Losses in the supply chain of Swedish lettuce – wasted amounts and their carbon footprint at primary production, whole sale and retail

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ABSTRACT

The waste flow of Swedish iceberg lettuce was followed through the value chain from field to retail shelf. The study also included estimations of the carbon footprint of the waste at the different stages. At the farm level 3 tons of high quality lettuce heads were wasted per ha and year (compared to 19 tons harvested), corresponding to ca 1100 tons CO_2-e per year at a national level. Ca 50% of the lettuce sold in Swedish retail stores is domestically produced and 50% imported. The carbon footprint of the wasted Swedish iceberg lettuce at retail level was estimated to 1500 tons CO_2-e per year at a national level. The conclusion was that the losses at the retail stage were of higher importance than the losses occurring during primary production for the lettuce supply chain, and that measures therefore should be targeted primarily to the retail sector.

Keywords: carbon footprint, food supply chain, food wastage, horticultural production

1. Introduction

1.1. Background

The Swedish National Food Agency has an official assignment to act for reduced food wastage in the Swedish food supply chain. As part of the background material for a new proposed environmental target on reduction of food waste, the Swedish Board of Agriculture initiated a study on the losses, and their carbon footprint (CF), during primary production of lettuce. The current paper highlights the main results of the study (Strid et al., 2014), which also includes the whole sale stage, and merges these results with findings from a study of the retail stage (Eriksson, 2012). The losses of lettuce in retail stores, and their carbon footprint, were studied by the authors in a previous project. By combining these studies, the flow of lettuce can be followed through the value chain from field to retail shelf, and the carbon footprint of the waste can be estimated at the different stages. This type of supply chain study, where the losses are quantified and environmentally evaluated, is likely to be of importance in the policy making for reduced food waste.

1.2. Swedish production and distribution of iceberg lettuce

This subject is described in detail in the background report: Wastage of iceberg lettuce during primary production and whole sale in Sweden (Strid et al., 2014), whereas some highlights are presented here. Iceberg lettuce is mainly produced in southern Sweden, amounting 2012 to 33 400 tons/year. Normally, two or three harvests can be taken each season. Packing can be done either directly at the field - by picking, quality checking, wrapping in plastic bags and packing in cardboard boxes placed on a slowly moving tractor in front of the workers – or at packing tables at the farm center. In the first case, outer leaves and rejected heads are dropped on the field and eventually ploughed down, whereas in the second case the rejected heads are sorted out at the table, and later brought back to the field as compost. The boxes with lettuce are usually continuously moved to a cold storage and then transported away from the farm the same day. At the whole sale distribution center the lettuce is normally loaded on trucks for further transport within a day. The supply chain can schematically be described as in Figure 1.

1.3. Purpose of the study

The present study aims at describing the waste flow of Swedish iceberg lettuce through the value chain from field to retail shelf. The study also aims at estimating the carbon footprint of the waste at the different stages, taking into account that the remaining product flow shrinks as losses occur along the supply chain.

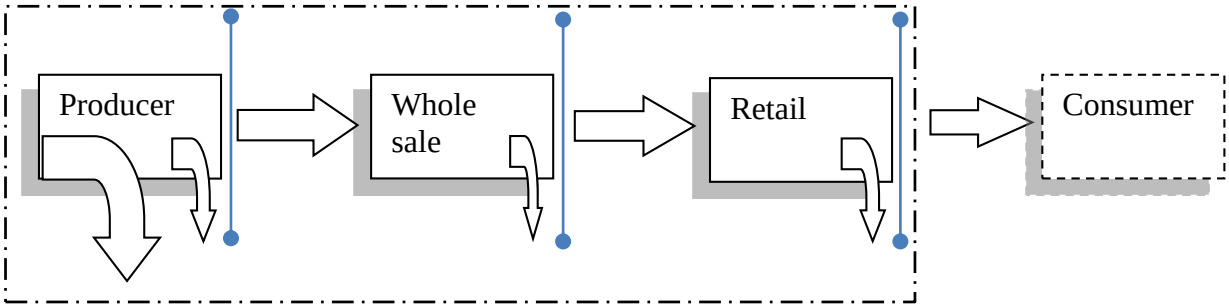


Figure 1. Schematic illustration of the supply chain of Swedish iceberg lettuce, and the system boundaries of the study. The fat waste flow represents un-harvested biomass, and the thinner, losses of prime heads. The vertical lines represent the CF check point belonging to the different stages: Ex-farm, Ex-whole sale and Ex-retail.

1.4. Scope of the study

The study covers primary production of iceberg lettuce, distribution to and waste at whole sale distribution center and distribution to and waste at retail stores, as illustrated in Fig. 1. At the farm, only the waste of high quality heads was considered, and not the type of waste occurring at the field during harvest (e.g., peeled off outer leaves and damaged heads left on the field), since this was defined as production losses instead of food waste. This type of waste can, however, be of interest in other studies, looking at valorization options for the produced biomass. At the whole sale and retail stages, all discarded lettuce was considered. The waste occurring in the households was not addressed in this paper. The study follows the lettuce produced in Sweden as this moves forward in the supply chain. About 50 % of the lettuce sold in Sweden is domestically produced and 50 % imported each year. The normal route for the imported lettuce is via the large distribution centers, and then further to, among others, retail stores. The flow of imported lettuce is not included in this study, but would roughly double the wasted amounts and thereby the CF of the whole sale and retail stages, if it was.

2. Methods

This paper merged and scaled up to national level the results from two studies on iceberg lettuce waste (Strid et al., 2014 and Eriksson, 2012), giving an overview of the losses in the value chain from primary production to retail shelf. The losses were also assessed for their carbon footprint, allowing the different stages of the supply chain to be compared. This was done by applying the product flow's CF at each stage to the wasted amount, thereby answering the research question: "How much extra environmental burden is caused by the losses, assuming that the lost lettuce is replaced by other lettuce produced under the same conditions?"

Each part of the study is described below. The methods used in the two waste inventory studies are briefly described in section 2.1, 2.2 and 2.3; for a full description of the methods, see the original studies.

2.1. Waste during primary production (Strid et al., 2014)

The method used for the study on losses during primary production was a combination of a field study on 5 farms in southern Sweden during the harvest period 2013, and an interview study with the same farmers. The farms practiced direct packing on the field as their harvest method. The biomass left on a number of test squares at the harvested fields was weighted one hour after harvest. During the interview it was explained that 10-20 % of the fields usually are never harvested, mainly due to mismatching orders (if the lettuce gets to old it loses quality and cannot be sold). The losses during primary production was hence accounted as 15 % (mean of 10-20 %) of high quality lettuce ready for harvest, but never harvested. The hectare harvest before dismissing part of the fields was on average 22 tons/ha, thus leading to 18.7 tons actual harvested heads and 3.3 tons not harvested heads. The total biomass left on the fields after harvest was 34 tons/ha, of which 3.3 consisted of the un-harvested heads, and the rest of outer leaves, malformed or damaged heads.

2.2. Waste during whole sale (Strid et al., 2014)

For the whole sale stage, some of the main whole sale organizations were interviewed. The waste was of two kinds: some smaller losses during the normal handling at the whole sale storage and some larger as a result of the quality control of the incoming lettuce, i.e., rejections to the producer, but physically a waste at the whole sale stage. The waste level used for the study was 3.0 %, of which 2.7 % was due to rejections and 0.3 % was due to in-storage losses.

2.3. Waste during retail (Eriksson, 2012)

The waste during the retail stage was based on a Swedish research project on retail food wastage (www.slu.se/foodwastage), which has access to a database covering weekly sales and waste of perishable products during 2010-2012, per item, for 6 stores belonging to one of the larger retail chains in Sweden. In this study both in-store and pre-store waste were assessed, representing the products lost at the retail shelf and those lost already when the products are subject to quality control at delivery. The waste of lettuce was recorded as 10.7 % of the incoming flow, of which 7.3 % was pre-store waste and 3.4 % in-store waste, as documented by Eriksson (2012).

2.4. Up scaling to national level

For the primary production stage, the wasted 3.3 tons of ready heads in relation to 18.7 harvested heads per ha was scaled up to national level according to the mean national harvest 2012, which was 33 400 tons. This led to that 5900 tons per year of produced lettuce never left the farms.

For the whole sale stage, it was assumed that all iceberg lettuce produced in Sweden passes the whole sale stage, and that 3 % of this falls out as waste. 3 % of 33 400 tons equals 1000 tons of lost lettuce, and implies that 32 400 continues to the retail stage.

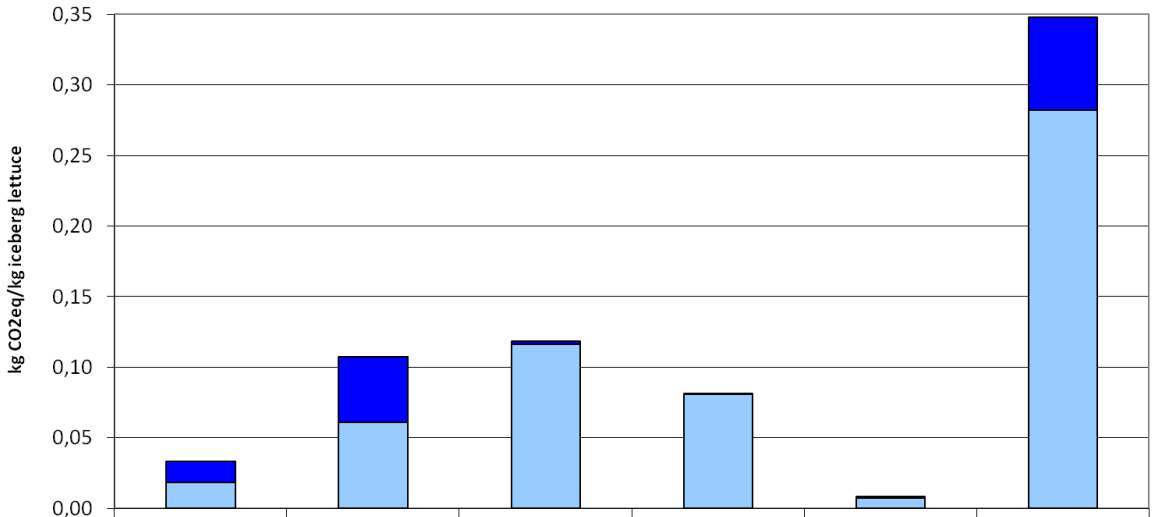
About 50 % of the lettuce sold in Swedish stores is domestically produced and 50 % imported each year. For the retail stage it was assumed that all domestically produced iceberg lettuce passing the whole sale stage also passed the retail stage. This led to a waste of lettuce by 10.7 % of 32 400 tons, i.e., 3500 tons wasted per year for the retail stage, and 28 900 tons passing on to customers.

2.5. Carbon footprint of losses

The last part of the study was to estimate the CF of the losses occurring at each stage. This was done by keeping track of the CF of the outgoing product flow at each stage and multiply this with the wasted amount at the same stage. It was assumed in this study that the wasted lettuce did not have any other offset, e.g., no biogas was produced from the waste. On the other hand, the energy use for transporting the lettuce to waste management facilities at the whole sale and retail stages were not included either. For simplification, these two factors were assumed to even out each other.

2.5.1 Input data used for Carbon footprint calculations

For the carbon footprint data on lettuce production, a Swedish study on emissions of greenhouse gases from production of 17 horticultural products up to and including retail stores were used (Davis et al., 2011). In this, the greenhouse gas emissions at the different stages of lettuce production and distribution were assessed (see Figure 2).



	Fertiliser production	Cultivation	Packaging	Transport	Retail	Total
N2O	0,02	0,05	0,00	0,00	0,00	0,07
CO2	0,02	0,06	0,12	0,08	0,01	0,28

Figure 2. Carbon footprint data of Swedish iceberg lettuce used as input data in the present study. Source: Davis et al., 2011.

However, in this study the waste levels were lower than those found in the more explicit waste studies by Strid et al. (2014) and Eriksson (2012). The waste levels during primary production in Davis et al.'s study were based on questionnaires, where the growers were asked questions about harvest residues and storage losses per hectare. The losses were stated to be 1 ton per ha, in relation to the harvest of 23 tons per ha, and the loss was assumed to be composted and returned to the field. This gives a waste ratio of 4.2 %. There was no question about the share of un-harvested fields, as in the study by Strid et al. (2014), which may have underestimated the actual losses. The waste level during whole sale was not assessed (thus assumed 0 %), but the waste level at the retail stores was included, and derived from Gustafsson, 2010. In Gustafsson's study, the waste at retail stores was obtained from interviews with the store owners, and was assessed to 1.9 % for iceberg lettuce. It is likely that the store managers only regarded the amount that is sorted out and discarded of the in-store products, and not also included the incoming lettuce that was rejected. In a study of Eriksson et al., 2012, it was however concluded that for assessing retail wastage accurate, it is necessary to include both pre-store and in-store wastage. Due to higher confidence in the specific waste studies, new CF values were calculated to reflect these higher loss ratios. The new CF values and the assumptions behind these are described below in section 3.

3. Results

3.1. Adjusting the Carbon footprint values to the assumed product flow

For the cultivation stage, the harvest was assumed to be 19.6 tons instead of 23 tons/ha, taking away the 15 % harvest loss not accounted for. This altered the CF Ex cultivation from 0.15 kg CO_2-e/kg lettuce to 0.18 kg CO_2-e/kg lettuce. Lettuce lost after cultivation, but before packaging, was ascribed this value. For the next stage (Whole sale), the burden from plastic packaging was added, 0.12 kg CO_2-e per kg lettuce, and ¼ of the transport burden, 0.02 kg CO_2-e. This sum was then ascribed to the 97 % of the lettuce making it through the whole sale stage, giving a new Ex whole sale CF of 0.33 kg CO_2-e. For the last stage (Retail), the remaining ¾ of transport, 0.06 kg CO_2-e, was added to the value coming out of Whole sale, and then ascribed to the 89.7 % of lettuce leav-

ing the retail stage for the consumer stage, thus giving a new Ex retail CF of 0.43 kg CO_2-e. The resulting new CF for each stage is listed in Table 1.

Table 1. Calculated carbon footprints per kg lettuce for the different stages of the supply chain

Stage of supply chain	Carbon footprint [kg CO_2-e per kg lettuce] according to Davis et al. 2011	Product flow according to Davis et al. 2011	Product flow in the present study	Carbon footprint [kg CO_2-e per kg lettuce] adjusted to the product flow in the present study
Ex cultivation	0.15	23 tons/ha leaving farm	19.6 tons/ha leaving farm	0.18
Ex whole sale	0.29	23 tons/ha leaving distribution center	19.0 tons/ha leaving distribution center	0.33
Ex retail	0.35	22.6 ton/ha leaving retail	16.9 tons/ha leaving retail	0.43

3.2. Lost amounts and CF of the losses at different stages of the lettuce supply chain

Table 2 gives an overview of the study, describing the relative and absolute waste levels and CF at the different stages of the supply chain. In the last column, the estimated CF of the losses at each stage is shown. The largest losses on a mass-basis occurred during primary production, whereas the largest carbon footprint was associated with the losses at the retail stage.

Table 2. Lost amounts and CF of the losses at the different stages of the domestic supply chain

Stage of supply chain	Loss percentage	CF of lettuce at different stages [kg CO_2-e per kg product]	Lost amount of lettuce at national level [ton per yr]	CF of losses at a national level [ton CO_2-e per year]
Primary production	15 %	0.18	5900	1060
Whole sale	3 %	0.33	1000	330
Retail	11 %	0.43	3500	1500
Total CF of losses				2900

4. Discussion

Contrary to many other agricultural products (tomatoes, broccoli, milk, meat, etc), but similar to other open field crops, the emissions at the production stage of iceberg lettuce is relatively small, leading to that the packaging and transport instead is relatively large; although the absolute value of the product is small. This explains why the smaller amount wasted at the retail stage still can be more important for impact on climate change than the larger amounts wasted at the farms.

When comparing the results with a life cycle assessment study on British and Spanish lettuce production (Hospido et al., 2009), data on losses or waste could unfortunately not be found. The harvest levels were between 15-27 tons of lettuce per ha for open field production, thereby comparable with both the yield without losses (23 tons/ha) and the yield after losses (20 tons/ha) of the present study. The global warming potential was in the study of Hospido et al. estimated to 0.33 kg CO_2-e/kg lettuce for the domestic UK open field production up to a regional distribution center. This can be compared to the CF at the whole sale stage in the present study, which also was 0.33 kg CO_2-e/kg lettuce. In the UK study some parts were different from the Swedish study: postharvest cooling was included, but packaging was excluded.

For mitigation of the environmental impact caused by lettuce waste, the retail stage is the most important stage to target of the stages covered in this study, and within the retail stage the pre-store waste causes the largest volumes of waste. As described by Eriksson et al. (2012), the pre-store waste occurs when the produce arrives at

the store. Since the products are formally rejected, the retail store does not have to pay for them. Rejecting a possibly not perfect product already when it arrives is economically favorable compared to be forced to discard it later. This creates economic incentives for pushing products to pre-store waste. Economic feedback systems, such as lower purchase prices if the store keeps a low pre-store waste pattern, might stimulate the development of creative routines and solutions for keeping the waste low..

The pattern of pushing the cost of waste back to the supplier was also found at the whole-sale stage, where more waste was created as rejections, than from handling of the products at the storage (see section 2.2). For the grower, there is no stage earlier to push the waste to. At farm level, development of other market channels for the lettuce that could not be sold to the primary buyer might be a possible solution for reduced wastage at farms.

For comparison, lettuce wasted at household level was in a British study (WRAP, 2014) around 38 % of purchased volumes (64 000 ton wasted of 170 000 ton purchased), thus being more important than all the earlier stages together, if these figures also holds for Sweden. The household waste is not only larger in volume, but also in its carbon footprint, since more impact has been accumulated. If the CF of Swedish household lettuce waste is estimated to 0.5 kg CO_2e/kg (the earlier 0.43 kg CO_2e/kg + home transport and fridge storage), and 38 % of 28 900 tons yr^{-1} leaving retail is wasted, a rough estimate would give that the CF of Swedish household lettuce waste corresponds to 5500 ton CO_2e per year.

5. Conclusion

The main outcome from this study was the indication on to what extent lettuce is wasted at the different stages of the Swedish supply chain of iceberg lettuce up to and including retail. The largest losses on a mass-basis occurred during primary production, followed by the retail stage and last the whole sale stage. The global warming potentials associated with these losses were highest for the retail stage, followed by the primary production stage and last the whole sale stage. Since the retail stage was responsible for the largest contribution to global warming, reduction measures should be targeted to this sector. Within the retail stage the pre-store waste caused the largest volumes of waste. Investigating the root causes behind the retail pre-store waste would give valuable information for reducing the impact of lettuce waste in a food chain perspective. Also, the amount and causes of household waste need to be investigated in future studies.

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