.1
fats	0.8	45.7
legumes and nuts	0.8	45.6
mushrooms	0.2	13.1
TOTAL	100	5522.9

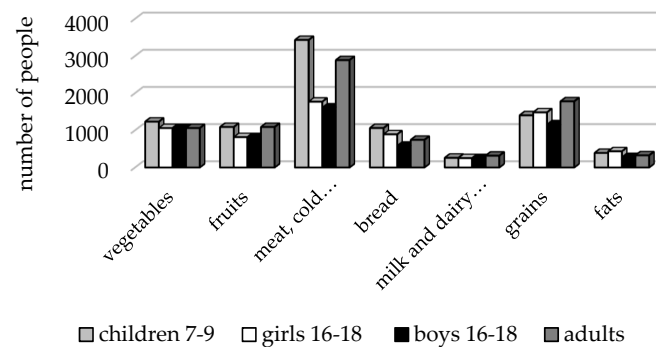
\* middle exchange rate of National Bank of Poland 4.1739 PLN/1 EUR on 30 May 2017 [35].

The product groups with the most significant impact on the increase in financial losses were meat, cold meats, and fish, followed by vegetables, sugar and sweets, fruits, milk and milk products, and, finally, bread. The following products have the smallest share in the financial structure of waste: eggs, fats, legumes and nuts, and mushrooms.

### 3.3. Potential for Cooperation between Retail and Charity Organizations

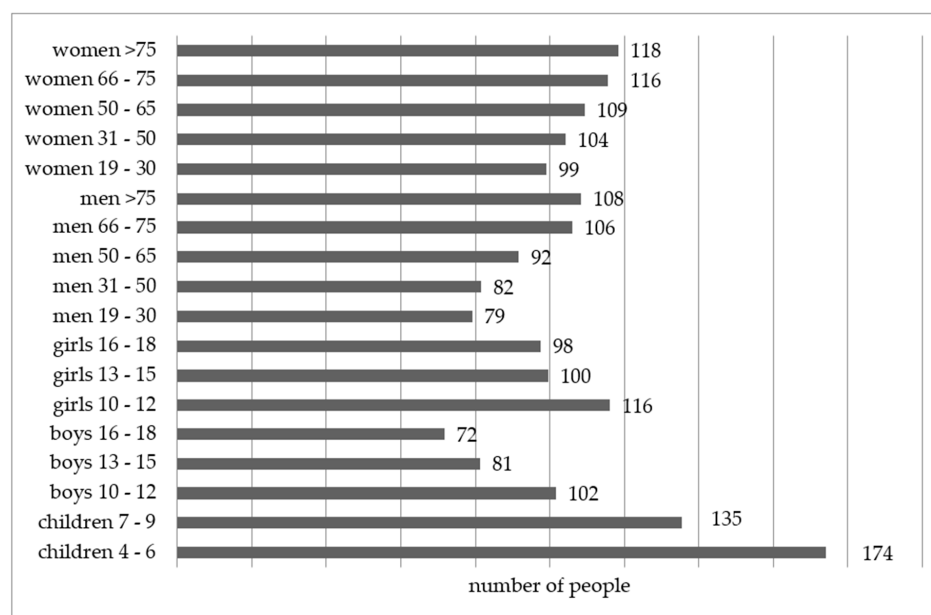
The assumption was made that two-thirds of wasted food could be used for consumption purposes. Thus, it may be assumed that the investigated supermarket wasted 2.2 tonnes of edible food over two weeks.

Based on the daily model of food rations for selected age groups [36], the potential number of people was estimated whose daily requirements for bread, cereal products, meat, cold meats, fish, vegetables, fruits, and fats could be covered by the food wasted in the space of two weeks in the commercial facility under research (Figure 5). It was found that the wasted meat, cold meats, and fish would allow for feeding about 2300 people, the wasted vegetables would allow for feeding about 1000 people, and the wasted grains about 1300 people.



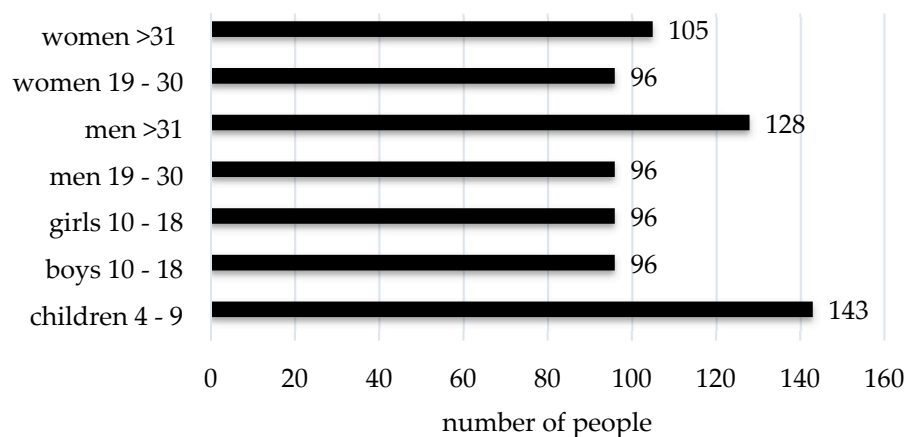
**Figure 5.** The estimated number of people who could be fed for one day thanks to the vegetables, fruits, meat, cold meats, fish, bread, milk and dairy products, grains, and fats wasted over two weeks in the supermarket.

The obtained result of the analysis was used for calculation of the potential number of people who could be fed if the wasted milk products had been redistributed. It was assumed that two-thirds of the 248.5 kg of milk and milk products withdrawn from sales was before its “use-by” date. The obtained result amounting to 165.6 kg of milk and milk products was converted to the average daily reference value of selected groups of people. It was found that the caloric value losses together with wasted milk and milk products (243,846 kcal) would allow for feeding from 72 (16–18-year-old boys) to 174 people (4–6-year-old children). To compare, the obtained value would allow for feeding of approximately 104 women or 82 men at an economically productive age (from 31 to 50) (Figure 6).



**Figure 6.** The estimated number of people who could be fed for one day thanks to the milk and milk products wasted over two weeks in the supermarket.

Figure 7 shows the estimated number of people whose one-day requirement for calcium could be covered thanks to the milk and milk products wasted over two weeks in the commercial entity under study. The obtained value would allow for covering the one-day requirement for calcium for from 96 to 146 people from different age groups.



**Figure 7.** The estimated number of people whose one-day requirement for calcium could be covered thanks to the milk and milk products wasted over two weeks in the supermarket.

#### 4. Discussion

We found that the total quantity of food waste produced over two weeks in the supermarket under study was 3.3 tonnes. The percentage share of wasted vegetables, fruits, meat, cold meats, and fish was more than 50% (Figure 2). According to Cicatiello et al. [19], in one year in one Italian hypermarket, 70.6 tonnes of food was wasted (on average 2.9 tonnes/two weeks/one hypermarket)—mostly bread, fresh fruit, and vegetables. The food groups with the highest share in food losses in Denmark are fruits and vegetables, bread, and yoghurt [20]. Kliaugaitė and Kruopienė [15] collected data from 21 retail stores in Lithuania and noted that fresh fruits and vegetables comprised the largest subgroup of retail food waste at 27%. The other product subgroups presented in the waste flows were meat (22%), milk and dairy (20%), and fish (18%).

The main product groups associated with food waste in Finnish stores are fruits, vegetables, and bread [21]. The obtained food waste structure resembles that published by the Swedish Environmental Protection Agency, in which fruits and vegetables generated the greatest losses (approximately 40%), followed by meat (29%) and bread (27%) [39]. By comparison, according to the U.S. Department of Agriculture, the hierarchy of products with the greatest share in food loss is as follows: vegetables (11.4%), fruits (9.7%), and meat, poultry, and seafood (9.7%) [8]. A report of one of the largest retail chains, Tesco, confirms the high share of fruit and vegetables in the wastage structure in stores located in Poland (42%) [17]. The reason why fruit and vegetables are usually accounted for as the largest quota of food waste, as confirmed by many studies, could be the fact that this kind of food in supermarkets is sold loose and stored in bulk in baskets, from which consumers choose them on their own. Keeping high stock levels of sensitive products in a small volume may lead to mechanical damage and, in consequence, waste. As noted by Buchner et al. [16], fresh products with a shorter shelf life, such as fruits and vegetables, make up the majority of waste.

The significant position of bread in the waste hierarchy obtained in our own study generally coincides with other results [17,19,21,39]. The percentage share of wasted bread in our own research was lower than in Tesco's results (respectively, 10% and 18%) [17].

Mena et al. [32] collected data through 43 interviews with managers in food manufacturing wholesaling and retailing in the U.K. (24) and Spain (19). According to Mena et al. [32], six product

types had levels of waste higher than 7%: two ambient products (bread and oils) and four chilled products (beef, sandwiches, yoghurt, and bagged salads).

As highlighted by Gunders [8], most of the waste in retail occurs in relation to baked goods, meat, seafood, and ready-to-eat foods due to their high level of perishability. In our own study, the food group of meat, cold meats, and fish was in the third highest position. As noted by Mena et al. [32], demand for meat products is also very volatile depending on the weather, and this can also create waste. The next reason is that these products tend to have a short shelf life.

Significant waste of meat, cold meats, and fish in the structure is distressing for various reasons. Firstly, meat is a good source of many minerals and vitamins and contains all the essential amino acids. Secondly, meat is considered to be the food product with the greatest environmental impact throughout the food chain. The meat chain sector is recognized as one of the leading polluters in the food industry [40]. According to Henschion et al. [41], the world's consumption of meat shows two significant increases—increase because of growth in the world's population and increase in the consumption of meat per capita. A comparison of the consumption structure in Polish households with the guidelines of “Livewell Plate 2020” indicates the need to reduce the share of meat and meat products [42]. As noted by Millward and Garnett [43], reductions in the intake of meat and dairy products, which account for approximately 40% of food-related emissions, are an inevitable policy.

Our study showed the largest waste of cold meats, with pork and poultry among the types of meat. According to research conducted by GfK PGD [44], people in Poland most often choose cold meats (18 times a month). They often reach for poultry (average 9.4 times a month) and pork (7 times a month).

Food types vary widely in terms of their water and caloric value per kilogram. For instance, a kilogram of wheat flour on average contains 12 percent water and 3643 kcal whereas a kilogram of apples on average contains 81 percent water and 1704 kcal. Consequently, measuring by weight does not consistently reflect the energy in food products that could have been consumed by people Gebhardt and Thomas 2002. cyt [45].

According to Wrzosek et al. [46], in the supermarkets under research, dairy products with the highest share in dairy waste were milk desserts, rennet cheese slices on trays, pasteurized milk, cottage cheese, and UHT milk. The lowest waste was recorded for buttermilk, kefir, and butter. The most common cause for dairy product waste was the expiry date (78%), while mechanical damage to the packaging represented 22% of the cases [46]. The results of the studies were close to those of ours.

We found that wasted vegetables (the weight of which was 803.4 kg) delivered about 270.7 kcal, while meat products (the weight of which was 416.9 kg) delivered about 1007.7 kcal. (Table 2). As noticed by Koester [22], wastage of relatively cheap food, such as vegetables and potatoes, is greater in mass than wastage of higher-quality products, such as beef. However, one kilogram of beef contains more calories than one kilogram of vegetables, and moreover, the production of one kilogram of beef consumes many more resources than the production of one kilogram of vegetables.

According to the research carried out by Eriksson et al. [47] in 2010 in six commercial outlets, the waste of vegetables and fruits amounted to 9605 tonnes/year/6 outlets. Among the fruits and vegetables included in the research sample, lettuce and grapes generated the highest loss, while apples, bananas, and potatoes the lowest. In our own research, the vegetables which generated the highest waste were carrots (18%), tomatoes (12%), cabbage (11%), onions (10%), peppers (9.8%), cucumbers (9.5%), lettuce (8.8%), and potatoes (7.5%). These vegetables are available all year round in markets. When it comes to fruits, apples (13.9%), watermelon (13.5%), grapes (9.8%), melons (7.9%), grapefruit (7.7%), oranges (7.5%), peaches (6.8%), lemons (6.5%), and bananas (6.4%) recorded the highest waste. Of the listed fruits, two types, watermelons and peaches, are sold seasonally (early spring). One of the factors affecting the variability in food intake is the time of year. The period of the year affects the consumption level of a certain group of products, mainly fruit and vegetables [48]. As noted by Lebersorger and Schneider [14], fruit and vegetables show the maximum food loss rates in the summer months between July and September, and their lowest food loss rates between January and March.

Papargyropoulou et al. [49] highlighted how food waste has economic implications for everyone within the food supply chain. These include food production and purchasing costs, as well as costs associated with the final disposal of food waste. According to our own research, the total value of financial losses in the supermarket under analysis resulting from food waste was €5523/2 weeks. According to Cicatiello et al. [19], the total in-store waste was 70.6 tonnes of food/year for a value of nearly €170,000 (average €7083.3/2 weeks).

The product groups with the most significant impact on the increase in financial losses were meat, cold meats, and fish (23.9%), followed by vegetables (15.2%), sugar and sweets (13.2%), fruits, and milk and milk products (10.5%). The obtained results, when compared to those presented by Buzby and Hyman [50], show that in the United States the highest financial losses were generated by meat, cold meats, and fish (41%), vegetables (17%), and milk products (14%). Eggs (2%) and nuts (1%) had the lowest share in the structure of financial losses. Both in our own research and in the paper by Buzby and Hyman [50], the products with the highest financial losses were everyday products, such as meat, cold meats, and fish, which have a relatively high price per unit. The products bought occasionally, e.g., mushrooms or legumes and nuts, had the smallest share in waste.

As noted by Cicatiello et al. [19], dairy products and groceries (e.g., packed pasta, rice, industrial bakery products), despite the limited weight of the products discarded, represented a large quota of the value of the food waste.

Redistribution of the surplus food to the most deprived population is a sustainable and appropriate option for reducing food losses [51].

To show the potential residing in the cooperation between retail and charity organizations for redirecting food to the poor, the potential number of people was estimated whose daily requirements for bread, cereal products, meat, cold meats, fish, vegetables, fruits, and fats could be covered by two-thirds of the food wasted in the space of two weeks in the commercial facility under research (Figure 5).

The estimated mass of dairy products appropriated for social purposes would feed from 72 to 174 persons a day (depending on the daily reference value).

The obtained value would allow for covering the one-day requirement for calcium for from 96 to 146 people from different age groups. As noted by Laskowski [52], the daily food intake consumed in 2011, per person, contained smaller amounts of minerals. The most spectacular and, at the same time, health related is the lower intake of calcium.

As noted by Giuseppe et al. [29], recovered products could supplement the diet of undernourished people of the local country sustained by non-profit organizations. Such organizations operate all over the world.

Buzby et al. [53] highlighted that food donations could additionally contribute to improving the image of a company. However, Giuseppe et al. [29] noted that food recovery is not always extensively practiced due to the risk that improper handling of the products donated can affect the company's reputation, especially for products that are closer to the expiration date. According to the research carried out by Lebersorger and Schneider [14], the majority of retail outlets only donate a very small percentage of their food loss to social services or do not donate any products at all.

Food donations are to reduce food waste and they are not only socially but ecologically and economically highly beneficial. The companies that donate products save money due to decreased waste generation [54]. The recovery of food waste can contribute to cost reductions (like storage) and profit loss; in some cases, it can represent a source of profit for the retailer. Concerning the economic benefits of the donation, they are mostly related to the fiscal deductions granted to donors [29]. The European Union allows its Member States to apply value-added tax (VAT) relief for businesses which donate food to charity organizations. In Poland, a piece of legislation which removes this important barrier is the amended Act on VAT [55], which entered into force on 1 October 2013 and relieved selling and distribution organizations from paying VAT on food donations. An important

benefit which is not economic in nature relates to the reputation of the donor engaged in humanitarian actions. This can increase consumer fidelity and further improve the profit achieved [29].

As emphasized by Lipinski et al. [45], reducing food loss and waste can alleviate poverty and provide benefits while reducing pressure on ecosystems, climate, and water. Reducing food loss and waste may be one of those rare multiple “win-win” strategies.

From the managerial perspective, our study yields the following implications:

- draws attention to the scale of wasted food in retail and the need to take action for limitation;
- can help in managerial decision-making about how to limit food waste and to use food in accordance with its intended purpose;
- show that donation for social purposes is beneficial from a waste management point of view—the proposed method can help the company’s manager to collect data of food waste in retail stores.

One limitation of this study is its non-generalizable nature. A key limitation lies in describing one particular situation and data from only one supermarket over two weeks. Further research on reasons for food waste should include a larger sample size, a longer time of data collection, and additional data, for example, causes of food waste and handling food waste.

This descriptive study is helpful for providing information about food waste in a supermarket in Poland and is advantageous for both academicians and practitioners. From the methodological viewpoint, the proposed approach can be used to develop monitoring of food waste in retail outlets.

However, additional research and data are necessary in order to evaluate the scale of food waste in retail in Poland.

## 5. Conclusions

In conclusion, the evaluation shows that in the supermarket studied approximately 3.3 tonnes of food was wasted every two weeks. Three groups of food together accounted for more than half the total mass. These groups were vegetables (803.4 kg), fruits (495.1 kg), and meat, cold meats, and fish (415.9 kg). It has been confirmed by many studies that fruit and vegetables usually account for the largest quota of food waste.

The total value of wasted food reached €5500. Three food groups were together responsible for more than 50% of the total value of food waste. These groups were meat, cold meats, and fish (€1357.70), vegetables (€863.80), and fruits (€740.30).

The assumption was made that two-thirds of the wasted food (2.2 tonnes) could be used for consumption purposes. The caloric value lost due to the two-thirds of 248.5 kg of milk and milk product waste every two weeks was 243,846 kcal. If the estimated mass of dairy products was appropriated for social purposes, it would feed from 72 to 174 people a day (depending on daily reference value). These data show the potential residing in cooperation between retail and charity organizations.

In spite of the fact that the share of retail in the structure of waste is not dominant, there are several reasons why the study of this sector is important. Retail constitutes an important link in the food supply chain, as many products may be acquired and redistributed from that sector to social purposes and charity organizations.

Investigating losses and waste of food in the food chain is extremely difficult. World and European data are estimates. In Poland, no comprehensive assessment has been carried out so far, but is planned as part of a newly launched project “Developing a system for monitoring wasted food and an effective program to rationalize losses and reduce food wastage” (acronym PROM) co-financed by the National Center for Research and Development. The method and concrete results presented in this article will be able to be used in further studies.

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