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Research Paper

Unveiling the potential of organic farming in mitigating beef losses in Sweden

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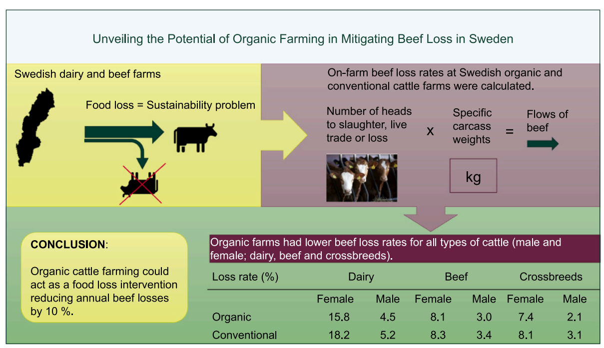
HIGHLIGHTS

- Food loss leads to environmental impact, especially from cattle production.
- The objective of this study was to investigate the loss of beef on Swedish organic and conventional cattle farms.
- Organic farms had lower beef loss rates for all types of cattle (male and female; dairy, beef and crossbreeds).
- If all conventional farms had the same loss rates as organic farms, Swedish beef losses would be 10 % lower.
- In addition to pasture-related benefits, organic cattle farming can also play a role for food loss reduction.

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: Food loss is a major problem, as it reduces food system efficiency. Loss of animals is of particular importance, as animal production generally has higher environmental impact.
OBJECTIVE: The objectives were to estimate beef loss rates on Swedish organic and conventional dairy and beef farms, to determine which system is better, and to calculate the food saving potential of assigning the loss rate of the best-performing system to the other.
METHODS: A material flow analysis based on data from the central register of bovine animals and slaughter weight statistics was performed. The flows included numbers and carcass weights of animals, grouped by breed, sex, age, and management system leaving farms for different destinations.
RESULTS AND CONCLUSIONS: Organic farms lost on average 7.4 % of the yearly initial beef production, compared to the 19 % higher 8.8 % for conventional farms. Due to widely different conditions, comparisons between organic and conventional management should primarily be made per animal group. All animal groups had lower loss rates in the organic than in the conventional system. The food saving potential of ascribing organic loss rates to the conventional animals was 1300 tons of beef per year, equivalent to 10 % of all Swedish farm-level beef losses.
SIGNIFICANCE: Organic dairy and beef farming could be a food loss intervention capable of a notable loss reduction. The results also revealed that there is no goal conflict between increased organic production and reduced food loss in Swedish beef production.

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1. Introduction

The European Commission's Farm to Fork strategy stresses the need to increase organic farming with a target for minimum 25 % of European Union (EU) agricultural land under organic farming by 2030 (European Commission, 2020a). To achieve this target and help the organic sector realize its full potential, the Commission has launched an action plan for organic production that also recognizes the important role of organic farming in improving animal welfare (European Commission, 2021). The Swedish government has set two targets for the organic sector: 30 % of Swedish agricultural land to be managed organically by 2030; and 60 % of food served in public catering establishments to be organic (Swedish Government, 2019). There are thus strong incentives for more organic farming.

The European Commission is also committed to reducing food loss and waste and has committed to UN Sustainable Development Goal (SDG) 12.3 to half food waste and reduce food loss (European Commission, 2020a). The Commission aims to investigate food losses at the production stage and explore ways of preventing these. The Swedish government has set a target for reduced food loss, where "an increased share of food produced shall reach retail and consumption by 2025" (Swedish Environmental Protection Agency, 2020).

As dairy and beef production are highly environmentally impacting food supply systems (Halpern et al., 2022), loss reduction within these systems is a top priority, in addition to reduced production (Poore and Nemecek, 2018). Globally halving food waste or halving meat consumption are comparable in size from a global warming perspective, and could cut 43 % of emissions if both strategies were implemented together (Zhu et al., 2023). If organic dairy and beef production has intrinsic values that can reduce beef losses, this opportunity should not be overlooked.

Meat loss and waste also entails that animals have been raised and killed in vain. A recent study on the quantity of animal lives embodied in global food loss and waste estimated that 74 million individual cattle annually are raised and killed without serving a purpose for human nutrition; hence, meat loss and waste comes with vast consequences for living beings (Klaura et al., 2023).

In 2015, there were 3.7 million heads of certified organic cattle in the EU-28 (European Commission, 2016). By 2021, the number had increased to 5 million heads, corresponding to 6.6 % of total EU cattle population (Eurostat, 2023). Despite fast growth, organic livestock production in the EU remains small. Sweden, Greece, Latvia, and Austria have the highest share of organic cattle: 24 %, 31 %, 26 %, and 22 %, respectively (Eurostat, 2023). In 2022, 3.7 % of EU milk production was organic (Research Institute of Organic Agriculture FiBL, 2024), while in Sweden the organic share was 16.6 %. The latter increased from 7.7 % 2009 up to 17.4 % 2020, after which it decreased to 12.8 % 2023, probably as a response to the financial crisis. A similar pattern appear for the organic share of beef, which peaked at 16.0 % during 2019, and then declined to 13.6 % 2023 (Swedish Board of Agriculture, 2024a).

Considerable differences exist in organic dairy production systems between countries, including production levels, herd and farm sizes, housing and milking systems, and animal health. Management strategies, such as feeding, animal health practices, and recruitment strategies, also vary across the organic dairy sector in Europe. These variations are associated with regional and national differences, including topography, land availability, and regulations (Wallenbeck et al., 2019).

When striving for both more organic production and less food loss, possible goal conflicts need to be identified. In an analysis of the EU Farm to Fork strategy from a food waste perspective a potential conflict between organic crop production and food loss was identified, but also a potential synergy between organic animal production and food loss (Strid, 2021). A synergetic effect between Swedish organic farming and better animal welfare has also been identified by Tälle et al. (2019). However, the question still remains, whether this better animal welfare is reflected in lower losses.

Previous studies have reported a reduced risk of on-farm cow mortality in organic dairy herds compared with conventional (Thomsen et al., 2006; Alvåsen et al., 2012) and a lower risk of having "loser cows" (Thomsen et al., 2007). A German study concluded that organic dairy production performs better in all four Welfare Quality principles: 'Good housing', 'Good feeding', 'Good health', and 'Appropriate behavior' (Wagner et al., 2021). In contrast, Fall et al. (2008) report no health and reproduction differences between Swedish organically and conventionally managed dairy cows. For suckler herds, Estonian conventional cow-calf herds were reported to suffer higher calf mortality than organic herds, although the difference was only borderline significant (Mõtus et al., 2020). Åkerfeldt et al. (2021) examined areas of health and welfare advantages within organic livestock production, but obtained no strong evidence of neither inferior nor distinctly superior animal health and welfare in organic systems.

Mortality and animal health issues are not the only factors influencing beef losses. Strategic decisions, such as euthanasia of young male dairy calves and avoiding sending animals to slaughter that risk exposing welfare issues, can also influence the losses.

To estimate beef losses from a food loss perspective, absolute quantities and loss rates are of relevance, regardless of the underlying reason. In earlier research, we estimated yearly beef losses for all Swedish cattle farms to 13,000 tons, or 8.5 % of produced carcass weight, and identified female dairy breeds as a hotspot group, with an 18 % loss rate (Strid et al., 2023).

In order to reveal possible differences between organic and conventional farming, our former results needed to be split per production system. If organic production has lower loss rates, this food saving potential needs attention, and if organic production has higher loss rates, this goal conflict needs to be acknowledged.

The objectives of the present study were thus: i) to estimate absolute and relative losses of beef in organic and conventional production systems in Sweden; ii) to compare beef loss rates in the organic and conventional production systems in total and per animal group and to determine whether organic beef production and food loss reduction have conflicting goals; iii) to estimate the food saving potential of reducing loss rates to the level of the best-performing system.

2. Material and method

2.1. Method

Food loss and waste flows are often assessed by material flow analysis (MFA), tracing flows of waste and production, as this can capture the waste in relation to the benefits of the flows (e.g., Amicarelli et al., 2020; Xue et al., 2021; Jiang et al., 2023). The MFA method is described in detail in a handbook by Brunner and Rechberger (2004). The method used in the present study was an extension of the MFA design previously used for assessing total beef losses in Swedish primary production (Strid et al., 2023). The loss rate was defined as a share of yearly initial production, which is in line with the methodological recommendations by FAO for the global food loss index SDG 12.3.1a (Fabi and English, 2019). However, FAO does not consider losses before slaughter in their scope.

In short, the method of the present study included quantification of heads leaving farms for different purposes (slaughter, loss, etc.), estimation of carcass weights for those animals, and calculation of loss rates as lost carcass weight per initially produced carcass weight.

These flows were possible to trace since all cattle are identified by a yellow ear tag and individually listed in a central registry, the CDB registry, maintained by the Swedish Board of Agriculture. Swedish cattle owners are obliged by Regulation EC 1760/2000 to report to the CDB registry all cattle events, including births, slaughter, home slaughter, unassisted deaths or euthanasia, and movements between farms (European Parliament, 2000). Additionally, as there is trade of animals between organic and conventional farms, movement data from CDB needed to be combined with data from the farm registry to detect animals that changed production system. Data was requested for the years 2017–2021, which determined the time frame of the study.

2.2. System description: Swedish organic and conventional beef production

The subsystems analyzed were Swedish beef production on organic and conventional farms. Beef production can roughly be described as beef from culled dairy or beef cows, from heifers not recruited to the cow population, from youngstock males and steers, and, to a small extent, from calves and culled bulls. Approximately 50 % of Swedish beef production relies on dairy cattle (Table 3). Traditionally, dairy cows are bred with dairy breeds, but the share of dairy-beef crossbreeds is increasing (Växa Sverige, 2022). Male dairy calves are mainly raised as bulls in intensive systems, with less than 20 % castrated and reared as steers. Steers are better suited than bulls to semi-natural grasslands, as they can handle lower nutrient availability and public presence, but have generally lower daily weight gain (Hessle et al., 2019). The other half of beef production constitutes of pure beef breeds or beef crosses in intensive systems or more extensive cow-calf operations.

2.2.1. Organic cattle production in Sweden

Organic farming is regulated by EU Directive 2018/848 (European Parliament, 2018) and aims to produce milk and meat in a sustainable system ensuring good animal health and welfare. Organic cattle production is characterized by having a high roughage/concentrate ratio based mainly of home-grown feed stuffs, a fertilizer- and pesticide-free crop production and prolonged grazing with an anti-parasite strategy without anthelmintic use (European Commission, 2020b). Organic calves are furthermore raised on whole milk, preferably from the mother, for 12 weeks compared to 8 weeks, and allowing milk replacer as feed source, in the conventional system. The organic production system also applies a doubled withdrawal period for delivery of milk and meat after treatment with registered pharmaceuticals, compared to the withdrawal periods stated by the Swedish National Food Agency. To compensate for the higher requirements, organic producers receive a premium of 1.0–3.5 SEK per kilogram of carcass weight, or roughly 3–10 % above conventional cattle prices, depending on the slaughter company (Scan, 2024; Skövde slakteri, 2024).

In Sweden, many organic beef and dairy herds are managed according to the standards of the Swedish organic certification association KRAV (www.krav.se). KRAV is certified by the International Federation of Agricultural Movements.

Organic cattle farms in the present study were defined as organic cattle farms included in the registry of farms (LBR registry) at the Swedish Board of Agriculture, and conventional cattle farms as all other cattle farms in the registry. To be defined as an organic agricultural cattle farm in the LBR, the farm must have fully transitioned to organic practices and be certified according to an accredited certification body (Swedish Board of Agriculture, 2024b).

2.2.2. Comparison of Swedish organic and conventional cattle farms

Conventional production dominates the Swedish cattle sector, especially the dairy subsector, and of the farms without cows (often specialized young bull fattening units), only 7 % are organic. Contrary, on organic farms, more than half of all cows are suckler cows. These and other characteristics of the organic and conventional beef production systems are listed in Table 1.

Table 1
Characteristics of the Swedish organic and conventional beef production systems, 2021.

Characteristics	Organic system	%	Conventional system	%
Number of farms[1]				
With dairy cows	540	19	2 300	81
With suckler cows	2 200	22	7 700	78
Without cows	160	7	2 000	93
Number of cattle[1]				
Number of dairy cows	57 300	19	242 000	81
Number of suckler cows	74 400	38	123 000	62
Other cattle	198 000	22	695 000	78
Delivered milk [1000 ton][1]	480	17	2300	83
Delivered slaughter weight [1000 ton][1]	21	15	115	85
Average farm size [dairy cows/ farm]	107		103	
Average farm size [suckler cows/ farm]	33		16	
Milk yield per cow [kg ECM/yr][2]	10 300		11 200	
Share of stillborn calves of all born calves [%][2]	4.8		5.0	

[1] Swedish Board of Agriculture 2024a.
[2] Växa Sverige 2022; ECM = Energy Corrected Milk.

2.3. Scope of the study and outflow destinations considered

The study covered yearly flows of registered cattle exiting Swedish farms in the period 2017–2021, subdivided by dispatching farm type (organic or conventional). The flows of animals were tracked to all first-hand destinations based on registered event codes in the CDB registry, which were: abattoir slaughter [code 3], home slaughter [code 6], sale of live animals to other farms [code 2], and lost animals [code 7 and 8]. The lost category included animals sent for destruction [code 7] and animals disposed of locally [code 8]. Animals were mainly traded from organic to conventional farms, but the opposite occurred, why the net flow of live animals was used in the analysis. The CDB registry records all animals going through the slaughter process [code 3] but does not take into account the fate of the carcass after slaughter. A small proportion of carcasses (~0.2 %; Swedish Board of Agriculture, 2022) are condemned during meat inspection, but this fraction was outside the scope of the present study.

2.4. Categorization of animals into groups

The animals were categorized according to sex, breed group, age group, and production system (see Electronic Supplementary Material, ESM). The dairy group consisted of the two dominant dairy breeds, Swedish Red-and-White and Swedish Holstein, plus other less frequent dairy breeds. Crossbreeds have their own code in the CDB registry (code 99), and the Beef breeds were defined as all other cattle, including dominant beef breeds such as Charolais and Hereford.

Twenty-two age groups were defined (including stillborns), with narrow intervals during the growing phase, and yearly intervals from 36 months upwards. In total, there were 264 different primary animal groups, comprising all combinations of 22 age groups, three breed groups, two sexes, and two production systems (ESM). After conversion to flows of carcass weights, the age groups were merged, leaving six main animal groups per production system for further analysis, i.e., males and females of dairy, beef, and crossbreeds.

2.5. Quantification of number of heads

Data on the number of heads of each animal group exiting farms for different destinations was obtained from the CDB registry. The dataset, which covered the period 2017–2021, was sent to the LBR registry at the Swedish Board of Agriculture, who subdivided the CDB data on organic and conventional farms based on holding site number (see orange sheets in ESM).

2.6. Estimation of flows of carcass weights

All beef flows in the present study refer to cattle carcass weight (cw), i.e., meat with bones, which constitutes approximately 50 % of live weight (Blomberg, 2022). Specific carcass weight data for each animal group were retrieved from our previous study (Strid et al., 2023; blue sheet in ESM). This data was based on the animal group's average official slaughter weight registered by the Swedish Board of Agriculture and on birth weights with a carcass yield of 40 % for the two youngest animal groups (0–1 months and stillborns). The data was updated on a five-year basis, to reduce the effects of breeding and management trends that may alter slaughter weight.

Animal group-specific weight data (e.g., 138 kg for male dairy breeds of 6–8 months during 2021) was used for all flows of animals of the same age/sex/breed/exit year group, thus assuming there was no difference between organic or conventional animals or between abattoir-slaughtered, home-slaughtered, moved, or lost animals within each animal group. Organic and conventional farms use more or less the same cattle breeds, so there is no major genetic difference between the two production systems (Swedish University of Agricultural Sciences, 2024).

The specific carcass weights were multiplied by number of head in each animal group, to compute the group's flow of carcass weight to different destinations (see yellow sheets in ESM). The weights were subsequently aggregated to form the six main animal groups per production system.

All flows of beef from and between the organic and conventional systems were converted to a Sankey diagram using the web tool SankeyMatic (Bogart, 2014).

2.7. Calculation of loss rates

The beef loss rate for each production system was calculated as:

$$Beef\ loss\ rate_{system} = \frac{Lost\ meat_{system}}{Initial\ production\ (Produced\ meat + Lost\ meat + Net\ moved\ meat)_{system}} \quad (1)$$

where *system* indicates type of farming system (organic and conventional), *lost meat* is lost carcass weight from stillborn calves, unassisted deaths, and euthanized cattle, *produced meat* is produced carcass weight from abattoir and home slaughter, and *net moved meat* is net carcass weight moved from organic to conventional farms. *Initial production* represents the sum of these flows, i.e., all carcass weight that left the farms each year. The change in carcass weight in the living stock or future potential weight of calves if they had lived longer was not considered.

2.8. Statistical analyses, carbon footprint and economic estimations

Possible differences in beef loss rates between the conventional and organic systems, as a whole and for each animal group, were investigated by paired *t*-tests. As paired t-tests build on the assumption of normal distribution, and this study only has results from five years, this pre-requisite might be hard to verify. However, since our previous study analyzed beef losses from the combined conventional and organic systems, was based on 20 years of data and showed only minor differences between years (Strid et al., 2023), we proceed with assuming that also the sub-systems are normally distributed and hence eligible for paired t-tests. The computations were performed using the software environment R (R Core Team, 2024).

Estimated carbon footprint (CF) of the saved beef in the scenario study was based on values from a study on the climate impact of Swedish cattle subdivided on different production systems: specialized dairy farms; dairy calf fattening; and suckler herds (von Greyerz et al., 2023). The farm types in that study were matched with the animal groups in the present study, to give the saved beef animal group specific carbon footprint values (Table 2).

The financial value of the saved beef in the scenario analysis was calculated from an estimated slaughter value of 4.8 EUR per kg of carcass weight (Swedish Board of Agriculture, 2024c). Since the saved beef would otherwise have been sent for destruction, we also estimated this avoided cost of 700 EUR per ton of carcass weight (Swedish Farm Services, 2024).

3. Results

3.1. Flows of animals

All conventional animal groups had higher average loss rates than their corresponding organic group, ranging from 10 % higher for female dairy breeds to 50 % higher for male dairy breeds on a per-head basis. Furthermore, there was substantial net trade of animals from organic to conventional farms, especially male dairy calves (median age group 1–2 months), but also male beef and crossbreed calves (median age group 6–8 months). The average numbers of heads (for the years 2017–2021) reported for different destinations and the corresponding percentage of total outflow for each animal group are presented in the ESM (sheet "Overview head").

3.2. Flows of beef

This section reports average flows of beef (2017-2021) in tons of yearly carcass weight and as a percentage of initial production. The organic production system, lost yearly 2.2 thousand tons of beef, corresponding to 7.4 % of initial production, while the conventional system lost 10.6 thousand tons (8.8 % of initial production). The conventional beef production system thus had a 19 % higher loss rate than the organic production system, where the higher share of dairy breeds in the conventional system contributes to this difference (see Table 1). All flows and flow rates are presented in Table 3. For input data and calculations, see ESM.

The beef flows in the entire Swedish production system are visualized in a Sankey diagram in Fig. 1, where the width of the arrows represents the size of the flows. The flow chart illustrates that: i) conventional farms dominate the Swedish cattle system; ii) a relatively large share of organic production is moved to conventional farms (17 %), thereby losing its organic status, iii) the relative losses from the conventional system exceed the relative losses from the organic system, and iv) home slaughter is small in comparison with other flows.

Table 2
Assignment of carbon footprint values to animal groups based on farm types.

Animal groups in the present study	Farm type in von Greyerz et al. (2023)	Carbon footprint
Dairy females	Specialized dairy farms	16 kg CO_2e/kg cw
Dairy males	Dairy calf fattening farms	22 kg CO_2e/kg cw
Beef females	Suckler herds	36 kg CO_2e/kg cw
Beef males	Suckler herds	36 kg CO_2e/kg cw
Crossbreed females	Suckler herds	36 kg CO_2e/kg cw
Crossbreed males	Suckler herds	36 kg CO_2e/kg cw

Table 3
Flows of beef, flow rates, conventional overshoot, and results from scenario study.

Main study: "Average flows for 2017-2021" [1000 ton cw]												Scenario study: "Organic loss rate" [1000 ton cw]					
Breed group	Production system	Sex	Abattoir slaughter	Home slaughter	Net Moved	Loss	Initial prod.	Home slaughter rate	Move rate	Loss rate	Conventional overshoot	Assigned (= organic) loss rate	New losses	Saved meat	Share of saved meat	Saved CF [1000 ton CO_2e]	Share of saved CF
Dairy	Organic	Male	1.8	0.1	0.8	0.1	2.8	2.6%	28%	4.5%							
Dairy	Organic	Female	5.0	0.2	0.2	1.0	6.4	3.3%	3%	15.8%							
Dairy	Conventional	Male	32.6	0.8	−0.8	1.8	34.4	2.3%	−2%	5.2%	1.15	4.5%	1.5	0.23	17%	5.0	17%
Dairy	Conventional	Female	26.1	0.9	−0.2	6.0	32.8	2.8%	−1%	18.2%	1.15	15.8%	5.2	0.78	58%	13	43%
Beef	Organic	Male	2.6	0.1	1.0	0.1	3.8	3.0%	25%	3.0%							
Beef	Organic	Female	2.9	0.2	0.5	0.3	3.9	4.7%	12%	8.1%							
Beef	Conventional	Male	11.4	0.4	−1.0	0.4	11.2	3.6%	−9%	3.4%	1.13	3.0%	0.3	0.04	3%	1.6	5%
Beef	Conventional	Female	7.9	0.4	−0.5	0.7	8.6	5.2%	−6%	8.3%	1.02	8.1%	0.7	0.01	1%	0.5	2%
Crossbreed	Organic	Male	4.1	0.1	1.8	0.1	6.2	1.9%	29%	2.1%							
Crossbreed	Organic	Female	4.8	0.3	0.7	0.5	6.3	4.2%	12%	7.4%							
Crossbreed	Conventional	Male	19.9	0.5	−1.8	0.6	19.2	2.6%	−9%	3.1%	1.43	2.1%	0.4	0.18	13%	6.4	22%
Crossbreed	Conventional	Female	13.8	0.6	−0.7	1.2	14.9	4.1%	−5%	8.1%	1.08	7.4%	1.1	0.09	7%	3.3	11%
All	Organic	Both	21.3	1.0	5.0	2.2	29	3.3%	17%	7.4%							
All	Conventional	Both	111.7	3.7	−5.0	10.6	121	3.0%	−4%	8.8%	1.19		9.3	1.3	100%	29	100%
All	Both	Both	132.9	4.6	0.0	12.8	150	3.1%	0%	8.5%							

cw = carcass weight.
CF = carbon footprint.

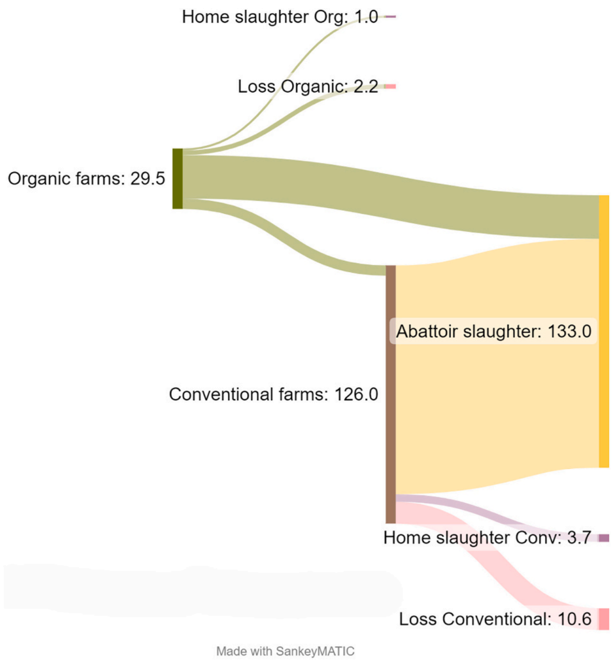

Fig. 1. Sankey diagram of yearly flows of beef (thousand tons of carcass weight) on Swedish conventional and organic cattle farms.

3.3. Loss rates over time

Loss rate per year 2017–2021 ranged between 7.0 and 7.8 % in the organic system and 8.0 and 9.1 % in the conventional system (Fig. 2). There was no apparent trend over time and inter-year variation was relatively low, with 2018 having the highest losses and 2020 the lowest. The magnitude of losses in both systems followed a similar pattern over the years, indicating common external influences. The paired *t*-test implied a significantly higher loss rate for the conventional system compared with the organic system ($p < 0.0001$).

When loss rates over time were divided per animal group, female dairy breeds of both production systems showed an increasing tendency for losses, whereas female beef and crossbreeds showed a decreasing tendency (Fig. 3). However, as the time series were limited in length, no statistical inference procedures were applied to test for possible significance of trends.

3.4. Average loss rates per animal group

There was a considerable difference between the animal groups, where female dairy breeds of both production systems had higher loss rates than all other groups. Conventional dairy females comprised a hotspot animal group, which lost 18.2 % of its yearly beef production. This was 15 % higher than for the organic counterpart, which lost 15.8 %. Females in general had higher loss rates than males, and dairy breeds had higher loss rates than beef breeds and crossbreeds.

The average loss rate per animal group was higher in conventional production for all animal groups (Fig. 4; Table 3). From paired *t*-tests, we found significant differences between production systems in particular for Dairy (females) and for Crossbred (males) ($p < 0.001$). Less marked significances were found for Dairy (males), Beef (males) and Crossbreed (females), ($p < 0.05$). Notably, Beef (females), had only a non-significant difference between production system ($p = 0.10$).

3.5. Absolute losses per animal group

Conventional dairy females accounted for nearly half (47 %) of overall Swedish beef losses at farm level (6.0 out of 12.8 thousand tons) (Fig. 5), and most of this (5.1 thousand tons, 86 %) originated from animals aged 24 months and older. The next largest contributor group was conventional dairy males, which accounted for 14 % of all losses, but only 15 % of these losses derived from animals aged 24 years and older. Absolute losses within the organic system were greatest for dairy females, followed by crossbreed females, who contributed 8 % and 4 %, respectively, of total beef losses (Fig. 5).

3.6. Goal conflict

Since organic beef production had lower losses than conventional, there was no goal conflict between reducing food losses and increasing organic beef production. Instead, there was a synergetic effect, where a change towards more organic cattle farming also would favor a reduced food loss target.

3.7. Scenario study of beef saving potential

The beef saving potential of letting conventional cattle have the same loss rates as organic, i.e., as the best-performing system, was estimated to 1300 tons per year or 10 % of total Swedish beef losses (Table 3). Most of these savings (58 %; 780 ton) derived from conventional dairy females.

The avoided carbon footprint from the saved beef, which all was of

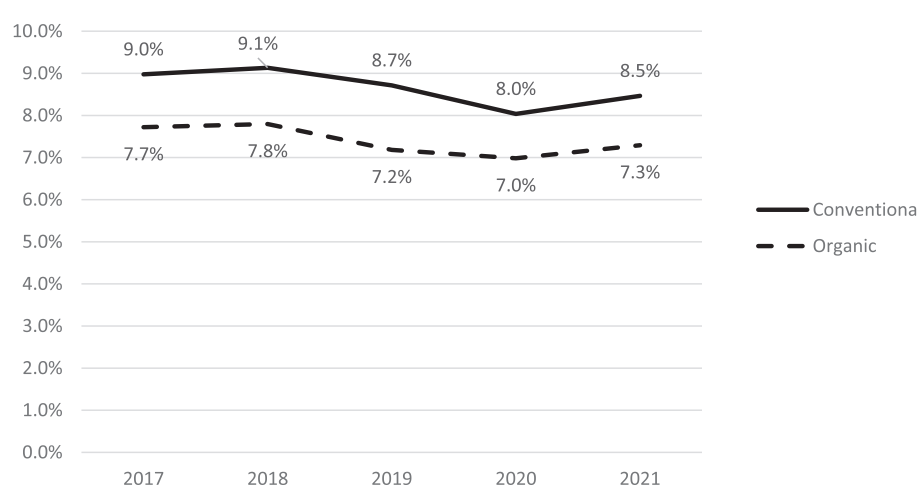

Fig. 2. Loss rates over time in the Swedish conventional and organic beef production systems, 2017 to 2021.

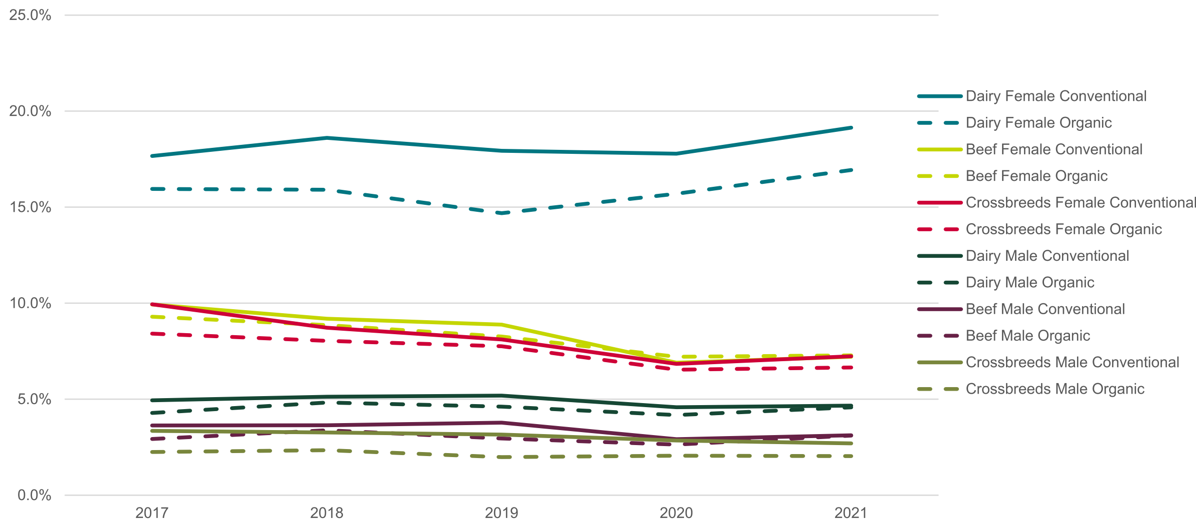

Fig. 3. Loss rates over time for conventional and organic animal groups, 2017 to 2021.

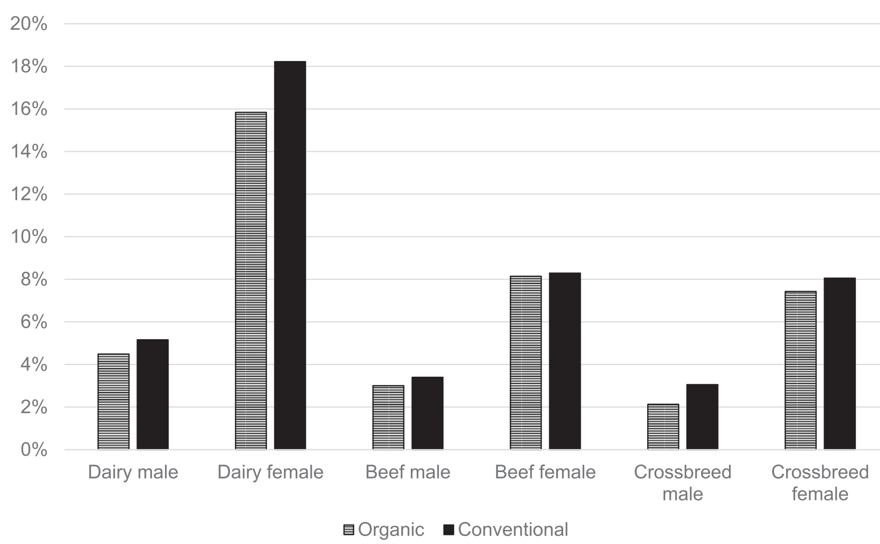

Fig. 4. Average loss rates (2017-2021) for organic and conventional male and female dairy, beef, and crossbreeds.

conventional origin, was estimated to 29,000 tons CO_2e per year, with the majority deriving from dairy females (43 %) (ESM).

The economic value of the saved beef if sold as meat was estimated to €6.4 M per year, whereas the avoided costs for sending fallen cattle to destruction was estimated to €0.9 M per year, altogether €7.4 M per year.

4. Discussion

4.1. Losses in organic and conventional beef production systems

Our analysis showed that organic production had lower average beef loss rates than conventional production, both overall (19 %) and for each animal group (2–43 %). Direct comparisons with other studies are challenging as there is generally a striking lack of primary loss data in the scientific literature (Xue et al., 2017). However, mortality rates (which measure yearly deaths in the living herd as opposed to loss rates that measure deaths as a share of the yearly meat production) of subsets of the cattle population can be found. In a German study on dairy cows, the yearly mortality rate was fond to be significantly lower for organic cows compared to conventional; 2.0 % and 3.2 %, respectively (Wagner et al., 2021). A significant difference in favor of organic dairy cows was also found in a Swedish study, where organic cows had 5.3 and conventional 6.4 mortality events per 100 cow-years (Alvåsen et al., 2012).

The production targets for different animal groups, i.e., males and females of dairy, beef and crossbreeds, differ greatly. They can be maximal milk yield for dairy cows, high beef quality and grazed acreage for suckler cows, and maximum beef yield for young bulls, creating different management situations and different levels of loss rates, as seen in our previous study (Strid et al., 2023). Therefore, we argue that the most relevant comparison between the organic and conventional systems should not be made at the overall level, but instead per animal group, if the aim is to analyze the effect of organic management on losses. Since all organic animal groups except beef females had significantly lower loss rates than their conventional counterparts, it seems likely that organic production has characteristics that favor low losses. However, the present study was not designed to investigate causal relationships, so this could not be confirmed or explained in terms of root causes. Despite the lack of solid evidence, we discuss some possible reasons in the section below.

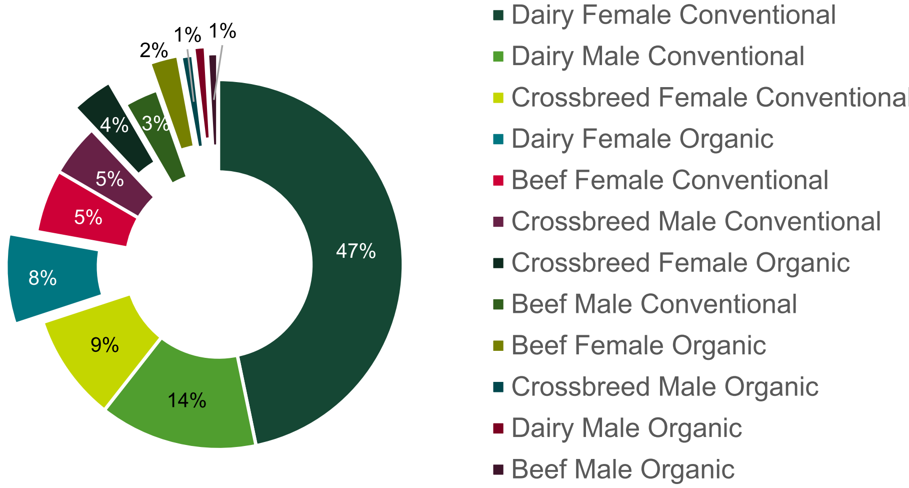

Fig. 5. Absolute beef losses for different animal groups in the Swedish beef sector, average 2017–2021. Organic animal groups are extending the circle.

4.2. Possible reasons behind the lower organic losses

This section presents some characteristics and differences between organic and conventional systems with possible implications for losses. Most focus is put on dairy cows as the majority of beef losses derive from this group.

4.2.1. Milk yield per cow

Organic dairy cows have approximately 9 % lower milk yield than conventional cows (Växa Sverige, 2022). To understand if higher milk yield will give more losses, a historic outlook was made. From 2002 to 2021, the average milk yield per cow (Swedish Holstein, the most common breed) went from 8900 to 11,400 kg ECM/cow and year, an increase of 28 %, whereas the loss rate for female dairy breeds during the same period went from 14.3 % to 18.8 %, an increase of 31 % (Växa Sverige, 2022; Strid et al., 2023). This coincidence suggests that increased individual milk yields could take a toll in the form of additional lost animals. If higher milk yield is a driver for increased animal losses, the 9 % higher milk yield per cow at conventional farms can partly explain the 15 % higher losses.

The lower milk yield in itself is a productivity problem, but if higher milk yields come with lower beef yields it is not immediately evident which strategy performs best. A similar conclusion was drawn by Hessle et al. (2017), stating that the environmental performance of dairy and beef production needs to be accessed by an integrated approach, to avoid the risk of suboptimal solutions, since the two systems are strongly interconnected.

4.2.2. Newer barns

Since 2009, over 160,000 new stable places have been built for dairy cows in Sweden, which means that more than half of the cows of 2021 live in barns 12 years or newer (Swedish Board of Agriculture, 2024d). At the same period, the number of organic cows has increased from 32,500 to 57,300, an increase of 76 %, whereas the conventional cows have gone from 329,000 in 2009 to 244,000 in 2021, a decrease of 26 %. It seems reasonable that the expansion of organic cows makes them proportionally more likely to be kept in new barns than the conventional cows. When building new stables, a large number of animal welfare aspects need to be taken into account for the new building to be approved, why newer buildings should be better equipped for preventing losses than older buildings. A possible explanation for lower losses of organic dairy cows could hence be that they are kept in newer buildings.

4.2.3. Feeding and welfare

The share of roughage feed and grazing is larger and the milk-feeding period for calves is longer in organic dairy systems (Swedish University of Agricultural Sciences, 2024). This could be attributed to higher animal welfare and thereby explain the lower losses to some extent. However, there is no consensus that organic cattle experience better welfare, as there are studies both supporting this connection (Wagner et al., 2021) as well as not finding evidence for a connection (Åkerfeldt et al., 2021). Langford et al. (2011) suggest that organic dairy cows experience more hunger, as their feed generally has a lower metabolizable energy content, and therefore compete more for feed, exhibiting more aggressions. The relationship between feed rations, feed quality, feeding behavior and loss of animals is too complex to be covered by the scope of the present study, but can be an interesting area for future studies.

4.2.4. Farm size

Organic dairy farms had on average 107 cows per farm compared to 103 at conventional farms (Table 1), i.e., organic dairy farms were 4 % larger. This difference is much smaller than the 15 % difference in loss rate and cannot fully explain the difference, if farm size would be an explanatory factor. For suckler cows, organic farms were double the size of conventional farms, but here the difference in loss rates were much smaller (2–8 %), why farm size does not seem decisive for beef loss rates.

4.2.5. Home slaughter

Home slaughter has in a questionnaire to Swedish beef producers been described as a measure to avoid losses, as animals unfit for abattoir slaughter instead can be slaughtered for use in the own household (Alvåsen, pers.comm). The home slaughter rate for dairy breeds was highest at organic farms, whereas the dito for beef and crossbreeds was highest at conventional farms (Table 3). For female dairy breeds the home slaughter rate was 18 % higher at organic farms than at conventional, in spite that the average farm size was similar (Table 1), thereby offering an equal opportunity to offset the meat in the farm household. The higher home slaughter rates at organic dairy farms, if used to save meat from animals unfit for slaughter transport, can partly explain the lower losses of organic dairy cows.

4.2.6. Economic incentives

In a perspective article, Sundrum (2024) concluded that efforts and expenditures to solve animal health and welfare problems have to be balanced between the costs for these problems and the preventive costs for reducing them. The somewhat higher meat price (3–10 % higher;

Scan, 2024; Skövde slaughterhouse, 2024) could act as an economic incentive for investing more in an organic animal to not lose it before slaughter.

4.2.7. Trade of young males and making of steers

For organic males, two thirds of initially produced heads were sold to conventional farms, mainly at young ages (median age group 1–2 months for dairy and 6–8 months for beef and crossbreeds). This could e.g., be incentivized by the extended milk feeding period on whole milk required within the organic system. The market for male calves is in itself a solution for not wasting them immediately, which can happen when this market is lacking such as in New Zealand (Boyle and Mee, 2021), but could also explain lower losses of organic males, as losses later in life are "exported" to conventional farms. Moreover, the few males that are kept at organic farms are to a larger extent made into steers, which have better access to pasture and constitutes a larger investment than an indoor bull calf, possibly explaining the 43 % higher loss rates ($p < 0.001$) for conventional crossbreed males than their organic peers.

4.3. Synergy between organic beef production and food loss reduction

The observed synergy between organic beef production and reduced food losses could act as a driver for a faster shift to organic production and consumption, if this property is recognized. Sweden has targets for both increased organic production and consumption and reduced food losses (Swedish Government, 2019), and could thereby use a shift to organic cattle production as a strategy to make progress on both targets. This can also be attractive for the public catering sector, which often has targets for both organic food consumption and reduced food loss and waste (e.g., Södertälje Municipality, 2022), where the synergy can strengthen arguments for procurement of organic beef.

4.4. Organic production as a food loss intervention

As shifting to organic farming is a preventive method, unlike value-recovery methods such as emergency slaughter, it should be a high-priority measure according to the waste hierarchy (European Parliament, 2008). Avoiding losses by organic farming instead of saving the meat from injured animals would also be favorable from an animal welfare perspective. Fortunately, these two measures (organic farming and emergency slaughter) are additional and can complement each other, as there will still be accidents on organic farms. Other preventive measures such as improving the health of transition cows, as suggested by Hagner et al. (2023), could also be effective, since 86 % of conventional female dairy losses in our study originated from animals aged 24 months or older (ESM), and since early post-partum is the period with the highest risk of cow culling (Rilanto et al., 2020).

To put the potential food saving from shifting to organic beef production into perspective, we reviewed beef losses in some other parts of the food supply chain. In the food industry, around 2 % of beef is lost (Swedish Board of Agriculture, 2023). In retail, an additional 1 % is lost (Eriksson, 2015) and in households another 2 % (Swedish Food Administration and Fritz, 2023). As concluded in a study of the European hospitality sector, initial high loss rates grounded for highest waste reductions, indicating that actors with the largest problems also can drop waste levels the most (Eriksson et al., 2019). Directing more attention to the high level of losses in the primary production segment of the beef supply chain could accordingly give the best return on investment in terms of effort, time and money.

Sweden is committed to reach SDG 12.3, aiming for reduced food losses by 2030, why rapid actions are needed. Organic cattle farming does not require new technology to be developed and could thus be a fast and viable option for reduced food losses. Moreover, the EU Commission is preparing for legally binding food waste targets, which are expected to come into force in 2024. If there will be a quantified food loss target for the primary production sector (the proposal from the Commission is a null target, but many stakeholders are calling for 10 % or more), Sweden would need to act on this (European Commission, 2023). Changing to organic farming could offer the 10 % reduction necessary for the beef sector to reach this target.

4.5. Carbon footprint value of avoided losses

When comparing the carbon footprint value of the avoided beef losses - around 29,000 tons of CO_2e/yr - to the total Swedish territorial greenhouse gas emissions from the agricultural sector – around 6,450,000 tons CO_2e/yr for 2021, the spared beef losses only accounts for 0.4 % (Swedish Environmental Protection Agency, 2024a)). But, if this intervention is compared to other climate mitigation options, such as the Swedish Climate Investment Program, where 915 actors in the agricultural sector so far have been funded for taking actions that in total are expected to reduce emissions by 290,000 tons CO_2e/yr (Swedish Environmental Protection Agency, 2024b), saving beef by converting to organic production could contribute with another 10 % to the already planned actions, if loss rates are decisive for the resulting carbon footprint. As the Swedish Government has committed itself to a net-zero climate target by 2045 (Swedish Government, 2017), reduced beef losses could be a mitigation measure to consider.

However, the carbon footprint of dairy and beef production is much more complex than only the level of losses. A Norwegian study on mitigation of greenhouse gas emissions from beef cattle concluded that reduced calf mortality can act as one of several mitigation strategies (Samsonstuen et al., 2020). In a Danish study on the effect on global warming potential from organic beef production, attributes more common at conventional farms gave lower impacts, such as low share of roughage feed and young bulls instead of steers (Mogensen et al., 2023). An Italian study comparing the production systems report higher carbon footprint for organic beef than for conventional, however losses were not included (Buratti et al., 2017). Including losses in carbon footprint studies of dairy and beef production could give better results.

4.6. Beyond the pasture

Organic dairy and beef production is acknowledged for its benefits for biodiversity (Knudsen et al., 2019; Angerer et al., 2021), lower freshwater ecotoxicity (Knudsen et al., 2019; Zira et al., 2023), and lower resource depletion compared with conventional systems (Knudsen et al., 2019). Lower beef losses can now be added to this list.

Reduced beef losses can in turn give rise to cascading benefits, such as reduced need for therapeutic medication if the reduced losses are a result of better animal health and welfare. This opportunity was identified in a review of the risks and opportunities of increasing yields in organic farming, where reduced animal losses was one of the strategies considered (Röös et al., 2018). Reducing the need for antibiotics would help combat the spread of antibiotic resistance (Majumder et al., 2020).

A system with lower food losses will have a smaller environmental footprint per output for all impact categories than a comparable system with higher losses. Reduced food waste has therefore been linked, via reduced ecosystem damage, to increased food system resilience (Bajželj et al., 2020).

4.7. Future outlook and recommendations

Further research is needed to determine why organic cattle farming has lower loss rates. The focus in such research should be on female dairy breeds, which contributed the majority of losses in both organic and conventional production systems.

According to Tälle et al. (2019), animal welfare and livestock epidemiology research should be integrated with other dimensions of sustainable food production systems in Sweden, but only a few previous studies have focused on this perspective. However, the predominant approaches of animal science may have to be transformed, as they so far have been ill-suited to solve animal health and welfare problems (Sundrum, 2024).

If animal welfare and health previously have been essentially missing in the discourse on sustainable food systems, our study may contribute by highlighting the importance of beef losses, which are the end-result of neglecting welfare and health issues, thereby encouraging to include the animal perspective in sustainable food systems studies.

A challenge for realizing organic cattle farming as a food waste solution could be the dominating market share for conventional dairy products and beef, with poor forecasts for increased shares in the near future based on the negative trends in recent years (Statistics Sweden, 2024). It is obvious that market demand alone cannot make this shift happen, which puts pressure on politics and other decision makers to find other solutions, if the benefits of organic cattle farming as a food waste solution should come into reality.

Based on our findings, we suggest that the Swedish government, livestock sector, and other relevant stakeholders come together to develop an ambitious national strategy to increase the proportion of organic cattle farming, as a measure to mitigate beef losses in Sweden by 2030 and also bring other sustainability benefits.

4.8. Uncertainties and methodological choices

One uncertain part of the study regarded data on stillborn calves, as reporting on this is voluntary. This was a minor problem for females, as stillborns only constituted 1–2 % of those groups' carcass losses, but a greater problem for males, as the share of stillborns was higher. For organic dairy males, stillborns constituted 18 % of total losses, since much of the later losses were "exported" to conventional farms, making the total loss rate sensitive to unreported stillborns. There was thus a risk of underestimation of organic dairy male losses. Not recording and reporting stillborn calves is a known problem, described as "farm-blindness" (Mee, 2020). However, since farmers are obliged by law to report all other cattle events to the CDB registry, the robustness of the overall data can be assumed to be high.

There was also some uncertainty regarding the assumption that lost animals had equal weight as their slaughtered counterparts of the same age, breed, sex, and production system. Deceased and euthanized animals may have somewhat lower body weight if death is preceded by sickness. On the other hand, pre-death loss of weight can also be considered a beef loss, making the first assumption still correct.

We made the methodological choice to include live animal production in initial production, as opposed to only including slaughtered weight, as we did in our first study on total beef losses in Sweden. This was motivated by the need to ascribe the full volume of production to the respective system, even in cases where the first stage of production took place within the organic system and the rest of production and slaughter within the conventional system.

5. Conclusions

Organic Swedish cattle production lost on average 2200 tons of carcass weight or 7.4 % of its yearly production, while conventional production lost 10,600 tons or 8.8 % of its yearly production, making the loss rate significantly ($p < 0.0001$) higher for the conventional system.

Mean organic beef loss rates were lower for all animal groups studied (males and females of dairy, beef and crossbreeds) and the difference was significant for all groups except female beef breeds. Female dairy breeds constituted a hotspot in both production systems, contributing 15.8 % of organic and 18.2 % of conventional yearly beef losses. This represented a 15 % higher loss rate for conventional females, which alone contributed nearly half (47 %) of all Swedish beef losses, but only 20 % of beef produced.

As the organic farms had lower beef loss rates, there would be no goal conflict between increasing the share of organic beef production and acting to reduce food losses.

A scenario study revealed that 1300 tons of carcass weight (10 % of national beef losses) could be saved annually if conventional farms had the same loss rates as organic farms, with most of the savings (780 tons) coming from dairy females. Based on this, shifting to organic cattle farming could act as a food loss intervention, reducing beef losses by 10 %. Hence, we recommend an ambitious Swedish strategy for increasing the share of organic cattle farming, as a measure to reach the targets for reduced food losses by 2025 (national goal) and by 2030 (UN goal).

CRediT authorship contribution statement

Strid Ingrid: Writing – original draft, Visualization, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Jacobsen Maria:** Writing – review & editing, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Rydén Jesper:** Writing – review & editing, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Alvåsen Karin:** Writing – review & editing, Validation, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no financial or personal interests that could appeal to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.agsy.2025.104262.

Data availability

Data will be made available on request.

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