Carrot Loss during Primary Production

Field Waste and Pack House Waste.

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ABSTRACT

Key words: Carrot, waste, harvest, wholesaler, out-grading.

- **Background:** it has been suggested that roughly one-third of all food produced for human consumption is lost or wasted globally. The reduction of loss and waste is seen as an important societal issue with considerable ethical, ecological and economic implications. Fruit and vegetables have the highest wastage rates of any food products; (45 %). And a big part of this waste occurs during production, but empirical data on loss during primary production is limited. Carrots are an important horticultural crop in Norway. In 2014, 55,139 tons were produced, covering 84% of the national consumption.
- **Aim:** Losses occurring during mechanical harvest and out-grading at packing houses of fresh market carrots were surveyed and analyzed to find the amount and reasons for waste.
- **Approach**: A mixed methods approach, including semi-structured interviews, empirical data collection through field surveys and secondary data from industry was central in understanding the wastage of carrots and finding solutions to reduce harvest and pack-house waste. Losses were estimated through a percentage method. Measures of harvest waste were conducted in the autumn of 2015 by weighing unharvested carrots on plots in 12 newly harvested fields in Southeastern Norway.
- **Results/Conclusions:** Almost 5 % of fresh market carrots produced in Norway is lost in field. This loss is ploughed back into the field (390.5± 107 kg/decar). Field variations made machine adjustments difficult, and results showed substantial variations of harvest loss within a field even with automatic adjustments. Choosing a cultivar with strong foliage is suggested for limiting field loss. We found that 10,000 tons of fresh market carrots is out-graded at packinghouses annually, 25% of this is redistributed to industry resulting in 20% loss at the packinghouses. Only half of the out-graded carrot loss was due to decay and storing diseases, suggesting that 70 % of the wholesaler loss is avoidable, and rejects from the packing house are suited for many products. The growers compensated the total losses by growing more carrots in order to fulfil their contracts with the wholesaler, some up to 50% more. Out-grading loss was considerably larger than field loss, causing farmers to be more concerned about this loss.

SAMMENDRAG

Nøkkel ord: gulrot, svinn, innhøsting, utsortering, grossist.

- **Bakgrunn-** omtrent en tredel av all mat som produseres på verdensbasis blir aldri spist. Reduksjonen at matsvinn sees på som et viktig tiltak både etiske, miljømessig og samfunnsøkonomisk. Frukt og grønnsaker har den høyeste svinnprosenten med hele 45 % og en stor del av dette svinnet skjer under produksjonen. Empiriske data er svært begrenset på svinn i primærledd av grønnsaker.
- **Problemstilling**- Gulerøtter en viktig grønnsak i Norge og i 2014 ble det produsert 55,139 tonn, som står for 85% av det årlige forbruket. Svinn skjer i alle ledd under produksjonen. Vi ta for oss svinn som skjer under mekanisk innhøsting og svinn under sortering på pakkeriet for å finne mengde og årsak til svinn under primærproduksjon av konsumgulrøtter til ferskvarehandelen.
- **Metode**- En blandet metode med semistrukturerte intervju av bønder, empirisk datainnsamling og sekundær data fra industrien var sentralt for å forstå mengde og årsak til innhøsting og pakkeri svinn. Innhøstingsvinn ble beregnet ved hjelp av undersøkelser på 12 jorder etter innhøsting høsten 2015 på Østlandet ved å veie gjenliggende gulrøtter.
- **Resultat/konklusjon-** Nesten 5% av avlingen ble liggende igjen på jordet som utgjorde et tap på 390.5. ±107 kg gulrøtter per dekar. Variasjon i innhøstingsforhold på jordet gjorde maskin innstillinger vanskelig og resultatene viste store svinnforskjeller innad på jordet. Faktorer som ugrasbekjemping og manøvrering av innhøstingsmaskinen samt gulrotsort med sterkt ris var viktig. Utsortering på pakkeriet viste seg å være 27 % av mottatt gulrot, der 25 % av dette ble redistribuert til industrien. Dette utgjør 7 500 tonn some er 20 % av all gulrot produsert til fersk konsum ender opp som svinn på pakkeriet med nåværende produksjon. En stor andel kunne vært redistribuert, da halvparten av gulrota som ble utsortert skyldes kosmetiske feil som størrelse og form. Utsortert gulrot passer til mange ulike produkt. Bøndene kompenserte svinnet med å produsere mer gulrot, ofte opp til 50 % mer for å fylle kontrakt kvoten til grossisten. Bøndene var mest opptatt av pakkerisvinn da dette utgjorde størst andel.

CONTENTS

PREFACE

During my years studying Agriculture at Hedmark university college I visited several vegetable farmers. It came to my attention that a substantial amount of their produce is never eaten due to postharvest out-grading and strict cosmetic standards set by wholesalers. I also observed a conspicuous amount of vegetables left unharvested, and this left me curious and with an urge to find answers to this phenomenon. This thesis is part of a bigger work of initiatives aiming for joint solutions to shared problems regarding resource efficiency and waste reduction (Norden n.d.). In 2012, the food ministers initiated three projects to reduce food waste in the Nordic countries. Collaborations between the Nordic Council of Ministers are aiming for green solutions and standards, as well as green investments in innovation and research field survey. The harvest loss surveyed in this paper has been part of this project. It is essential to create awareness among the growers, farm workers and managers, traders and exporters about the extent of losses to improve the marketing systems. Limiting waste is a contribution towards a more sustainable carrot production and I hope this work can help growers and wholesalers to understand this subject and realize the responsibility food producers have in this area. Thanks to Erik Svanes from Østfoldforsking for inviting me to join your project and write about this topic. Thanks also to Erling Stubbhaug in NIBIO for your advice and expertise regarding field surveys. And last but not least, thanks to farmers and pack-house managers for your time and patience answering the questions needed to conduct this survey.

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1 INRODUCTION

1.1 Global food loss

We draw attention to the topic of food waste with concerns about feeding the world population and depleting natural resources as key motives. Expected socioeconomic trends and developments make the current priorities more relevant and critical. Addressing and revealing the resource inefficiency food waste represents, we can form a strategy for tackling food waste and reaching a 'sustainable food' system. Current numbers show that up to one third of all human food produced is wasted along the food supply chain (Gustavsson, Cederberg & Sonesson, 2011). Studies commissioned by Gustavsson et al., (2011) estimated yearly global food loss and waste by quantity at roughly 30 percent of cereals, 40–50 percent of root crops, fruits and vegetables, 20 percent of oilseeds, meat and dairy products, and 35 percent of fish (Gustavsson et al., 2011). Several authors and researchers, (Stuart, 2009; Gustavsson et al., 2011; Parfitt Barthel & Macnaughton., 2010, European Parliament Council, 2013) have demonstrated the extent of this problem on a bigger scale. Unfortunately, empirical data and hard statistics are somewhat limited (Stuart, 2009, European Commission Joint Research Centre for Environment and Sustainability (JRC-IES), 2010). Norwegian food loss is estimated to be 361,000 tons annually (Hanssen & Møller, 2013). This waste is equivalent to 660,000 tons of CO2 and amounts to 13 % of Norwegian agricultural land (Lindahl, 2015). However, these numbers do not include loss on the farm level. Food loss represents a loss of economic value for actors in the food production and supply chains. The value of food lost or wasted annually at the global level is estimated at US $1 trillion (Gustavsson et al., 2011). The European commission and numerous nations have become aware of this problem and are implementing measures for reducing food waste (European Parliament Council, 2013; Gunders, 2012; European Commission for Environment and Sustainability, 2010; This is Rubbish (TIR), 2016; ReFed, 2016; Fox, 2013; WRAP & Global Commission on the Economy and Climate 2015).

1.2 Loss in primary production

Massive amounts of food go to waste even before leaving the farms, however the exact quantity of waste from farms is the biggest unknown of all waste statistics (Gustavsson et al., 2011; Stuart, 2009; Fox, 2013). Researchers have calculated waste from manufacturing, retail, catering and at the domestic level (Gustavsson et al., 2011; Parfitt, Barthel & Macnaughton, 2010; Stewart, Shepherd, Bellwood-Howard & Bowman, 2013). Yet, agricultural waste at the first step of the food chain is not adequately quantified. Waste separated on the farm is often not classified as waste, as farmers can plough it back into the fields. However, when farmers eliminate crops they have grown, it is still a huge squandering of food, land, water, agrichemicals and fuel. Loss at the agricultural level of the food chain has regional differences (Food and agricultural organization of the united notations (FAO), 1981; Parfitt, Barthel & Macnaughton, 2010). There is a clear relation between high income and quantities of food waste. In low-income developing countries, waste is minimal, and food loss is associated with wide-ranging managerial and technical limitations, lack of infrastructure, refrigeration, pasteurization, storing, and harvest techniques. The causes of pre-consumer food waste in medium- and high-income industrialized countries relate to overproduction to ensure contractual duties with supermarkets, appearance standards, failure to meet food safety standards (decay), an attitude that it is cheaper to dispose than redistribute, overstocked supermarket shelves (bad planning), consumer behavior and the policies and regulations put in place to address other sectorial priorities (Gustavsson et al., 2011; FAO, 1981). For example, agricultural subsidies may contribute to the production of surplus quantities of farm crops, of which at least a proportion is lost or wasted (FAO, 2014; FAO, 1981; Kader, 2005; Stewart et al., 2013). Cosmetic specifications imposed on exporters and farmers, predominantly by retailers, have led to systemic waste within the sector (Colbert & Stuart, 2015). Farmers bare the cost of this waste, even though it is not their fault. Farmers throw away on average on third or more of their harvest because of cosmetic standards (Stuart, 2009). Many will agree that this is not an efficient use of global resources (Fox, 2013; Gunders, 2013; ReFed 2016).

As far as current numbers tell us, harvest losses have several causes, including timing of the harvest, as well as harvesting techniques, equipment and conditions (FAO, 2013). In connection to harvest, products may be left in the field or be discarded when sorted, either due to defects making them unsellable or due to the price being so low that it is not profitable to sell them (Colbert & Stuart, 2015). In many cases farm workers are trained to only pick sellable produce. Produce that does not meet specifications is left on the plants or the ground. Market requirements, i.e. the requirements on appearance, variety, size, maturity etc. that wholesalers, importers and in the end consumers have are as essential as is the price they are prepared to pay for the products (Parfitt, Barthel & Macnaughton, 2010). Cosmetic specifications dictated by retailers are a challenge for many farmers across the world where strict cosmetic specifications lead to food being graded upon its appearance rather than nutritional content (Stuart, 2009).

1.3 Agricultural Environmental Pressure

Food production is the single biggest impact we humans have on nature (Gustavsson, 2011; Hertwich et al., 2010; Foley et al., 2005). The increased demand for food has raised concerns about environmental impacts related to expansion of agricultural land worldwide (Van Kernebeek, 2015; Foley et al., 2011). Environmental pressures from agriculture cause habitat change, climate change, increased water use and toxic emissions (Hertwich et al., 2010). Substantial habitat losses have arisen due to increased demand for land for agriculture. Furthermore, increased pollution, habitat changes and species distribution changes have impaired the services that ecosystems provide (Hertwich et al., 2010). Between 1970 and 2010, approximately 18% of the Brazilian Amazon was deforested (Baccini et al., 2012), with the primary cause being demand for new land for agricultural cultivation (Barona, Ramankutty, Hyman & Coomes, 2010; Hosonuma et al., 2012). Agriculture is also one of the main drivers of climate change, water pollution and soil degradation when indirect impacts are accounted for (Hertwich et al., 2010). In the last 50 years, greenhouse gas emissions related to the food surplus increased from 130 Mt CO2eq/yr to 530 Mt CO2eq/yr, an increase of more than 300% (Hiç, Pradhan, Rybski, & Kropp, 2016). Avoiding food loss and waste may counteract the increasing food demand and reduce greenhouse gas (GHG) emissions from the agricultural sector (Hiç et al., 2016; Munesue Masui, & Fushima, 2015; Grizetti et. al., 2013). Minimizing postharvest losses of horticultural perishables is also a very effective way of reducing the area needed for production, enhancing food security (Kader, 2005; Kernebeek, 2016), as well as saving water resources (Lundqvist et al., 2008).

1.4 Sustainability in Norwegian agriculture

The desire for agricultural sustainability is well recognized in the Norwegian government and agricultural industry and is now accepted by most farmers (Landbruks og matdeaprtement Meld. St. 9, 2012, s. 16). However, a lack of sound environmental impact data considering the production cycle overall restricts implications. It is only with the development of risk assessment techniques and sophisticated models to map environmental fate that the problem can be addressed.

Food waste reduction is an area of growing importance among the Nordic governments as well as at the EU level (Gram-Hanssen, 2016). Tackling food waste has received much attention and governments, international agencies, businesses, local authorities, community groups and many others have worked with reducing food waste in different levels of the food chain (ForMat n.d.; matvett n.d.; CYCLE n.d.;).

In 2015, the Norwegian government signed an agreement of intent with the food industry, which aims at reducing food waste. A plan indicating goals and responsibilities is expected to be signed by mid-2016 (Regjeringen, 2015). The government has recognized the importance of reducing food waste in the name of reducing resource inefficacy and pollutants. The higher value and less loss and waste philosophy is strongly directing research policy in Norway. However, Norwegian food safety authorities are inclined to let the industry itself enhance food utilization and redistribution (Hanssen et. al. 2015).

1.5 Definitions of terms

Food losses refers to the decrease in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption. Food losses take place at production, postharvest and processing stages in the food supply chain (Parfitt et al., 2010). Food losses occurring at the end of the food chain (retail and final consumption) are rather called “food waste”, which relates to retailer and consumer behavior. (Parfitt et al., 2010).

We use the term waste and loss to include products that are grown with the intent of being used as food that are never delivered for human consumption. Products delivered to the food industry do not count as waste. Hence, waste includes products that are left in the field or used as animal feed. The food waste hierarchy posits that prevention, through minimization of food surplus and avoidable food waste, is the most attractive option. The second most attractive option involves the redistribution of food waste, followed by the options of converting food waste to animal feed. Unutilized food being disposed of is considered the least attractive opinion of the hierarchy (Papargyropouloua et al., 2014; European Parliament Council, 2008).

2 BACKGROUND

2.1 Carrot production

Carrots are the most widely consumed vegetable in Norway and are grown and stored for the fresh market, as well as canning, freezing and processing. It is a specialized crop, grown on contract for processing or consumption. Carrots are successfully produced and marketed and is the main vegetable grown in Norway (excluding potatoes). They are grown on about 15,563 dekar, with 52,635 tons produced (2014) (Statistik sentralbyrå (SSB), 2016), covering 84 % of the national consumption. Carrots have been cultivated in Norway since the 1600s (Balvoll, 1999), and have a strong position in Norwegian traditional food consumption (Vittersø et al., 2005). According to Totaloversikten (2014), carrots consumed per capita 2014 was 7.9 kg with an increase of 8.4 % from 2012 (Norwegian Fruit and Vegetables marketing board, (NFVMB), 2015). In 2015 carrots were sold for 322,420 000 kr annually (SSB, 2015) and accounted for 10% of vegetables (excluding potatoes) sold in Norway. The price for carrots is somewhat stabile and in 2014 was on average 7.18 kr/kg for class 1 to producers (Norwegian institute on bioeconomic research (NIBIO), 2015).

2.1.1 Key carrot growing regions

Norway's natural resources do not allow carrot production on a large scale all over the country and some regions have a higher concentration of carrot production. Production occurs on a range of soil types, typically sand, loam, and silt) and within different rainfall regions (low, moderate and high). Main carrot growing areas are situated in the most favorable areas; table 1.

Table 1*; Key carrot growing regions, productions area and development.*

County	*1996 Decar*	*2014 Decar*	*% of total area 2014*	*No. of farmers 2014*
Rogaland	2501	2786	17.9	43
Agder	581	279	2	8
Telemark	200	183	1.9	6
Vestfold	2812	3386	21	35
Østfold	557	741	2.5	11
Oppland	1008	2725	17.5	11
Hedmark	1866	2353	15.1	31
Nord og Sør Trøndelag	1574	2038	13	39
Møre og romsdal (Smøla)	184	281	1.8	11
Total production	12 332	15 563	-	-

2.1.2 Packing houses

There are 14 bigger packinghouses in Norway, and some smaller farm-based packing facilities. Packing houses are situated in carrot growing areas, owned by wholesalers or farmers or a combination. When selling to the fresh market, carrots are washed, graded and packed according to the retailer's requirements; damaged and misshapen roots usually go for livestock feed or for processing for industrial products. It is up to the wholesaler to decide crookedness or size. Carrots with visual fungal agents are not excepted in packaging to the retail market. Each market requires different root size, and grading for different requirements can ensure a high proportion of sellable roots.

The bigger packinghouses in Norway do sorting preformed with an optic sorting system. Carrots are washed, then on a high-speed conveyor belt, pass through a photographic sensor. A camera searches for defects like lack of color, bends, breakage or blemishing. Any specimen the camera detects which fails to match the pre-programmed ideal of carrots is discharged to an out-grading pile. The conveyor belt with the carrots left then passes to manual sorting for defects the camera is not able to detect. The remaining carrots are then packed and shipped straight off to the supermarkets. Some smaller packing houses do the sorting process manually. The wholesaler will only pay for what they are able to deliver to the client. The rest of the carrots are rejected, in turn being fed to livestock or sold to industry processing. Packing houses pack based on standards received from the wholesalers, and this is confidential information.

2.2 Measures of harvest and postharvest Waste

As we look into this important crop we want to find actual solutions on how to reduce waste with the intention to make this production more profitable and effective and at the same time save limited resources. There is a strong interrelationship between the three stages of production, harvest and post-harvest. I will not go deeply into pre-harvest topics, but will look at the broad reasons for decay under storage and size variations causing out-grading at the packing house, also mentioning factors contributing to harvest difficulties contributing to higher loss during harvest.

2.2.1 Storage

Mature carrot roots are usually harvested during autumn and placed in cold rooms until washing, sorting, packaging and distribution over the following year. During storage, carrots are vulnerable to different microorganisms that can cause a variety of postharvest diseases (Ghorbani et al., 2008). Carrots is a perishable product, and inadequate temperature management during storage causes water loss and decay. Most carrots are stored for a time after harvest, up to 8 months and fungal agents cause considerable loss due to improper storage conditions (Thorne, 1972; Van der Berg, 1981; Suojala, 2000). These agents and diseases causing loss are many and are a major concern to growers (Tülek et. al., 2011). Type of decay is temperature dependent and carrots must be stored at 0-1 Celsius with relatively humidity on 98-100% for minimum loss (Apeland & Hoftun, 1974; Van den Berg, 1981). In Norway, the two most important post-harvest diseases in carrots are licorice rot, caused by *Mycocentrospora acerina* and crater rot caused by *Fibularhizoctonia carotae* (Wold et al., 2015; Hermansen et al., 1995). Also Cavity spot (*Pythtium Sulcatum and P. Vialoe)* leads to frequent high rejection rates during grading worldwide. Preharvest conditions such as the type of soil, cropping systems and fertilization can also influence the development of storage pathogens (Ghorbani et al., 2008).

Water loss from carrots substantially increases susceptibility to infection by fungi (Gooliffe & Heale, 1977; Thorne, 1972). Quality and storability have also been found to be affected by sowing time, harvest time and development stage when harvested (Suojala, 2000; Wold, 2015; Hardenburg, 1986). Least storage loss has been found to be when carrots are harvested when yield increase or improvement in quality or storability is at the top without increasing the risk of frost injuries (Suojala, 2000). Fritz & Weichmann, (1979) found a very close correlation between storage loss and weather conditions during the last two weeks before harvesting. The study showed that increased rainfall intensity and relative humidity led to a higher rate of storage loss. Likewise, late sowing date has been shown to be good for storability and low decay (Wold et al., 2015). Uniform seed quality is also essential for limiting emergence of storage diseases (Gray & Benjamin, 1991). Factors affecting storability are partly explained by development of antifungal metabolites (Furocoumarins) within the carrots, which develop late in the season (Suojala, 2000; Wold, 2015; Hardenburg, 1986; Davies & Lewis, 1981). Diseased carrots displayed lower levels of Furocoumarins (Ceska et al., 1985).

2.2.2 Cultivation

Plant density and spatial arrangement will affect the plant fresh weight and size (Salter, Currah & Fellows,1980), and the grower can achieve a high rate of saleable produce by choosing right row systems and using suitable harvesting equipment. Disease control is also a pre-harvest concern, and by controlling pathogens in the field, growers minimize opportunities for postharvest decay to develop (Gooliffe & Heale, 1977; Apeland & Hoftun, 1974). The risk of storage loss posed by fungal agents can also be reduced through a well-planned and long crop rotation, typically 5- 6 years (Hermansen et al., 1997). Also, the right level of fertilization of all essential nutrients is crucial to prevent various nutrient deficiencies or over-fertilization, implying problems with storability and required size (Harrington, 1960).

Chemical and other forms of suppression of diseases and weeds is common practice, and consequently numerous sprayings and other measures are needed during growing season. How successful the grower is with pest control procedures will determine the later extent of problems with losses. Weed management is essential to reduce storage loss and harvest loss. Many plant species including ornamentals, vegetables and weeds are host to soil borne diseases (Hermansen, 1992). Weeds cause reduced yield due to competition and cause uneven development of the crop and hence uneven ripening or maturity and choke the harvesting machinery so as to make the operation less efficient (Swanton et al., 2009; Arthey & Dennis, 1991). Cultivation practice, like sowing date and weed management, has a clear effect on the amount and adverse effects of weeds (Swanton et. al., 2010). Swanton et. al. (2010) and Williams (2006) found that early planting increased the duration of the critical weed-free period and increased the need for multiple herbicide applications.

2.2.3 Harvest operation

Harvesting is a very crucial operation in which fresh carrots are removed from the ground after completion of growth and development. This also marks the last cultivation operation for the crop in the field and the beginning of its postharvest handling. The method of harvesting, injury to carrots during harvesting, and weather conditions during harvest greatly determine the extent of decay loss during subsequent handling and storage (Apeland, 1974; Nilsson, 1987; Geeson et al.,1988). Much of postharvest decay occurs in conjunction with breaks in the epidermal layer, and careful handling during harvest is important to minimize mechanical injuries (Bartz & Brecht, 2003). Stress failure has been shown to be higher with increased dropping heights and force applied (Cantwell et al., 1991). Hence, developers of carrot harvesting machines are also striving towards minimal breakage during harvesting operations (per com. Stobbe ASA- Lift). Cracking of carrots that occurs during various handling stages is detected at the sorting table before packing.

In Norway carrots are harvested with a top lifter from mid-august to late October and later washed and packed to be shipped off to the retail marked. With a top lifter carrots are harvested before the leaves have died down. The carrots are loosened and lifted in the soil by a share blade. As they are loosened, the tops are grasped between 2 belts and conveyed up to the toppers. Rotating bars or discs remove the foliage, which are dropped out in the back. When the carrots are topped, they drop in a cross conveyor that moves them to a sorting table or to an elevator. From this point, the carrots are conveyed into boxes after harvesting. Dirt is removed during these processes with shakers and rubber bumpers. The smaller machines have sorting tables, with manual sorting of misshaped carrots, rocks, and foliage that is not supposed to be in the boxes for storage (ASA-Lift A/S, n.d., b.). Wastage during this process takes place. Adjustments of harvest machinery is essential to provide good harvest procedure that give good produce and low field losses (ASA-lift n.d. a.). The top lifter offers a very effective harvester technique with possibilities to harvest big areas in a short amount of time with few workers, and has been the major machinery for harvesting carrots for the last 40 years (Nordby, 1979; Apeland, 1974). Typically, one row harvester has been the most common, however farmers tend to invest in even bigger machines striving for more effective harvest (personal communication ASA-lift AS Norway).

2.2.4 Cultivars

The carrot as we know it today is the result of constant selection from its origin in the old Persian empire (Rubatzky, Quiros & Simon, 1999; Bradeen & Simon, 2007). The first documented orange carrots were in Netherland during the seventeenth century. With clear breeding goals carrots have become an important crop, globally ranking as the seventh most important crop based on nutrition (Alasalvar et al., 2001). Carrots have a stable production worldwide with some increase in Asia (Bradeen & Simon, 2007). Cultivars vary considerably in color, shape phenolics, antioxidant vitamins, and sugars (Alasalvar et al., 2001). Selection for improved carotenoid content has been highly successful for carrots (Rubatzky et al., 1999). Improved cultivars, especially hybrids have enhanced average carrot yields. Close to half of yield increase between 1955 and 1975 is due to use of hybrid carrot cultivars (US) (Simon, 2000).

In regard to reducing harvest waste, selected breeding for increased foliar strength is essential. This is done by screening for resistance to diseases weakening the foliage, particularly Alternaria leaf blight (Caused by fungus A. dauci) and numerus other diseases (Bradeen & Simon, 2007). Regarding storage waste, selecting for resistance for storage diseases is important, especially for the northern countries where storage time is considerable long. Big breeder companies have altered breeding programs to diverse markets in different regions. M. Simon Williams, a carrot breeding expert for Clause vegetable seeds AS, confirms this (pers. Com. 29. November, 2015). Along with year, variety has been shown to have the highest impact on carrot quality (Seljåsen, 2012). Indicators such as the metabolism of phenolics are used to evaluate the quality and storability of carrots (Alasalvar et al., 2001). In addition to cultivar genetic differences, root size and quality are also strongly influenced by plant population, sowing date, time of harvest, soil fertility and water supply; complete uniformity is considered unachievable (Soffe et al., 2003; Tsukakoshi et al., 2009).

During harvesting, transportation, washing, sorting and packing, carrots are subjected to mechanical stress that may bring about a high percent of product loss. Mechanical damage results in substantial economic losses to the carrot industry (Knott, 1980; Cantwell et al., 1991) and have been one of the main concerns when developing new cultivars (Hole, 1999). Environment, developmental stage and cultivars have been shown to affect cracking susceptibility (Millington, 1984). Carrot breeders are continuously working at increasing the tissue tensile strength, fracture toughness and residual strain for roots (Cantwell et al., 1991). High root turgor has been found to promote splitting, and is associated with irrigation and fertilizer regimes (McGarry, 1993, 1995).

3 THE AIM

Loss during fresh market carrot production in Norway was determined through a number of objectives. The main objectives of this study were: 1) to quantify the amount of the unharvested carrots after machine harvest of carrots in southeast Norway, 2) to determine the factors contributing to carrot harvest loss, we expected to find less waste where machines were fully automated and easier to maneuver, less waste where soil conditions were dry, and possibly that cultivar or grower would have a correlation to field loss. Additionally, we wanted to 4) quantify the amount of out-grading/rejects at all packinghouses in Norway, 5) determine the causes for out-grading, and 6) to discuss possibilities for redistribution of out-graded carrots to further processing industries and other measures to avoid pack house loss. Questions around waste during primary production of carrots allows discussion of barriers, challenges and dilemmas preventing the objective of contributing to sustainably feeding the world through total utilization of raw materials in the food supply chain. By our empirical measures and a deeper insight, possibly our measures contribute to avoiding some of the field loss.

3.1 Further limitations

This current paper discusses waste at the first stages of the distribution and marketing chain starting with harvesting and continuing on to storage then to sorting at the packing house. On the other hand, it does not include waste during further transport or during the retailer and consumer stages. In this paper, storage diseases of carrots and the proposed control methods against these diseases have not been compiled further. Nor have pre-harvest management strategies for post-harvest disease control. However, I will investigate the broad extent fungal diseases cause grade out at the wholesaler. The economy plays an important role in waste as profitability is an essential factor driving the choices in many areas regarding carrot production and sale. This will not be included in this study. We looked at quantities of harvest and pack-house loss, but loss and its impact on marketing cost, margin and efficiency will not be thoroughly elaborated. The numbers also did not account for unharvested carrots caused by wet areas and spillage beyond the harvest operation.

4 MATERIAL AND METHODS

4.1 Field investigation harvest loss

The data collection was conducted during the 2015 harvest season at 12 different carrot field locations in the eastern part of Norway (closer description in table 2). In the period from 21.09 until 14.10.2015, the 12 fields were investigated for waste of carrots on field after mechanical harvest.

4.1.1 Field investigation

There were 5 carrot varieties represented; see table 2. Soil condition was determined after visual and physical testing and divided in three categories; very dry, dry, wet, very wet.

Table 2. *Field places and further information.*

Field	**Place**	**Date**	**Soil**	**Condition**	**Variety**	**Machine**
1	Romedal	13.10.	Moraine	Dry	Triton	130 D
2	Stange	13.10	Muck soil	Dry	Romance	Standard
3	Romedal	30.09	Muck soil	Dry	Romance	Standard
4	Ridabu	25.09	Muck soil	Wet	Romance	Standard
5	Stange	28.09	Moraine	Dry	Panter	T250
6	Stange	28.09	Moraine	Dry	Rainbow	T250
7	Lågendalen	21.09	Silty sand	Very wet	Romance	T250
8	Romedal	14.10	Moraine	Dry	Nominator	Standard
9	Ridabu	13.10	Moraine	Dry	Namdal	Standard
10	Lågendalen	22.09	Silt	Very wet	Nominator	T250
11	Oppakermoen	21.09	Silty clay loam	Wet	Romance	T250
12	Oppakermoen	21.09	Silty clay loam	Wet	Romance	T140B

4.1.2 Provisions

Baskets for collecting carrots, tape measure, rope and sticks for marking the area and a digging fork with flat tines, ensuring digging without further damage of the roots, scale with two digits

4.1.3 The harvester machine

Mechanical harvesting was performed by different ‘Asa-Lift’ harvesting machine with 4 different models performing top lift harvesting, Asa-Lift A/S Dianalund, Denmark. The main differences between the models were automatization of several devices see table 3.

Table 3: *Some specifications in the different top-lifter models.*

Model	*T250*	*Standard*	*D130*	*T140B*
Two row lifter	Yes	No	Yes	No
Manual out grading at sorting table	No	Yes	No	No
Automatic gathering belt speed	Yes	No	Yes	Yes
Automatic steering of torpedoes	Yes	No	Yes	Yes
Automatic share depth	Yes	No	Yes	Yes

4.1.4 Machine settings and daily inspection lists

The harvester process involves numerous operating procedures. The location, functions, movement and control of these aspects requires a lot of ability to command. To obtain ideal efficiency under harvest these segments require continuous monitoring. The machines have a variety of settings and adjustments to accommodate the variety of crops, soil and moisture. Settings require adjustment according to operating conditions in field (ASA-Lift A/S). For instance, the adjustments of the share depth and width have different requirements regarding soil conditions. The foliage gathering belt and torpedo width and angle adjustments also need specific adjustments due to conditions in the field (ASA-Lift A/S), see picture 1 and 2.

Ground speed and gathering belt speed adjustments are important points for reducing loss on the field. The best results are obtained when the gathering belts are set to move 10 % faster than the ground speed. This allows the belt to clamp onto the foliage just as the share loosens the soil and lifts the carrots out of the ground. If the belts run faster, they can break the foliage from the carrot before the soil has been loosened and the carrot will not be picked up. If the belts run too slow, some foliage will slip through the belts and be missed or grabbed too high and go through the topers without being topped. Digging depth of the share can also effect the loss. Set too shallow it cuts off the tips and parts of carrots are left in the field (ASA-Lift A/S).

Picture 1,Torpedoes (Photo ASA LIFT A/S).

Picture 2. Foliage gathering belt and share.

4.1.5 Method of measuring waste

The fields were harvested the same day or in two cases the day before the investigation was conducted. Selecting 3 random areas of the field, of 6 m x 1,5 m. Preferably, the location is placed on the last harvested row, to prevent the location to be compacted from field machines. With a flat peaked fork, the area is carefully gone through at a depth of 30 – 40 cm (the depth of the share). Moreover, all carrots within the plot were collected in plastic baskets. The carrots were weighed. Yield samples were collected in an unharvested row, preferably next to the place where the loss sample was measured by registering the weight of 1 m. of a row, repeated 3 times; as seen in the picture 3. In both cases, foliage and soil are discarded before weighing. Notes were made on harvester model, soil type, soil water content under harvest, grower and crop variety.

Picture 3, 4, 5: From the left: 3. yield sample, 4. loss sample area after digging, 5. counting and overview of loss sample.

Statistical analyses were performed by using Excel, version 2010, and responses were analysed by generalised linear models in R 3.1.1 (http://cran.r-project.org/).

4.1.6 Interviews and observations

In addition to talking to the farmers on site during the field investigations, primary data was gathered through informal semi-structured interviews held with the farmers. Interviews were conducted either face to face or by telephone after the harvest season ended. Semi-structured informal interviews were chosen as a method of research to avoid restricting interviewees to answering questions within a strict format.

4.2 Parkhouse survey

4.2.1 Mjøsgrønt and reasons for outgrades

Secondary data was collected from one major packinghouse to find out-grading reasons the last two seasons 2014, 2015. This packing house was chosen because they kept accurate registration of status of all carrots before packing, registering exactly what error would be the reason for the out-grading. This is one major packing house in Norway and numbers are a good representative for the whole industry. Carrots out-graded for cosmetic reasons like size, shape and mechanical damage or breakage were considered edible.

4.2.2 Gathering out-grade numbers from all packinghouses

Secondary data was gathered via desktop research and communications with industry experts. Semi-structured interviews with managers of all pack houses selling carrots to wholesalers in Norway were conducted where and a total of 19 replied, see Appendix A for a list showing the different packing-houses. Information on amounts of out-grades, and to what extent rejects being sent to industry or sold as livestock feed was essential.

4.3 Growing season recap for 2014-2015.

The growing season of 2015 was characterized by a cold spring and summer and warm fall in the eastern part of Norway. Precipitation was much higher than normal, coming as heavy rain in a short amount of time (Stabbetorp et al., 2016). The 2014 season was warmer than normal, especially July was 4,2 °C warmer than normal temperature. Precipitation was a bit lower than normal, but there were some periods of heavy rain (Stabbetorp et.al., 2015).

4.4 Usage of rejected carrots in industry

Semi-structured interviews of managers of carrot processing industries were conducted to get information on where some of the out-graded carrots are used and to what extent. We received numbers of used out-graded carrots from industry from 6 different industries, See appendix B:

5 RESULTS

5.1 Carrots left unharvested

We found on average 4.7 % carrots left unharvested in field; table 4. We expected to find less waste where machines were fully automated and sensors and the machine will adjust share height and belt speed during harvesting according to within-field variations in soil conditions and carrot size. We also expected to see more loss under harvesting in wet fields where harvesters have more difficulty pulling carrots up. However, analysis shows no significant variations between the parameters harvester model, soil type, soil conditions under harvest, grower or crop variety. No p values under 0. 21. We consider carrots left in field as lost since the carrots are crushed by the machines and the soil is compacted and carrots are impossible to salvage.

Table 4: *Waste on field showing kg. waste per decar and percent waste according to yield.*

Farm	Waste kg/decar	SE	Waste % of yield	SE
1	379	169.99	3.5	1.57
2	137	41.65	2.59	0.78
3	279	44.25	3.07	0.49
4	368	98.86	5.44	1.46
5	381	173.98	5.09	2.32
6	222	43.15	2.62	0.51
7	826	355.17	8.60	3.70
8	611	276.66	9.12	4.13
9	409	125.74	4.83	1.49
10	320	58.38	3.69	0.67
11	150	66.07	1.50	0.66
12	601	275.21	5.99	2.75
Average	390	53,53	4,67	0,63

5.1.1 Field observations

While gathering field waste samples harvesting was ongoing and we were able to observe the process closely to see what could be evident causes on unharvested carrots.

- **Carrot with foliage intact** still standing, indicating misplaced torpedoes. In some cases, this amounted to a big share of the loss in field. This was observed as few meters here and there specifying where driver had missed the row with the torpedo. Typically, when driving fast and with uneven grown making harvester unstable and shake.

- **Foliage ripped of** - Carrots were observed still standing in the ground, but with the foliage gone.
- **Unharvested areas** - Occasionally farmers reported that they left crops unharvested in certain areas of the field if carrots did not meet the specification requirements from the wholesaler or harvesting conditions were too wet for the machine to go through. Typically, this occurs in sunken areas of field where growing conditions have been bad and soil water content is too high.
- **Carrots dropped off the belt-** carrots dropping off while lifted up.
- **Field variations** -We found a large variation on loss within individual fields especially where soil type was non-homogeneous and in hilly fields.

5.1.2 Interviews by growers

Semi-structured interviews of the nine carrot farmers about their methods and experiences with harvesting regarding loss on field was conducted. Growers were in general aware of the many choices that could affect loss under harvest.

- **Optimal maneuvering** of the harvester was the most common reason for loss given. Especially with bigger machines demanding more headland. Small spacing required more skill in maneuvering the harvester.
- **Continual surveillance** while the harvester is running to detect any changes and need for adjustments was important. In cases with sufficient workers present, functioned as a guard for anything happening with the harvester. They recognized what was wrong and alerted the driver so the harvester could stop and deal with the problem. Several farmers that had changed from a smaller machine to a bigger without a sorting table mentioned not having a person paying attention in the back as a disadvantage. However, the harvest operation is a big expense involving 4-6 people and effective harvesting is crucial for net profit, and farmers looked at this as an important part of the assessment of the harvest. Well aware that loss occurred, driving slower and closer maintenance implies bigger expenses in form of labor cost. The farmers reported that hiring an additional person or spending more time adjusting and monitoring the machine could cost more than the value of reducing carrot loss in field.

- **Soil variations within a** field is a big disadvantage. For instance, carrots varying in size due to different growing conditions, soil conditions being different, different harvesting conditions in general. This makes adjustment choices in the harvester difficult. Adjustments must in the cases with big field variations be made with some compromises, trying to hit an optimal medium.
- **Soil preparations** creating a uniform and even seedbeds and growing carrots on drills was mentioned as important factors for limiting harvest loss. Harvesting was harder with uneven ground in field. Also growing only two rows on a drill and not three, preventing soil from covering the third row. This was explained as factors making the machine easier to maneuver and subsequently reducing harvest loss.
- **Choosing the right cultivar** was also an important aspect for the farmers, choosing a cultivar with a strong foliage that reduced the risk of waste on the field. But the cultivars had to meet the expectations on storage and yield requirements. Farmers were satisfied with the cultivars available on the market.
- **Weed management** was mentioned as important in regard to limiting field loss. This was due to the weeds becoming tangled up in the harvester and requiring additional stops to remove the weeds. Every stop was mentioned as a risk for increasing the loss. After a stop, the machine requires several meters before functioning optimally. Additional stops are also costly due to extra time spent. This was also the case in stony fields whenever big rocks struck the share and needed manual adjustments.

Negligible losses

The interviews showed that harvest loss was in many cases considered as unavoidable and in most cases negligible losses and the farmers were not concerned about loss of carrot yield under mechanical harvest. However, the farmers that had recently changed to new harvesters were more concerned about loss on field and to ensure good routines and making sure the harvester's adjustments were right. When the growers were familiar with their own machines, concerns about loss under harvest was no big matter. The farmers were well aware of some loss in field and this was accounted for when estimating the amount sown in spring. The farmers plan to grow 30 -50 % more than contracted to supply in case a bad season and high out-grading percent.

5.2 Grade out at the Wholesalers Mjøsgrønnt

A closer survey at one wholesaler through two seasons 2014-2015, with in total of 25 samples was used. Results showed carrots rejected for many reasons divided into 5 categories; table 5. We found that ca 50% of the out-grades was at this specific packing house considered highly edible and were rejected for being the wrong size – too big, too small, too wonky or suffered some form of damage during harvesting and had no problems with nutritional value. The rest, approximately 50% of the out-grades was rejected due to different fungal disease creating brown spots and decay tops and ends. Decay loss is increasing as longer the carrots are stored. In the beginning of the season loss due to decay is almost nonexistent, whereas later in season can be up to 70% in some lots.

Table 5: Average out grade % with different reasons at the wholesalers' packinghouse

Grade out reason	*Average*	*SE*
Size	5,7	1,3
Storage Disease	15	2,7
Mec. damage	3,44	0,55
Wrong shape	14,4	1,6
Growth crack	2,3	0.53
Total out-grade	34	3,3

Out-graded carrots in September, utilized as animal feed. (photo Rebekka Bond)

5.3 Interviewing packing house managers and industry production

In total of 20 managers were interviewed both big packing facilities and small farm based packing houses. Pack-house waste was in total 20 % after subtracting loss being redistributed to industry. We found that 27 % of fresh market carrots where out-graded on a national level at packing houses. With current production this amounted to be 10,000 kg annually. Only five packinghouses had routines of shipping out-grades to industry, in total 2500 kg of the out-graded carrots were utilized as human food and redistributed to industrial processing. The remaining 7500 kg of out-grades was used for animal feed, mainly cattle, horses and wild cervids. Due to short durability of the carrots after washing and cold storage requirements, not all packing houses had facilities for an efficient handling of out graded carrots. Once the carrots have been washed they need to be treated quickly in order to maintain quality. In many cases it is not profitable to transport small amounts of out-graded carrots. All facilities receiving carrot rejects for further processing was situated in south east Norway. Some of the carrots where transported from Trøndelag region to these fa cilities. . Out-grading of carrots from the packinghouses was found to be highly season dependent

5.3.1 Industrial usage of carrots.

Interviews of carrot processing industries managers revealed that 10.000 tons of Norwegian-produced carrots is annually used for industrial products. 25 % percent of these carrots came from rejects at packing houses. As seen in 6.3 this amounted to be 2,500 kg. The other 75 % of industrial usage of carrots is contract based where industry order carrots directly from farmers, so called "black" carrots, sorted and washed at the industry facility. Carrots used in industry from out-grading is mostly used for fresh produce like different salads, carrot puré and precuts to commercial kitchens. Major bakers also use carrots in their assortment.

We found industries which facilitated high optic sensors sorting carrots before and after pealing made use of carrots to the greatest extent. Some facilities using mostly out-grades had a waste percent of 30 % including ends and peel indicating a total utilization rate on 70 %. This allows use of carrots with an early stage of licorice rot *(Mycocentrospora acerina*) and Carrot cavity spot (*Pythium spp*.) and other fungus where the decay easily can be peeled away or cut off with the ends.

Producers of frozen and canned products do not prefer out graded carrots, as these products require different quality, with size and texture and color. However, these industries are still using some out-grades, especially in years with higher demand, and failing yields from contract growers.

In cases where carrot size does not matter it was more profitable for industry to use out-graded carrots. In many cases using bigger carrots was still preferable for easier and faster handling with higher output. Different industries showed variance in suitability of out-graded carrots in different products; table 6. Considering potential uses when pack-house rejects are currently used with good experience regarding quality.

Table 6: Existing and potential use of out-graded carrots.

Uses of out-grades	*Existing*	*Big potentials*	
Direct sales	x	X	Bunnpris n.d.
Juice		X	Bama, Coop. (abroad) n.d.
Marmelade	X	X	Hansylte n.d.
Salat	X	X	Bama, Bondensgrønt n.d.
Frozen	X		Findus, NORREK n.d.
Canned	X		Smaken av Grimstad, n.d.
Bread	X	X	Bondensgrønt n.d.

6 DISCUSSION

Current study on loss under production of carrots resulted in the following findings; 1) The amount of the unharvested carrots was measured after machine harvest and revealed that on average 390 ± 53.5 kg was lost per dekar. This amounted to 4.6 ±0.68 % of the total gross yield. 2) The main factors contributing to carrot harvest loss were accuracy with machine adjustments and maneuvering due to uneven soil conditions in field, carrot foliar strength and weed management. However, no significant support was found correlating soil condition, soil type, grower, or cultivar and machine model to field loss. 3) The level of avoidable losses is hard to confirm since none of the factors tested proved to be significant, however enhanced continual surveillance of the harvester during harvest was repeated as essential, regardless of all the factors mentioned and despite the extra cost this measure will imply.

4) Additionally, we found that 10,000 tons (27%) of carrot produce is out-graded, rejected at packinghouses annually with current production. About 25% of the rejects were redistributed to processing, meaning in total of 7,500 tons of fresh market carrots is wasted annually. 5) numbers from Mjørgrønt showed the mean cause of reject of the total produce was shape and size 20 %, decay 17 % and mechanical injuries 3.3 %. 6) The mean utilization rate was 70 % from current uses of pack-house rejects for industrial processing. This implies possibilities for increased redistribution of out-graded carrots. In addition, allowing a bigger share of imperfect carrots to the retailer market is suggested to avoid pack house loss.

Our results on field waste can be supported by earlier studies done on waste during primary production of carrots (Svanes, 2013, Franke et al., 2013; Stuart, 2009).

Looking at studies on field waste of other vegetables, increased experience and familiarity with the best practice led to a reduction in farm level losses (Shahzad et al., 2013; Davara & Patel, 2009). We did not find significant support for this in the current study, but this question must be looked at more closely to exclude this factor. In other studies with handpicked fruit and vegetables, field loss seems to be higher due to a higher level of sorting in field during harvest (Stridh et al., 2014; Colbert & Stuart, 2015; Liu et al., 2014).

Our observations in field revealed some measures of improvement with the harvest procedure. Some loss was due to carrot foliage being ripped off, making the harvester unable to pick up the carrots. This could indicate that the gathering belt and ground speed are not synchronized, and adjustments are not precise. These problems were also present in fields using harvesters with automatic share depth, ground speed control and picking belt synchronization. This could indicate that these functions have improvement potentials. However, some cases where foliage is ripped off can be due to weak foliage, cultivar characteristics, foliage disease or crispy foliage due to frost (Suojala, 2000). In some cases the driver missed the row indicating the harvester is hard to navigate, especially where the field inclines or is uneven or where fields were small, causing difficulty on headland, especially with the biggest machines. However, automatic torpedo adjustments, which should be able to navigate in some unstable conditions, showed no significant reduction in waste in field. Our results were unexpected because the newer and more advanced harvester models were expected to leave less carrots behind. The automated adjustments not making any difference to field waste suggests other factors contribute to field waste. These uncertainties need closer inquiries to be definite.

Our numbers on average loss in field is estimated on the relationship between gross yield compared to unharvested carrots. However, carrot yields are not uniform on the whole field. Headland with increased soil compaction and other unfavorable conditions will give uneven yields (Johansen et geal., 2015). A field survey yield sample will have a net yield that is 25-35 % lower than gross yield after correcting for areas with lower yield (Personal communication with Ole Morten Nyberg, Norwegian Agricultural Extension Service). This could presume that our yield sample site and field loss site influenced our numbers depending on the conditions at the specific area, since our sample sites were decided randomly.

Loss due to mechanical injures occurring during harvesting and postharvest handling could indicate that handling of carrots through the different stages could be improved. Also, damage and physical injuries leads to increased decay during prolonged storage (Suojala, 2000). Interviews of farmers revealed improvement potential when filling the boxes regarding dropping height and breakage of roots. Earlier studies imply that loss due to breakage has had pronounced improvements (Knott, 1980).

What is most striking with our findings regarding out-grading reasons is that such a big share of the rejected carrots was due to cosmetic errors like size and shape. Arguably it is less justifiable to grade out carrots with the wrong size or shape compared to decayed carrots.

Our interviews with pack-house managers and growers confirmed the importance of seasonal differences in the causes of carrot rejection amount and reason. Seasonal differences are also claimed in numerous literature both when it comes to storage loss and size (Bratz & Brecht 2003;

Gray & Benjamin 1991). Season 2015 had a considerably late spring and many farmers sowed their carrot fields up to 3 weeks later than usual, resulting in many small carrots being out-graded. The previous year (2014) was warm and the out-grading percent was high due to many carrots being too big. The significance of season is most definite and will have an effect on the decay and size rejects. We could see that our secondary data from Mjøsgrønt had an out-grading rate on 34%, 7 % higher than the national average, indicating that these last seasons had a high out-grading rate.

Wold et al. (2015) confirms decay is a major problem in Norway regarding the goal of a high salable share of the produce. Carrots with decay are not wanted in the retail market, and if the carrots have incurred a disease during storage, there is not much left to do. However, many carrots with minor spots of decay have the potential of being utilized as human food., after cutting out the small affected part. As current interviews revealed, industry could utilize a big share of these carrots with current optic sorting systems. Carrots are produced in big quantities around the country, but facilities processing out-grades are only situated in southeast Norway. This may cause further problems due to shipping carrots across the country.

As the waste pyramid states (Papargyropouloua et al., 2014, European Parliament Council, 2008), the goal is to prevent waste from occurring, and therefore the farmers must do what they can to meet the specifications that the wholesaler demands, but as literature shows uniformity is unachievable (Soffe et al, 2003). And most definitely there will be some carrots that will not fit the set standard and become unwanted for the retail market. How cosmetic appeal is defined and what or who drives standards further in the direction of extreme stringency is a matter for debate. It is likely however that industry will need to reassess and reconsider some of these definitions if substantial waste reduction is to be achieved. And as far as some retailers have experienced, the portion going to fresh market can also be discussed, and be substantially higher if the sale of unusually-shaped carrots outside the common standard is increased (Intermarché, n.d.; Bunnpris, n.d.). However, this means selling carrots previously rejected at a substantially lower price. This is an important aspect of this phenomena. Selling class 2 carrots at half the price to the market will probably effect the sales of class 1 carrots, and the farmers' net profit. RedFed, (2016) claims in their report that this factor is the most problematic measure in reducing farm level waste, since selling cosmetically imperfect produce may partially cannibalize sales for top-tier, cosmetically perfect products. This is a matter of debate and is not intended to be answered here, but could suggest further inquiries.

6.1.1 Further possibilities

In order to reduce the waste, the existing carrot processing industry could use more of the out-graded carrots rather than contract-based carrots. However, some of the products produced in industry require specific types of carrots and out-graded carrots do not apply very well.

It's hard to know how much of the unutilized rejects can be redistributed in industry for further human consumption. Adler et al. (2014) found that if the packing house has the right facilities utilization rate is high. The cost of the process and the price of the products will often determine if there is any potential in the project. Carrot juice is for instance a good way of utilizing the nutritional value (Alklint, 2003) especially with new technology with no heat treatment (Savse n.d.; Dede et al., 2007). Currently there is no commercial carrot juice production in Norway and with technology and current imported juice there is reason to believe carrot juice could be sold and produced in Norway. Marmalade is a good example of uses that are innovative and promising, but current production is on a small scale (Hansylte n.d.). However, marmalade production is a big production in other countries (Sahar food industry n.d.). There is ongoing and recent research to increase nutritional quality of vegetable co-stream-based smoothies and other products through fermenting with health-promoting probiotic bacteria (Juvonen et.al., 2015; Løes, 2015). Research has also looked at carrots as an ingredient in bread (Blatt, 2011). Incorporated carrots in bread and other food also has benefits regarding nutritional and energy intake (Blatt et al., 2011). Also, with additional considerable social and economic implications, food redistribution can be seen as a way to enhance overall sustainable development.

We found that farmers plan to grow far more carrots than needed. Growers noted they planned to produce 30 -50 % more than contracted to supply in case there is a bad season and high out grading-percent. This has ethical implications regarding the resource utilization, extraction and emissions increased carrot production implies. Arguably, if the rejects go on to be used in other ways they are not actually wasted. I believe by exploiting available information and application of available technologies for the appropriate product there are big possibilities for greater redistribution of rejected carrots. Processing and product development through value addition has been found to be the best alternative to reduce postharvest losses with other crops (Davara & Patel, 2009) and could also prove to work for reducing carrot loss.

7 CONCLUSION

The main objective of this survey has been to generate knowledge about waste in primary production of carrots and how it can be prevented. As predicted, there is great potential for reducing carrot loss in the current system. Reducing waste during harvest is possible, with closer maintenance and adjustments of the harvester being one obvious option. Choosing the right cultivar and keeping diseases and weeds at a minimum level is also evident.

Measures to minimize loss during harvesting need to be profitable for farmers to initiate changes. Further development of carrot harvesters and awareness of waste among growers could lead to a better harvest with less waste.

We found as seen many times before that out-grading at the wholesaler packing house is substantial. A big part of the out-graded carrots was found to be fully edible. Further suggestion for avoiding pack house loss is that wholesalers' standards should be somewhat flexible, permitting more carrots to be packed and sold. And more focus should be on sending edible carrots for further processing so they end up as human food, rather than animal feed. This study suggests that of the 7500 tons currently wasted in packing houses, at least 70 % of this waste could be redistributed and avoided. As far as this thesis goes this requires technical upgrading and logistical adjustments, particularly in regions with no utilization of packing house rejected carrots, which is currently up to industry to initiate.

7.1 Further research

A more comprehensive study, including machine modifications and efficiency in different conditions is required to elucidate further uncertainties. Further research also needs to include infrastructure such as storage and cooling facilities as well as solutions for more specific usage of out-grades and its impact on farmers' net profit.

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9 APPENDIX

A: Packinghouses replied

Smøla produsentlag
Namdalen produsentlag
Jæren gulrot
Lauritz stokkeland
Jens Kase østfold
J&J Wiig, Orre
Lundstad grønt Toten
Haugslia grøntpakkeri
Lågen gulrot
Solør grønt
Trøndergrønt levanger
Produsentpakkeriet frosta
Børge sortland , Valnesfjord
Geir Hendrickson Valnesfjord
Valborgs gulrøtter , Stange
Toten grønt
Anders Tore Eggen
Mjøsgrønt , Stange

B:

FINDUS AS	3127 Tønsberg
BAMA Industri AS avd. Vegetabiler	3402 Lier
BAMA Industri AS avd. Salater	3414 Lierstranda
NORREK AS,	3267 Larvik
Bonden grønt AS	3070 Sande
Smaken av Grimstad AS	4886 Grimstad