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# Waste of organic and conventional meat and dairy products—A case study from Swedish retail

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ABSTRACT

Many retailers take initiatives to reduce food waste, which can lead to enhanced sustainability, including reduced environmental impacts and cost savings. Another common environmental strategy in retail management is to increase the range of organic products. This study examined if organic food products have a higher level of waste, which thereby risk to counteract the environmental ambitions behind offering these products. The study also examined to what degree differences in waste level could be explained by turnover, shelf-life and wholesale pack size. In the study, six Swedish supermarkets provided data on all articles sold or wasted in the deli, meat, dairy and cheese departments during 2010 and 2011. 24 organic products were compared to their conventional counterparts; 22 of these had higher waste levels (from 1.5 to 29 times higher). Differences in wastage were also compared across departments; in all four departments, organic products as a group had higher waste percentage at all four departments. There was a negative correlation between the total mass sold of a product and the percentage waste. Also, longer shelf-life was associated with decreased waste, but only for products with low turnover. The systematic problem of retail food waste – particularly of organic products and other products with a low turnover – may be mitigated by increasing turnover, by stocking products with longer shelf-life or by decreasing the ordered volume (e.g. through decreased wholesale pack sizes).



## 1. Introduction

The Food and Agricultural Organisation of the United Nations (FAO) has estimated that about one-third of the food produced world-wide is wasted along the supply chain (Gustavsson et al., 2011). This causes significant global problems in three major areas. Firstly, wasting food while millions of people are suffering from hunger raises moral questions (Stuart, 2009), and could contribute to a future food crisis (Nellemann et al., 2009). Secondly, food production consumes finite natural resources, such as freshwater, fossil energy, land, and mineral fertilizers; contributes to environmental degradation; induce antibiotic resistant pathogens; contributes to animal suffering and occupational hazards, all of which result in vain if food is wasted. Thirdly, wasting food has a large economic impact for all stages of the food supply chain (FSC), and especially final consumers, who spend significant amounts of money on food, wasted in the households (Ventour, 2008). For these reasons, initiatives need to be taken to reduce waste in all stages and by all actors in the FSC.

One of these actors is the retail sector, where waste reduction measures for environmental reasons constitute a rather new area of work. Waste management and waste reduction in the FSC are addressed in several recent studies, which focus on money, hunger, environment or combinations of these (Alexander and Smaje, 2008; Buzby et al., 2009, 2011; Lee and Willis, 2010; Gustavsson and Stage, 2011; Hanssen and Schakenda, 2011; Mena et al., 2011; Stenmarck et al., 2011). Supermarkets are not the largest contributor to food waste in the food supply chain, with estimates of 3% of the waste in the German FSC (Göbel et al., 2012) and 3.8% in the Swedish supply chain (Jensen et al., 2011). While percentage waste in supermarkets is lower than in other sectors of the FSC, the amounts are still high, with 39 000 wasted tonnes per annum in Sweden (Jensen et al., 2011) and 4,433,000 tonnes per annum in the whole European Union (EC, 2010). Active work to reduce waste is a potential way of working with sustainability for retailers. Another way of addressing the corporate responsibility connected to environmental issues is to obtain environmental certification for retail outlets (Axfood, 2011). To keep these certifications the supermarkets have to fulfil several criteria regarding waste management and what to sell, which is all audit by an external organisation. The three main supermarket certification systems currently used in Sweden do not yet address the problem of food wasted within supermarkets (Sjöberg, 2012), but all require supermarkets to carry a basic selection of organic products (SSCN, 2009; Nordic Ecolabeling, 2010; KRAV, 2012). Since the food waste problem is not taken into consideration in the certification process, it is likely that the effects

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on waste of increasing the range of organic products offered have not been evaluated. As long as organic products have a low turnover, the risk of excess waste can counteract the intended positive effect aimed for by carrying a broader range of organic products. If considered by the customers, this rebound effect could potentially harm the confidence in organic products, since the environment is an important attribute in customer preferences for organic food (Wier et al., 2008). Therefore, addressing the problem with food waste of organic products may be of higher importance than only the footprint of the wasted kilos.

One basic reason for retail food waste is that supermarkets order more products than their customers buy. Therefore customer preferences are an important determinant of waste for all products, but may have an even greater effect on organic products since they often sell at a higher price than their conventional counterparts, and therefore require stronger demand. A lack of demand can cause a low sell rate, or turnover (here defined as sold mass over time), which may result in higher percentage waste (Hanssen and Schakenda, 2011). Only a small share of products sold are organic (Axfood, 2011), and therefore these products risk to have lower turnover and therefore higher percentage waste.

Turnover in combination with shelf-life (the time between packaging and the best-before or use by date) may influence percentage waste, since it sets the rate of sell and time available for supermarkets to sell the products. A possible cause of waste could be that too many items of each product are ordered, so that not all of them are sold before the best-before date. Therefore the minimum order may be important for the amount of waste. This minimum order is often set by the wholesale pack size, i.e. the size of the wholesale box in which products are packed for delivery to supermarkets. Aside from these more structural possible causes of waste, there are also accidental causes such as faults in refrigeration or mistakes with orders that may result in occasionally high percentage waste.

This study sought to investigate differences between the percentage waste of organic and conventional animal products, and whether these could be caused by lower turnover of organic products. The overall aims were to identify areas where waste reduction measures could best be targeted and to gain knowledge about causes of waste in order to eliminate these causes and decrease waste.

## 2. Materials and methods

Six supermarket branches located in the Stockholm-Uppsala region of Sweden provided data for the study. Data from their fresh meat, deli, dairy and cheese departments were used to compare organic products within these departments with their conventional counterparts. The supermarket branches belong to the Willy:s AB chain and were selected for participation by the company head office.

### 2.1. Descriptions of departments

The departments are defined by the supermarket chain, mostly for practical reasons. For example, the meat department sells fresh meat from terrestrial animals and the deli department processed meat products, such as sausages and smoked ham. Other than dairy products, the dairy department sells eggs and fruit juices, while the cheese department sells different cheeses and cheese-like products, e.g. tofu.

### 2.2. Ecolabelling of food products and supermarket certification

All six supermarket branches are enrolled in an environmental certification system known as *Bra Miljöval* (Good Environmental Choice, our translation), which obliges them to carry a basic selection of organic products within the four departments studied (SSCN, 2009). Certification is awarded and monitored by the Swedish Society for the Conservation of Nature, a non-government organisation, and the branches studied met the criteria by a good margin. This was due perhaps to a more ambitious sustainability programme within the corporate group, which includes the target to sell >3% organic products by 2012 and >6% by 2015 in the whole company (Axfood, 2011).

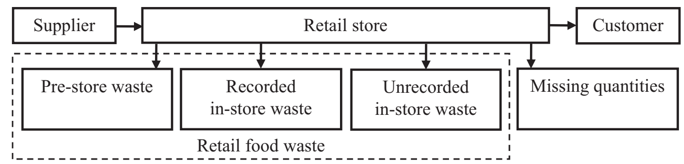


**Fig. 1.** Description of the physical flow of food and the different categories considered as food waste (Eriksson et al., 2012). Pre-store waste and recorded in-store waste was considered in this study.

### 2.3. Data collection

Data were collected for two years, 2010 and 2011, as part of the normal waste recording routine (Åhnberg and Strid, 2010; Eriksson et al., 2012), which was established several years before the study period. The daily routine started every morning with an inventory and a collection of all products that had passed or were close to their best-before or use-by date. Products assumed by the staff to be unsellable for other reasons, due e.g. to damaged packaging or colour changes, were also culled. The culled products were recorded with a scanner using the European Article Number (EAN) code and then discarded. This waste was defined in accordance with Eriksson et al. (2012) as recorded in-store waste. There is a possibility that products can be wasted without being recorded, i.e. unrecorded in-store waste or stolen products, which results in missing quantities (Fig. 1). Here, since everything was sold as packed items, both unrecorded in-store waste and missing goods were assumed to be sufficiently small so as to be negligible, in accordance with findings by Eriksson (2012).

Pre-store waste as described by Eriksson et al. (2012) was also recorded. At delivery, all products that did not fulfil the quality requirements were recorded as pre-store waste by scanning the EAN codes.

All recorded data were stored in databases at either the supplier (belonging to the same corporate group) or at the retail company head office. Data on total amount of pre-store waste, expressed as yearly sum of waste for each item delivered, were obtained from the supplier. Data on in-store waste, expressed as weekly total of each item, were obtained from the retail head office. The head office also supplied data on weekly totals of each item sold during this period. The information about sold products was recorded at the pay points in each branch.

### 2.4. Data analysis

The number of items sold was multiplied by the mass of each package and a material flow analysis was used to determine the wasted mass. Each waste flow was compared against the mass delivered, which was assumed to be equal to the sum of pre-store waste, in-store waste and sold products, since there was a lack of data on actual mass delivered. Therefore the equation $Q = W/(TW + S)$ used the recorded in-store waste, or wasted mass ($W$); combined pre-store and recorded in-store waste, or total wasted mass ($TW$); and mass of sold products ($S$) to calculate the waste quotient ($Q$). Unrecorded in-store waste and missing quantities were assumed to be negligible for the investigated departments in accordance with Eriksson (2012).

#### 2.4.1. Influence of turnover and shelf-life, respectively, on waste percentage

The influence of some factors that were assumed to affect the waste percentage was tested. Turnover was plotted against waste percentage to graphically express the relationship, and shelf-life was tested by comparing products with short (milk) and long (fermented milk) shelf-life, respectively.

#### 2.4.2. Combined indicator for turnover, shelf-life and wholesale pack size

An indicator was designed to analyse the combined effect of turnover (T), shelf-life (SL) and wholesale pack size (WPS) on percentage waste, using the equation: $\beta = T \times SL/WPS$. This indicator, $\beta$, was calculated for 345 deli articles, for which data on turnover, shelf-life and wholesale pack size were available. The indicator does not have units, since it comprises ((items/week) × week)/items, and increases when turnover and/or shelf-life increases or when wholesale pack size decreases. Turnover was defined as sold items over time and shall therefore not be confused with economic turnover or other uses of the word turnover. The wholesale pack size, equal to the minimum order size, sets the minimum number of items that can be ordered from the supplier per order. Shelf-life describes the time from packing to the best-before date, but this does not equal the actual time in the supermarket, since storage and transportation occupy some time. Therefore, on delivery from the supplier the supermarkets have a guarantee on the number of days remaining until the best-before date for every product. This guaranteed time is often half or two-thirds of the shelf-life and the actual time products spend in the store is somewhere between the shelf-life and the guaranteed minimum number of days until the best-before date. Both of these times were used to calculate the $\beta$-indicator in order to determine whether the choice of method affected the results. Using the guaranteed number of days until the best-before date to calculate the $\beta$-indicator gave similar results as to using the shelf-life. The difference was that the shelf-life factor was approximately twice the $\beta$-indicator calculated from the guaranteed time, reflecting that many guaranteed times are 50% of shelf-life. The results in Fig. 5 are based on shelf-life.

#### 2.4.3. Simple model for predicting waste percentage

The $\beta$-indicator was further used to develop a simple model to predict waste percentage, based on knowledge of turnover, shelf-life and minimum order size. Thus, a curve ($r^2 = 0.347$) was fitted to the relationship between the $\beta$-indicator and the percentage waste (Fig. 5). In order to test the model, the $\beta$-value for some products were calculated, and then inserted in the model equation. Since a large share of the organic waste in the deli department was due to a few products (meatballs, Falun sausage and garlic mettwurst), these products were used to validate the model.

#### 2.4.4. Multiple linear regression analysis

The effect of turnover, shelf-life and wholesale pack size on percentage waste was also analysed, by multiple linear regression analysis. This analysis was made for 331 deli articles, for which data on turnover, shelf-life, wholesale pack size and percentage waste were available. For both the dependent variable (percentage waste) and the independent variables (turnover, shelf-life and wholesale pack size), the log(10)-value for each observation was used. In total, seven linear regression models were tested; one for each of the independent variables (3), one for each pairwise combination (3) and finally one for the combination of all three variables (Table 4).

## 3. Results

### 3.1. Wasted quantities and percentages

During the two study years, a total number of 141 unique organic products and 3019 unique conventional products were sold on at least one occasion in one of the deli, meat, dairy or cheese departments in at least one of the six supermarket branches investigated. The largest number of organic products was sold in the dairy department, which also by far sold the largest mass of organic products (Table 1). This was due to the high water content of many dairy products.

The average mass of each product sold was lower for organic products than for conventional, in all four departments. For conventional food, the mass sold of each product decreased from 2010 to 2011 in all four departments, as did the percentage waste. This means that for conventional products percentage waste decreased with decreased sold mass. For organic products the opposite pattern was found. For example, percentage waste for organic cheese and dairy increased from 2010 to 2011, while the average mass sold of these products decreased (Table 1). For organic meat and deli products, percentage waste decreased while the mass of product sold increased.

For all departments combined, percentage waste was higher for organic food than for conventional food during 2010, and the difference increased during 2011. The average wastage level over the two years was 0.56% for conventional and 0.70% for organic cheese, dairy, deli and meat products, respectively; i.e., 25% higher for organic products. The average product specific mass of products sold in all departments together was higher for organic products than for conventional, but this was due to the dominant position of organic dairy products, which contributed with 95% of the mass, but only 50% of the number of articles.

For individual products, the waste quotient was generally larger for organic than conventional products. The products listed in Table 2 were chosen for comparisons, since they were sold in both an organic and a conventional version. Other parameters such as product flavour, fat content, pack size, pack type or brands were the same, but the price differed. In this comparison, most organic versions of the products had higher waste quotients. In fact, of the 24 product types investigated, the percentage waste was only lower for organic than for conventional for two products, 12-packs of eggs and 120-g packs of bacon. Västan cheese had a larger turnover of the organic version, but its waste quotient was still higher than that of the conventional counterpart. All other 21 products had a smaller mass of organic products sold and a higher waste quotient than the conventional versions.

The weekly proportion of organic products sold was lower than the conventional and the proportion of organic waste was higher during most weeks in the 2-year test period (Fig. 1). The average proportion of weekly organic mass sold was 5.8% and that of wasted organic mass was 7.9%.

During the two-year study period, there was a trend for the proportion of organic products to increase, from 3.8% during 2010 to 4.5% during 2011 (Table 1). Contrary, there was a decreasing trend in mass of organic products sold (from 6.1% in 2010 to 5.5% in 2011), while the fraction of the departments waste originating from organic products increased (from 6.5% 2010 to 9.4% 2011) during the same period in all four departments.

### 3.2. Relationship between turnover and percentage waste

One reason for the larger organic waste quotient was assumed to be the lower turnover of organic products (Table 1). The connection between percentage waste and mass sold over time (Fig. 3) confirmed this, since all departments showed the same pattern

**Table 1**
Number of articles, sold and wasted mass, percentage waste, and average mass of product sold, presented per retail department and in total for 2010 and 2011 respectively, divided on conventional (Conv.) and organic (Org.) products, aggregated for the six retail stores studied.

| Dept., product label | Year | No. of articles | Mass sold (tonne) | Pre-store waste (tonne) | In-store waste (tonne) | Total waste (%) | Average mass per product sold (tonne) |
|---|---|---|---|---|---|---|---|
| Cheese, Conv. | 2010 | 512 | 1072 | 0.23 | 5.88 | 0.57 | 2.1 |
| Cheese, Conv. | 2011 | 657 | 1050 | 0.99 | 4.01 | 0.47 | 1.6 |
| Cheese, Org. | 2010 | 9 | 4.45 | 0.00 | 0.08 | 1.88 | 0.50 |
| Cheese, Org. | 2011 | 12 | 4.76 | 0.01 | 0.10 | 2.41 | 0.40 |
| Dairy, Conv. | 2010 | 680 | 10430 | 0.35 | 37.3 | 0.36 | 15 |
| Dairy, Conv. | 2011 | 865 | 10209 | 1.63 | 30.3 | 0.31 | 12 |
| Dairy, Org. | 2010 | 56 | 843 | 0.00 | 4.69 | 0.55 | 15 |
| Dairy, Org. | 2011 | 73 | 721 | 0.09 | 3.98 | 0.56 | 9.9 |
| Deli, Conv. | 2010 | 684 | 1363 | 3.79 | 21.6 | 1.83 | 2.0 |
| Deli, Conv. | 2011 | 857 | 1239 | 6.58 | 9.12 | 1.25 | 1.5 |
| Deli, Org. | 2010 | 8 | 3.20 | 0.01 | 0.10 | 3.25 | 0.40 |
| Deli, Org. | 2011 | 9 | 4.12 | 0.01 | 0.09 | 2.32 | 0.46 |
| Meat, Conv. | 2010 | 455 | 1388 | 0.51 | 20.5 | 1.49 | 3.1 |
| Meat, Conv. | 2011 | 640 | 1350 | 0.81 | 13.8 | 1.07 | 2.1 |
| Meat, Org. | 2010 | 46 | 28.0 | 0.00 | 1.14 | 3.90 | 0.61 |
| Meat, Org. | 2011 | 47 | 30.3 | 0.01 | 1.22 | 3.89 | 0.64 |
| All depts., Conv. | 2010 | 2 331 | 14252 | 4.89 | 85.2 | 0.63 | 6.1 |
| All depts., Conv. | 2011 | 3 019 | 13848 | 10.02 | 57.3 | 0.48 | 4.6 |
| All depts., Org. | 2010 | 119 | 878 | 0.01 | 6.01 | 0.68 | 7.4 |
| All depts., Org. | 2011 | 141 | 760 | 0.12 | 5.38 | 0.72 | 5.4 |

**Table 2**
Products for which the organic (Org.) version had a conventional (Conv.) equivalent in terms of pack size, pack type and brand. The quotient = percentage of organic food waste divided by percentage of conventional food waste.

| Product | Pack size | Conv. mass sold (tonne) | Org. mass sold (tonne) | Conv. waste (%) | Org. waste (%) | Quotient |
|---|---|---|---|---|---|---|
| **Cheese** | | | | | | |
| Philadelphia cheese | 200 g box | 15.30 | 0.19 | 0.12 | 1.18 | 9.8 |
| Barbeque halloumi | 200 g | 2.16 | 0.33 | 0.16 | 0.60 | 3.8 |
| Halloumi | 200 g | 2.24 | 0.30 | 0.10 | 0.27 | 2.7 |
| Västan cheese 10% | 400 g | 0.64 | 1.47 | 0.24 | 0.37 | 1.5 |
| **Dairy** | | | | | | |
| Whipping cream 36% | 500 mL | 9.56 | 0.44 | 0.09 | 0.69 | 7.7 |
| Whole milk 3% | 1 L Tetra pack | 980.85 | 47.86 | 0.15 | 1.16 | 7.7 |
| Eggs 6-pack | 378 g box | 37.09 | 76.37 | 0.12 | 0.56 | 4.7 |
| Crème Fraiche 34% | 200 mL carton | 37.43 | 5.47 | 0.13 | 0.48 | 3.7 |
| Low-fat milk 0.5% | 1 L Tetra pack | 575.17 | 39.11 | 0.36 | 0.85 | 2.4 |
| Medium-fat milk 1.5% | 1 L Tetra pack | 1541.21 | 187.09 | 0.17 | 0.40 | 2.4 |
| Bregott spread, normal salted | 300 g box | 9.93 | 0.65 | 0.05 | 0.09 | 1.8 |
| Acidophilus fermented milk | 1 L Tetra pack | 4.10 | 0.50 | 0.73 | 1.18 | 1.8 |
| Eggs 12 pack | 798 g box | 51.68 | 141.00 | 0.31 | 0.19 | 0.6 |
| **Deli** | | | | | | |
| Falun sausage | 800 g | 176.48 | 0.63 | 0.30 | 5.13 | 17.1 |
| Onsala sausage | 300 g | 2.28 | 0.72 | 1.28 | 3.27 | 2.6 |
| Meatballs | 300 g box | 5.12 | 1.24 | 3.08 | 5.14 | 1.7 |
| Bacon | 120 g pack | 3.14 | 2.16 | 0.85 | 0.29 | 0.3 |
| **Meat** | | | | | | |
| Fillet of pork | 500 g | 154.40 | 0.49 | 0.22 | 6.30 | 28.6 |
| Entrecote piece | 1 kg | 7.15 | 1.05 | 1.90 | 9.59 | 5.0 |
| Minced beef 10% | 500 g | 71.65 | 15.58 | 0.43 | 2.15 | 5.0 |
| Spare ribs | 1 kg | 11.68 | 1.22 | 1.95 | 8.32 | 4.3 |
| Roast beef | 1 kg | 5.92 | 0.18 | 1.75 | 3.99 | 2.3 |
| Fillet of beef | 800 g | 6.68 | 0.48 | 1.67 | 3.58 | 2.1 |
| Shoulder of pork | 800 g | 4.20 | 0.37 | 6.82 | 12.5 | 1.8 |

**Table 3**
Comparison between the organic and conventional versions of regular milk and fermented milk.

| Type of product | Shelf-life (days) | Mass sold (tonne) | In-store waste (tonne) | Pre-store waste (tonne) | Total waste quotient (%) |
|---|---|---|---|---|---|
| Milk | 9 | 6437 | 12.90 | 0.07 | 0.20 |
| Milk, Org. | 9 | 804 | 5.13 | 0.02 | 0.64 |
| Fermented milk/yoghurt | 22 | 1367 | 5.23 | 0.16 | 0.39 |
| Fermented milk/yoghurt, Org. | 22 | 260 | 0.96 | 0.05 | 0.38 |

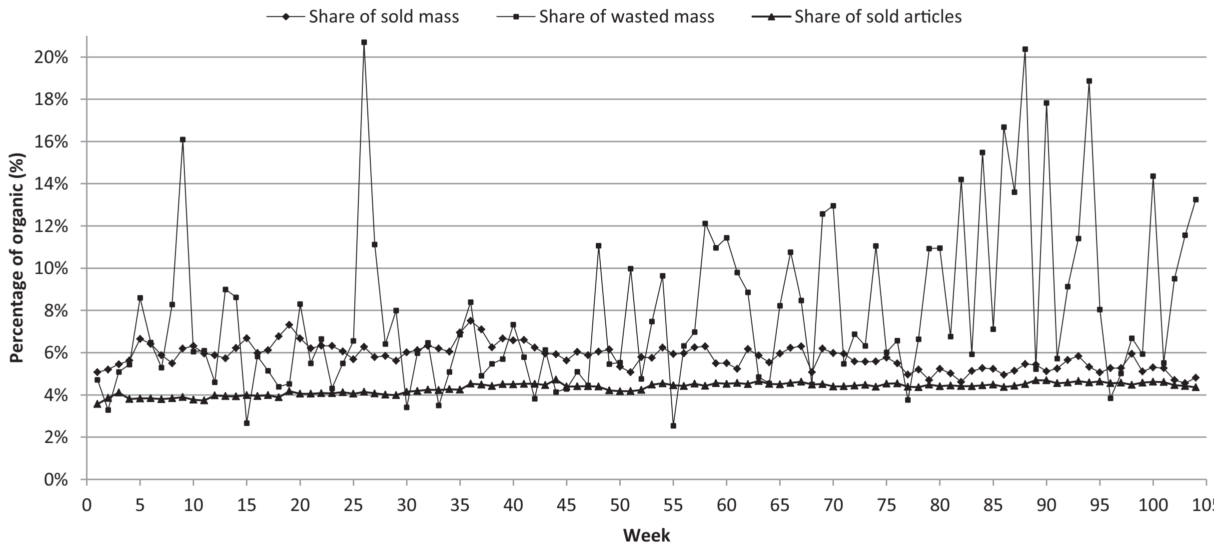


**Fig. 2.** Time series of 2010–2011 showing the proportions of organic products in: articles sold, mass sold and mass wasted, in relation to the corresponding total values for the four departments investigated.

with high percentage waste only for products with low mass sold, i.e. low turnover. Except for a few dairy products, all the organic products sold had a low turnover compared with the conventional products.

A *T*-test showed no significant difference between organic and conventional products in terms of the percentage waste of products depending on the mass sold over the two study years, i.e. the slope of the two trend lines in Fig. 4 did not differ sufficiently to make the difference statistically significant.

### 3.3. Relationship between shelf-life and percentage waste

Another reason for different percentage waste values between organic and conventional products could be differences in

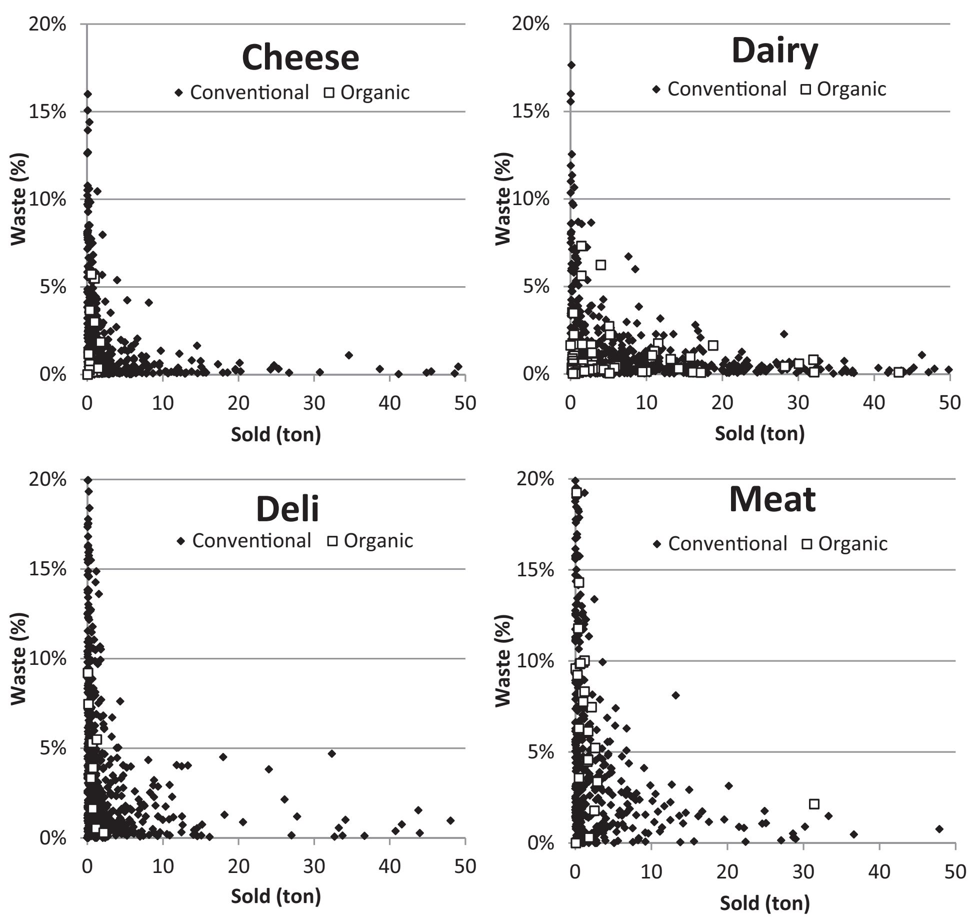


**Fig. 3.** Relationship between mass sold (tonne) and percentage waste for every product in each of the four departments. Both axes are cut and therefore extreme values are not shown.

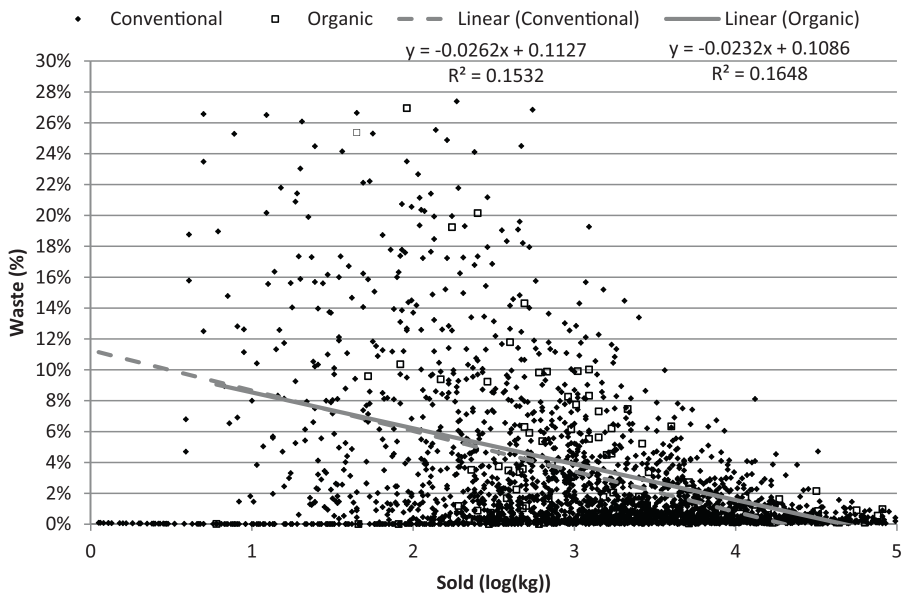


**Fig. 4.** Relationship between the logarithm of mass sold and percentage waste for all products sold in the four departments combined.

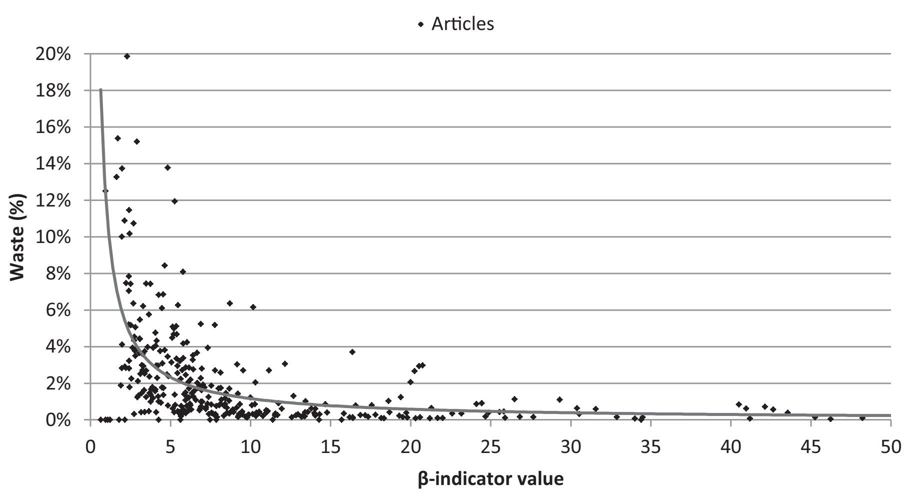


**Fig. 5.** Percentage waste plotted as a function of the β-indicator calculated as $\beta = T \times SL/WPS$, i.e. turnover (T, number of items sold per week) multiplied by the shelf-life (SL) in weeks divided by the number of items delivered in one wholesale pack (WPS). Both axes are cut.

shelf-life. However, in the data on shelf-life of products, there was no such difference between the organic and conventional articles of a particular type of product. Therefore only products using the same raw material, but with different processing methods, are listed in Table 3. Fermented milk is produced from the same raw material as regular milk, but with bacterial additives that lower the pH and increase the shelf-life. Thus the shelf-life of fermented milk is more than twice that of regular milk. The difference in waste between

**Table 4**
Seven multiple linear regressions with log(10) percentage waste as dependent variable, and standard error in brackets.

| Model number and independent variables tested | Model 1 Turnover | Model 2 Shelf-life | Model 3 Wholesale pack size | Model 4 Turnover and shelf-life | Model 5 Turnover and wholesale pack size | Model 6 Shelf-life and wholesale pack size | Model 7 Turnover, shelf-life and wholesale pack size |
|---|---|---|---|---|---|---|---|
| Log(10) Turnover | −0.807*** (0.070) | | | −0.829*** (0.072) | −0.832*** (0.073) | | −0.879*** (0.077) |
| Log(10) Shelf-life | | 0.154 (0.122) | | −0.135 (0.107) | | 0.228** (0.126) | −0.202* (0.113) |
| Log(10) Wholesale pack size | | | −0.341* (0.177) | | 0.184 (0.157) | −0.424* (0.182) | 0.287* (0.167) |
| Intercept | −1.07*** (0.082) | −2.22*** (0.206) | −1.62*** (0.185) | −0.822*** (0.212) | −1.23*** (0.160) | −1.90*** (0.245) | −0.950*** (0.224) |
| N | 331 | 331 | 331 | 331 | 331 | 331 | 331 |
| $R^2$ (adjusted) | 0.287 | 0.002 | 0.008 | 0.289 | 0.288 | 0.015 | 0.292 |

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

conventional and organic regular milk was much larger than the difference between conventional and organic fermented milk. The difference in mass sold between the different milk products was in the same range as the difference between the different fermented milk products. This indicates that a longer shelf-life mitigates the effect of low turnover.

### 3.4. Relationship between the $\beta$-indicator and percentage waste

Percentage waste increased when the $\beta$-indicator decreased, i.e. it was positively correlated to wholesale pack size and negatively to average weekly turnover and shelf-life. All organic products had $\beta$-indicator values <10. They did not differ greatly from their conventional counterparts in terms of shelf-life or wholesale pack size, so therefore turnover was responsible for the difference. The $\beta$-indicator relationship also indicates that longer shelf-life or smaller wholesale pack size can be used to compensate for low turnover, when a waste reduction is sought.

#### 3.4.1. Model development

Fig. 5 illustrates the relationship between the combined turnover/shelf-life/wholesale pack size-indicator (the $\beta$-indicator), and the percentage waste, for the 345 deli articles investigated. A simple model was developed by fitting a curve to the plotted data points and finding the equation to the curve; the equation was $y = 0.116/x$.

#### 3.4.2. Model testing

In order to test the model (the curve in Fig. 5), the $\beta$-value for some organic products were calculated, and then inserted in the model equation. Organic meatballs had $\beta = 3.08$, corresponding to 3.7% expected waste, which was somewhat lower than the actual waste (5.5%), and Falun sausage had an expected percentage waste of 4.9% ($\beta = 2.39$), compared to the actual value 5.2% waste. Organic garlic mettwurst had $\beta = 3.34$, corresponding to 2.2% expected waste, which was lower than the actual waste (5.4%), and smoked organic ham had an expected percentage waste of 1.8% ($\beta = 6.53$), compared to the actual value 1.6% waste. The last example was organic Bacon that had an expected percentage waste of 0.31% ($\beta = 9.29$), compared to the actual value 0.12% waste. According to the $r^2$-value (Table 4), the model can reasonably well predict the actual waste.

### 3.5. Multiple linear regression analysis

A multiple linear regression analysis was used to analyse the single as well as combined effects of turnover, shelf-life and wholesale pack size on percentage waste (Table 4). Of the seven tested models, the adjusted $r^2$-value was highest for the model that combined the log(10) of all three variables: turnover, shelf-life and wholesale pack size. The value was slightly higher than for the combination only turnover and shelf-life, which in turn was slightly higher than the combination turnover and whole sale pack size followed by only turnover. This means that the triple combination model was slightly better to predict the percentage waste than the other tested models. The analysis also confirmed that increased turnover and shelf life had a decreasing effect of the percentage waste, while increased wholesale pack size had an increasing effect of percentage waste. Turnover was the single variable that had the largest effect on percentage waste (=highest $r^2$-value) of the three tested variables in Table 4. Shelf-life and whole sale pack size had only a minor correlation with waste percentage.

## 4. Discussion

Organic and conventional products were compared on department level, on product level for comparable products and over time. On department level, percentage waste was higher for organic products in all four departments investigated. On product level, 22 of the 24 organic products compared with their conventional counterpart had higher percentage waste than the conventional version. However, the waste in absolute mass was dominated by conventional products, owing to the fact that the organic products comprised only a small part of the departments, both in terms of mass sold and number of items sold.

The proportion of sold and wasted organic to total products varied over time, but the two-year average proportion of number of organic products sold (4.3%) and proportion of mass sold (5.8%) were lower than the two-year average proportion of wasted mass of organic products (7.9%) (Fig. 2). Over the time series, there were weeks in which the organic percentage waste was lower than the corresponding sales volume, but these were few.

Few previous publications have studied waste levels from organic and conventional food products. Bjurkull (2003) compared the waste of organic (KRAV-certified) milk and eggs against that of the conventional counterparts in three Swedish supermarkets, and found that organic milk had an average waste of 0.4% and conventional milk 0.07%. Eggs showed the opposite pattern, with organic waste of 0.06% compared to conventional egg waste of 0.3%. While our percentage waste values were higher, some of the products we studied fitted this pattern of higher organic milk waste and lower organic egg waste (for eggs in 12-pack, not in 6-pack) (Table 2).

On department level, there were differences between the average mass of conventional and organic products sold (Table 1). The smallest difference was found in the dairy department, where the smallest difference in percentage waste was also found. This indicates that low mass sold was one explanation for the higher organic percentage waste, a finding that was confirmed on product level, since for 22 of the 24 articles in Table 2 smaller mass sold gave higher percentage waste. When this relationship was plotted for all departments (Fig. 3), the L-shaped plots obtained indicated a connection between large mass of product sold and low percentage waste for all four departments. Hanssen and Schakenda (2011) observed a similar inverse logarithmic relationship between mass of product sold and percentage waste, although they compared turnover for the whole supermarket with percentage waste. This relationship therefore appears to be general and explains the high percentage waste for organic products, which have lower turnover than their conventional counterparts. Similarly, Eriksson et al. (2012) found high percentage waste among products with low turnover (e.g., exotic fruits) and vice versa (e.g., potatoes).

Since the connection between mass sold and percentage waste was not linear, there must be other important variables affecting products with low turnover. High turnover represents rapid selling of products. Therefore the shelf-life of the products was of interest, since food is discarded as waste if not sold before the best-before date, according to company policy (Willy:s, 2010). However, we could not find any differences in shelf-life for similar products with or without an organic label. A shelf-life analysis of two dairy products indicated that a shorter shelf-life means that turnover has a greater influence on percentage waste. This is logical, since if supermarkets have a short time to sell a product, the speed of sales is more determining for the amount of unsold products before the best-before date, thereby creating waste, than it is for products with long shelf-lives.

To avoid waste, deliveries must equal sales during the shelf-life of the products. Since organic products are often sold in small masses at retail, the minimum order to the wholesale supplier is important. Therefore the minimum order size was included in the

$\beta$-indicator together with turnover and shelf life. It was also clear that there was a risk zone for the investigated 345 products, since 98% of those with higher than average percentage waste (2.2%) had a lower than average $\beta$-indicator value (12.1). In simple terms, percentage waste was high if the turnover was low and especially if the minimum wholesale pack size was large, giving the supermarket less chance of selling the items before the best-before date.

Over the full range of $\beta$-values, shelf-life and whole sale pack size had little correlation with waste percentage compared to turnover. However, there is reason to believe that for small $\beta$-values, the impact of each variable would be larger. Analysing the impact of different variables at critically low turnover rates, would typically be an interesting development of the present model.

The multiple linear regressions confirmed that the $\beta$-indicator (triple combination) model had the best correlation with the waste percentage, and that increased turnover and shelf life had a decreasing effect on the percentage waste, while increased wholesale pack size had an increasing effect on percentage waste. Since turnover by itself explains the main part of the percentage waste, 29% in model 1 from Table 4, this would be the target with highest potential for waste reduction measures.

There are many possible reasons why organic food is wasted in supermarkets, but low turnover in combination with short shelf-life and large wholesale pack size might have a large potential effect. Our model indicated that measures that increases the $\beta$-indicator has the potential to significantly reduce waste of organic products, since they all had $\beta$-values below 10, i.e. where the fitted curve was steep. Increased turnover is already on the supermarket chain's agenda (Axfood, 2011), but until this is achieved, measures that increase shelf-life or decrease wholesale pack size can be successful directly. One way to increase shelf-life could be to decrease temperature in the supply chain in combination with prolonging the best before labelling, while the minimum order size could be decreased by lowering the wholesale pack size. Both these measures require further studies to evaluate their effect on reducing supermarket food waste.

A potentially significant way to reduce waste of organic products could be to discontinue sales of all products with low turnover, but this might have fundamental consequences for supermarkets, making it impossible.

Since turnover was so critical for percentage waste among products with low turnover, a measure that increases turnover would have a good potential to reduce waste. Increased turnover had a major potential for lowering waste of organic products, but also for conventional products with low turnover. This is in line with environmental policy for the corporate group, where the goal is to increase the economic proportion of organic sales to >3% in 2012 and to >6% by 2015 (Axfood, 2011). According to Blombäck and Wigren-Kristoferson (2011), it is more common to meet new demands regarding corporate social responsibility by adding products rather than to exchange conventional assortment to organic. If the company can achieve the goal of increased organic sales without increasing the number of organic articles offered, it has the potential to reduce waste of organic products. Therefore our recommendation to the retail sector as well as the environmental certification organisations is to focus more on how to increase the turnover of organic products rather than just having a broad selection of organic products. There is an obvious risk that the confidence in organic products decreases unless measures are taken to reduce the waste.

## 5. Conclusions

Organic products as a group had higher percentage waste in all four supermarket departments studied (cheese, dairy, deli and meat). Percentage waste was also higher for 22 of the 24 specific organic products that were compared to their conventional counterparts. For organic products, the average weekly proportion of the total waste (7.9%) was higher than the average weekly proportion of the mass sold (5.8%); i.e., the relative waste was higher than the relative sales for organic products. The average wastage level over the two years was 0.56% for conventional and 0.70% for organic cheese, dairy, deli and meat products, respectively; i.e., the wastage was 25% higher for organic products. Mass sold over time, or turnover, was central in explaining the higher percentage waste for organic products, in all four departments. Most organic products in the pairwise comparison (22/24) had lower turnover than their conventional counterparts. The relationship between turnover and percentage waste was the same for organic and conventional products, where the majority of the organic products were sold with low turnover and high percentage waste.

For products (organic or conventional) with low turnover, the shelf-life and wholesale pack size (which determines the minimum order volume) are critical in determining percentage waste. Waste reduction measures that involve decreasing wholesale pack size and/or increasing shelf-life thus have the potential to be efficient in this case, as would measures that increase turnover. Disclosure of products with low turnover would most likely also reduce the overall waste, but for organic products there may be other justifying reasons for offering these products, why increased turnover in combination with an increased focus on reducing the waste, probably is seen as a more attractive solution to most stakeholders.

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