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Solutions for minimising food loss on farm

March 2024

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Food Waste Innovation
Office of the Prime Minister's Chief Science Advisor

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Kaitohutohu Mātanga Pūtaiao Matua ki te Pirimia

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Project overview

The global challenge of food waste has gained increasing attention in recent years and the Sustainable Development Goal 12.3 is to halve global food waste by 2030. On-farm practices play a pivotal role in influencing the amount of food lost before it reaches consumers. The need to reduce food loss has never been more important, particularly in regions with a significant agricultural footprint such as New Zealand. Globally it is estimated 15% of food is lost before it leaves the farm.[1] This research project focuses on on-farm food loss and conducts a literature review of existing tools, technologies, management practices, and strategies designed to prevent, minimise, and manage on-farm food loss. Food loss occurs during the harvest/production stage which is what this review surveys. Resources pertaining to the later stages of the supply chain i.e. processing and retail are not included in the review.

Please note that due to time limitations, not all fruit or arable crops are covered in this table, which was completed over a 10-week period. The selection of produce for review was guided by production volumes in New Zealand, ensuring relevance to the New Zealand's agricultural landscape. Strategies were also categorised based on their applicability pre- or post-harvest. Google scholar, Web of Science, and Science Direct were the main search engines used in the literature review however grey literature was also included. This project was a collaborative effort with the Office of the Prime Minister's Chief Science Advisor, aimed at providing resources for their upcoming report on food waste prevention.

***Table 1: The table is a literature review on resources for food loss prevention, minimisation, and management during production for various types of produce*.**
String Example: “food waste” OR "food loss" OR "harvest loss" OR "on farm food recovery" OR "post harvest loss" OR "pre harvest loss" “storage loss” AND apple OR orchard OR horticulture

Table Column Definitions:

1. *Type of food loss and crop type:* Specifies the type of produce and identifies whether the food loss occurs pre-harvest or post-harvest.
2. *Production volume:* Indicates the quantity of the specified produce produced, with statistics primarily sourced from New Zealand if available.
3. *Volume of loss*: Provides an illustrative measure of the amount of waste generated, preferably with data sourced from New Zealand.
4. *Technological solutions*: Refers to innovative technologies utilised to prevent on-farm food loss.
5. *Management practices/Behavioural strategies:* Encompasses non-technological strategies and management practices aimed at mitigating on-farm loss.
6. *Challenges to implementation:* Identifies obstacles and difficulties encountered in implementing waste reduction solutions on farms.
7. *Examples from New Zealand:* Highlights specific instances of waste reduction solutions implemented in New Zealand, including companies involved in their development or deployment.
8. *Comments:* Offers additional commentary, insights, or supplementary sources related to on-farm food loss and waste.

Crop and type of food loss	Production volume	Volume of loss	Technological solutions	Management practices/ Behavioural strategies	Challenges to implementation	Examples from New Zealand	Comments
Apple production: Pre-harvest food loss. Main causes of loss:[2] • Labour shortages. • Not profitable to harvest. • Weather events.	In 2023, the projected apple production in New Zealand was 553,000 tonnes.[3]	In 2012 in the Central Otago region, it was estimated 2,669 tonnes of apples were lost due to not being harvested.[4]	*Automated harvesting:* Automated harvesting applications can solve the issue of labour shortages and harvest faster and more consistently than humans.[5] *In- field sorting:* Utilising an in-field sorting machine is a way growers can reduce the cost of post-harvest handling making harvesting more economically viable.[6] *Genetic engineering:* Genetic engineered apple varieties can reduce the impact of severe weather events making them stress tolerant and therefore less likely to fail to meet quality standards. Artic apples are a good example, as they don't brown easily when bruised allowing for fewer rejections.[7] *Protective netting*: Protective netting in orchards has a range of benefits for reducing fruit loss. They protect against intense sunlight and extreme weather events like hail and strong winds and provide a physical barrier against pests.[8]	*Gleaning:* Farmers could implement gleaning onto their apple orchard. This can rescue produce that has not been harvested by allowing volunteers and gleaning initiatives to pick remaining apples post-harvest.[9]	*Automated harvest:* Automated harvesters require a large upfront cost so adoption by growers is low.[10] *Gleaning:* Gleaning has many liability concerns for a farmer due to needing to be adherent to the food safety act which can affect farmer willingness to implement this strategy.[9] *Genetic engineering:* Genetic engineering has seen limited commercial success in horticultural crops to date. The commercial release of transgenic crops also has many regulatory challenges.[6]	Perfectly imperfect is an example of a company that practice gleaning to prevent food loss on farm in New Zealand.[11] Automated harvesters by Abundant Robotics are being used in the Hawkes Bay area to harvest apples.[12] Crop tide is a New Zealand company who have developed a novel sensor which allows growers to read the plant status directly from stem. This is an example of precision agriculture.[13]	The *New Zealand Food Act 2014* protects donors from civil and criminal liability that results from consumption of food donated by the donor as long as a few requirements are met.[14] *Image of a harvest assist application*

Crop and type of food loss	Production volume	Volume of loss	Technological solutions	Management practices/ Behavioural strategies	Challenges to implementation	Examples from New Zealand	Comments
 **Apple production: Post-harvest food loss.** Main causes of loss:[15] • Transport quality issues such as firmness loss. • Decay. • Internal disorders such as scab. • Bruising. • Consumer expectations.	(No Data)	In the Central Otago region, it was estimated by the Central Otago District Council that 124 tonnes of apples were lost in 2021 after being harvested.[4]	*Automated harvesting:* Automated harvesting applications minimise bruising and the picking of unripe fruit reducing food loss and waste.[5] *In-field sorting:* In-field sorting integrated with harvest assist platforms can be used to minimise losses in post-harvest storage by avoiding contamination of diseased fruit with healthy fruit and allowing gentle filling of buckets reducing post-harvest loss.[16] *Edible coatings*: Edible coatings can be applied to improve the shelf life of apples minimising post-harvest food loss.[17]	*Good harvest practices*: Quality issues can be greatly reduced in the apple industry when good harvest practices are employed:[15] • Not harvesting fruit when wet. • Padded buckets. • Gently filling of bins. • Opting for air suspension in transport vehicles. • Opting for the smoothest road to the pack house. • Training pickers to minimise damage. • Have strategically placed waste bins for unwanted fruit. • Avoid direct sunlight on harvested fruit with bin covers. *Training of staff:* Training of staff to focus on gentle handling of fruit when harvesting has the ability to greatly reduce rejections due to quality issues stemming from bruising and cuts on the fruit.[18] *Donations:* Donations give a destination for food not consumed or sold and help minimise food loss and loss by giving to those in need.[19]	*In-field sorting:* Currently there is minimal in-field sorting technology available to growers and upfront cost is high which means adoption by growers is low.[6]	Hazel Technologies works within the New Zealand horticultural sector across a range of produce to extend and optimise shelf life and quality of produce. Innovations they have created for the apple industry include:[20] • 1-MCP (1-Methylcyclopropene) treatment sachets which reduce ethylene production. • Hazel CA (an applicator product) which deploys 1-MCP. • Hazel Datica which allows the remote monitoring of post-harvest storage facilities. • Hazel Trex which is pre- and post-harvest genetic testing to improve quality of produce.	

Crop and type of food loss	Production volume	Volume of loss	Technological solutions	Management practices/ Behavioural strategies	Challenges to implementation	Examples from New Zealand	Comments
 **Kiwifruit production: Pre-harvest food loss.** Main causes of loss:[21] • Labour shortages. • Low market price. • Overproduction. • Pests. • Birds. • Weather.	In 2022, 568,000 tonnes of kiwifruit were sold which contributed to 38% of New Zealand's total horticultural export revenue.[22]	(No Data)	*Internet of things*: Internet of Things (IoT) can provide pest and disease information to farmers so they can quickly control them.[23] *Protected cultivation:* Protected cultivation by way of nets, foil or glass makes fruit much less affected by weather conditions and pests which reduces food losses.[18] *Electronic bins:* E-bins help open up kiwifruit picking jobs to a wider range of people as it reduces the need for pickers to carry around a bucket which can be physically straining.[24]	*Gleaning:* Farmers could implement gleaning onto their kiwifruit orchard which can rescue produce that has not been harvested by allowing volunteers and initiatives to pick remaining kiwifruit post-harvest.[8]	*Gleaning:* Gleaning has many liability concerns for the farmer due to needing to be adhering to the food safety act which can affect farmer willingness to implement this strategy.[8] *Protective netting*: Upfront investment costs of netting solutions are high.[15] *Automated harvesting:* Automated harvesters require a large upfront cost so adoption by growers is low. Many mechanical harvesters also require orchards to alter the shape of the kiwifruit vines.[5] Variation of crops and environment makes automated harvesters difficult to make commercially available.[5]	Perfectly imperfect is an example of a company that practice gleaning to prevent food loss on farm in New Zealand.[11] Growtech group is a NZ company developing specific hail and wind resistant nets for the kiwifruit industry.[25] The electronic E-bin was developed by the University of Waikato in collaboration with Zespri to combat the labour shortage issue and will be implemented in the 2023/2024 season.[24]	In order to grow gold kiwifruit, you need to obtain a licence in NZ which is costly, and many orchards opt to not cover their crops with netting solutions.[25] Although the article for the E-bin say it aims to be technically feasible, financially viable and desirable for all stakeholders data on cost of E-bin is not yet available.[24] *Image of an E-bin* 
 **Kiwifruit production: Post-harvest food loss.** Main causes of loss:[21] • Pre-mature harvesting. • Improper handling. • Mould. • Perishability. • Firmness loss during storage causing rejection.	(No Data)	The kiwifruit industry reports an estimated 38,000-40,000 tonnes of post-harvest food loss per year, amounting to approximately 8% of the total yield in New Zealand.[26]	*Treatments:* Calcium treatments have success in the storage of kiwifruit to maintain their firmness levels for longer.[27] 1-MCP treatments and melatonin have been successful at delaying ripening, reducing weight loss, and maintaining fruit firmness.[28]	*Training of staff:* Training of staff to focus on gentle handling of fruit when harvesting has the ability to greatly reduce rejections due to quality issues stemming from bruising and cuts on the fruit.[18] *Donations*: Donations give a destination for food not consumed or sold and help minimise food loss and loss by giving to those in need.[19]	(No Data)	Hazel Technologies is a company that works with New Zealand kiwifruit growers to provide solutions to extend shelf life, reduce rejections, and combat food loss. They have developed a sachet containing 1-MCP.[20] A Tasman grower donated 35 tonnes of hail damaged kiwifruit to New Zealand food networks distribution hub in late 2020.[29]	Training staff can be challenging as many horticultural workers come from overseas and so there may be a language barrier.

Crop and type of food loss	Production volume	Volume of loss	Technological solutions	Management practices/ Behavioural strategies	Challenges to implementation	Examples from New Zealand	Comments
Stone-fruit production: Pre-harvest food loss. Main causes of loss:[21] • Labour shortages. • Low market price. • Overproduction. • Pests. • Birds. • Weather.	In 2021, the average years production estimated in Central Otago were: • 11,987 tonnes of cherries. • 2,886 tonnes of apricots. • 5,906 tonnes of peach/nectarines.[4]	In 2021 volumes of loss due to non-harvested fruit loss occurred in Central Otago were estimated to be around:[4] • 1,086 tonnes of cherries. • 163 tonnes of apricots. • 233 tonnes of nectarines.	*Internet of Things:* IoT has the ability to provide real time data for the orchard environment which can assist in early pest signs, maturity and temperature which can help the farmer make decisions to ensure quality of fruit. These can be fitted with frost alarms and early pest detection systems.[30] *Protective covers*: Installing covers allows protecting against weather events, pests, and can also improve ripening.[31]	*Gleaning:* Farmers could implement gleaning onto their orchard which can rescue produce that has not been harvested by allowing volunteers and initiatives to pick remaining produce post-harvest.[9]	*Gleaning:* Gleaning has many liability concerns for the farmer due to needing to be adherent to the food safety act which can affect farmer willingness to implement this strategy.[9] *Protective covers*: Installation of covers requires a large initial investment and also has reoccurring costs due to maintenance.[19] Farmers and agricultural companies tend to only adopt new technologies based on financial assessment.[31]	Perfectly imperfect is an example of a company that practice gleaning to prevent food loss on farm in New Zealand.[11] Harvest is a New Zealand company which integrates IoT into their monitoring systems.[32]	
Stone-Fruit Production: Post-harvest food loss.	(No Data)	(No Data)	*Value-add products*: Value-add products are a way to manage waste and give a premium to the farmer. Stone fruit have a variety of beneficial properties and have many valorisation options.[33] *Treatments:* 1-MCP treatments can extend shelf life in stone fruit.[20]	*Donations:* Donations give a destination for food not consumed or sold and help minimise food loss and loss by giving to those in need.[19]	(No Data)	Eden's orchard makes a wide range of juices from imperfect fruit including cherry juice. They are also trialling freezing of processing grade cherries preventing them from going to waste.[34]	Usually some infrastructure required to make a value add product which could be costly in the beginning for the farmer.

Crop and type of food loss	Production volume	Volume of loss	Technological solutions	Management practices/ Behavioural strategies	Challenges to implementation	Examples from New Zealand	Comments
Grape Production: Pre-harvest Food loss. Main causes of loss:[21] • Labour shortages. • Low market price. • Overproduction. • Pests. • Birds. • Weather.	In 2023, there were 41,860 ha of producing vineyards in New Zealand, with 71% of them located Marlborough in the South Island.[35]	(No Data)	*Mechanised harvesters:* Mechanised harvesters could be implemented to solve the issue of labour shortages in vineyards and reduce losses.[36] *Precision agriculture:* Precision agriculture has a place in viticulture and has the ability to reduce risk of crop loss, disease incidence, labour costs and time management.[37]	*Gleaning:* Grape growers could implement gleaning onto their orchard which can rescue produce that has not been harvested by allowing volunteers and initiatives to pick remaining grapes post-harvest.[9]	*Mechanised harvesters:* Mechanised harvesting equipment can end up being more expensive than hiring workers and could cause the price of grapes to increase.[36]	Grape marc is the seeds, stalks and skins of grapes. Grape marc is a waste product of wine making and kiwi vineyards have been turning them into pellets as an alternative to burning coal.[37] Crop tide New Zealand has developed a novel sensor which allows growers to read the plant status directly from stem. This is an example of precision agriculture.[38]	NZ wine reports that 98% of wineries in NZ have waste reductions programmes in place and 75% of wineries have reduction initiatives. They also target for the New Zealand wine industry to achieve zero waste by 2050.[35] *Image of mechanical harvester in Slovak.* 
Grape production: Post-harvest food loss.	(No Data)	(No Data)	*Treatments:* Ozone treatments are shown to reduce decay of cold store grapes and are effective for controlling postharvest losses. Hazel technologies also works with grape growers and has 1-MCP treatments that can extend shelf life and also developed a mat that absorbs excess moisture reducing risk of fungal infection.[20]	*Donations*: Donations give a destination for food not consumed or sold and help minimise food loss and loss by giving to those in need.[19]	(No Data)	(No Data)	Most grapes produced are used in wine making and very few articles could be found on post-harvest loss of grapes.
Tomato production: Pre-harvest food loss. Main causes of loss:[21] • Labour shortages. • Low market price. • Overproduction. • Pests. • Birds. • Weather.	Approximately 60,500 tonnes of field grown, process tomatoes are produced each year, in Hawkes Bay and Gisborne.[40]	Estimated between 71.2% and 84.1% of produced tomatoes were left in the field and not harvested by two commercial growers in Australia.[41]	(No Data)	*Gleaning*: Farmers could implement gleaning onto their orchard which can rescue produce that has not been harvested by allowing volunteers and initiatives to pick remaining produce post-harvest.[9]	(No Data)	(No Data)	(No Data)

Crop and type of food loss	Production volume	Volume of loss	Technological solutions	Management practices/ Behavioural strategies	Challenges to implementation	Examples from New Zealand	Comments
Tomato production: Post-harvest food loss.	(No Data)	Estimated post-harvest loss for two commercial tomato growers in Australia was found to be between 40.3% (55.34 tonnes) and 55.9% (29.61 tonnes) of the total harvestable product. It was determined that between 68.6% and 86.7% of undamaged, edible, harvested tomatoes were rejected as out grades and consequently discarded due to product specifications.[42]	Evaporative cooling has shown to be effective at increasing shelf life in tomatoes.[41] Hazel technologies also works with tomato growers and has 1-MCP treatments that can extend the storage potential of tomatoes.[20]	Donations give a destination for food not consumed or sold and help minimise food loss by giving to those in need.[19]	(No Data)	(No Data)	This article talks about a method of making juices to reduce waste in the tomato industry.[43]
Grain Production: Food loss. Main causes of loss: • Pests. • Diseases.	(No Data)	(No Data)	*Integrated crop management*: Pests and diseases are the main reason for losses in grain production. Integrated crop management is a way to reduce losses. An example of this is introducing natural predators as a way to control pests.[44] *Cameras:* Farm Wave has developed a camera that attaches to harvesters and lets the farmer know how much grain is left behind during harvest so they can make adjustments to reduce waste.[45]	(No Data)	(No Data)	(No Data)	This article provides insights into food loss and waste technologies in a range of agricultural industries including grain production and how they can reduce greenhouse gasses.[46]

Conclusion

By categorising strategies based on their applicability pre- or post-harvest and including grey literature in our review, this has provided a review of diverse technologies and strategies currently available for mitigating food loss on farms. Also, by including examples it shows real world examples of these solutions in action and an insight on the extent they can mitigate food loss during production.

Glossary

Non-harvested loss	Loss that is not harvested (left on the tree). This could occur due to a variety of reasons such as maturity, quality, market demand, or labour availability.
Harvested loss	Fruit that is harvested but not able to be sold for human consumption and is lost on property (orchard or packhouse). Commonly called dumped fruit by most growers.
Food loss	Food loss is the decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retailers, food service providers and consumers.
Food waste	Food waste refers to the decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers, and consumers.
Internet of things (IoT)	Describes the network of physical objects - “things” - that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet.

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