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# Life cycle-based environmental management of food-related waste in a student dining hall

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## INTRODUCTION

Environmental problems require forward thinking and innovative planning to deliver robust and effective solutions to stand the test of time. Food waste (FW) quantification, behaviour and insight is largely focused on consumers, particularly households, as they are viewed as the biggest FW producers along the supply chain (Visschers, Wickli, & Siegrist, 2016). In this


**Figure 1: Interior of student dining hall at Massey University**

context, this paper discusses relevant FW management technologies, provides a stimulating approach in waste minimisation utilizing the nudge theory, and helps develop a better understanding of the environmental trade-offs between compostable containers and reusable plates in the student dining hall at Massey University, Palmerston North (Figure 1).

## SYSTEMATIC REVIEW

With many existing life cycle assessment (LCA) studies for FW management, it was determined that a systematic review would be beneficial in providing insight and recommendations for FW in the student dining hall. Zumsteg, Cooper, and Noon (2012) defines a systematic review as an organized evaluation of existing literature with the objective of answering a specific research or application question with a mixture of the best available evidence and data. This review methodology has proved important in producing robust synthesized results from existing research which would otherwise prove difficult due to inconsistent methods and differing assumptions that can affect the outcome found in individual studies (Heath & Mann, 2012). The common function unit used in the review was 1 tonne of FW and 13 different impact category results were extracted from the studies, (e.g. Global warming potential (GWP)) and data harmonization was used to make the results comparable in each impact category and waste treatment methods with recalculation and correcting differences in system boundaries. Not all of the 12 studies contained all 13 impact categories included in this review, but all studies included GWP as a common reference point for comparison, with the main findings from each study detailed in Table 1.

Table 1: Existing FW management LCA studies included in the systematic review

| Reference | Waste technologies | Main findings from individual studies |
|---|---|---|
| Mondello et al. (2017) | LF, AD, CP & AF | AF is better than CP for material recovery, AD is better than LF for energy recovery |
| Edwards, Othman, Crossin, and Burn (2017) | 2 x LF & 2 x AD | AD has lower environmental impact than LF |
| Salemdeeb, zu Ermgassen, Kim, Balmford, and Al-Tabbaa (2017) | AD, CP & 2 x AF | AF preferred treatment option, difficulty with municipal FW to livestock is banned in the EU |
| Martinez-Sanchez, Tonini, Møller, and Astrup (2016) | AD & AF | Indirect effects affect results greatly, AF reduces this impact with land use changes avoided |
| Padeyanda, Jang, Ko, and Yi (2016) | CP & 3 x AF | Collection & treatment processes are the highest contributors, particularly in CP & combined wet/dry AF scenario |
| Xu, Shi, Hong, Zhang, and Chen (2015) | LF & 2 x AD | AD of FW has best environmental performance, LF has the worst |
| Evangelisti, Lettieri, Borello, and Clift (2014) | LF & AD | AD is the best waste treatment option, LF is worst |
| Vandermeersch, Alvarenga, Ragaert, and Dewulf (2014) | 2 x AD | AD of FW with AF of bread FW is better than AD of all FW due to high dry matter content in bread |

| Reference | Waste technologies | Main findings from individual studies |
|---|---|---|
| Righi, Oliviero, Pedrini, Buscaroli, and Della Casa (2013) | LF, 2 x AD & CP | Transportation of FW should be avoided/minimized, AD with CP of digested matter is the best option |
| Matsuda, Yano, Hirai, and Sakai (2012) | 2 x AD | FW prevention reduced GWP more than AD |
| Kim and Kim (2010) | LF, CP & 2 x AF | Wet AF is the best waste treatment option, LF is worst |
| Lundie and Peters (2005) | LF, AD & 3 x CP | Home CP is the best option, FW collection is a high contributor |
| Mean ranking score (out of 4) | LF = 3.4 | AD = 2.2 CP = 3 AF = 1.4 |

Where LF = Landfilling, AD = Anaerobic digestion, CP = Composting, AF = Animal feed production

When analysing the different impact category results, it is important to note that each category cannot be compared with one another as the results are not normalized, but rather a comparison between different waste technologies for each impact category can be made. Examining the average results compiled from data harmonization (Table 2), each technology was then ranked from best (1) to worst (4) for each of the assessed impact categories and averaged to formulate a mean ranking score in accordance with the methodology used in the study completed by Salemdeeb et al. (2017). Landfilling achieved the worst environmental performance out of the four technologies with a mean ranking score of 3.4 out of 4 and animal feed production achieved the best environmental performance with a score of 1.4 out of 4. Additionally, anaerobic digestion achieved the second best environmental performance with a score of 2.2 out of 4 and composting achieved the next best environmental performance with a score of 3 out of 4.

Table 2: Average impact category results from systematic review

| Impact category | Landfill | Anaerobic digestion | Composting | Animal feed |
|---|---|---|---|---|
| Global warming potential (kg $CO_2$-eq) | 582.58 | 176.94 | 449.66 | 97.88 |
| Acidification potential (kg $SO_2$-eq) | 0.67 | 0.29 | 1.54 | -0.30 |
| Eutrophication potential ($PO_4^-$-eq) | 0.63 | 21.10 | 1.38 | 0.21 |
| Human toxicity potential (kg 1,4-DB-eq) | 40.56 | 15.51 | 1.13 | 1.78 |
| Freshwater aquatic eco-toxicity potential (kg 1,4-DB-eq) | 13.89 | 43.53 | 60.49 | -164.07 |
| Terrestrial eco-toxicity potential (kg 1,4-DB-eq) | 0.01 | -27.48 | 54.67 | 0.06 |
| Marine eco-toxicity potential (kg 1,4-DB-eq) | $6.70 \times 10^4$ | $6.20 \times 10^3$ | $2.95 \times 10^4$ | $1.19 \times 10^4$ |

| | | | | |
|---|---|---|---|---|
| Ozone depletion potential (kg CFC-11-eq) | $1.18 \times 10^{-5}$ | $-3.45 \times 10^{-5}$ | $7.84 \times 10^{-6}$ | $-9.83 \times 10^{-7}$ |
| Photochemical oxidant formation (kg NMVOC-eq) | 1.25 | 0.71 | 0.67 | 0.22 |
| Photochemical ozone creation potential (kg $C_2H_4$-eq) | 0.26 | 0.05 | 0.15 | 0.06 |
| Abiotic depletion potential (kg Sb-eq) | 0.74 | -0.64 | 0.18 | -0.34 |

## NUDGING THEORY AND ANALYSIS

A new policy with the aim of composting all FW from the Massey University dining hall lead to sugarcane-based compostable containers and starch-based bio-plastic cutlery being introduced to reduce contamination concerns from non-compostable eating utensils, such as non-compostable plastic. However, following this change, 332.7 kg of landfill waste was being generated per week which consisted largely from the compostable containers, lack of clear signage on bins, and high contamination rates of food and compostable waste in other recycling streams. Previous studies analysing FW behaviour, particularly among consumers, generally refer to the Theory of Planned Behaviour proposed by Ajzen (1980) relating to people's beliefs determining their behaviour. However, this paper draws upon another theory which has been used successfully in healthy eating and policy-making studies and has been identified as a potential approach for waste behaviour studies. The nudge theory, proposed by Thaler and Sunstein (2008), suggests that pro-environmental behaviour can be encouraged through small interventions in processes through influencing consumer choices by "activating the unconscious mind and altering human behaviour predictably". More simply, subtle prompts ("nudges") can be used to change behaviour without taking choices away from the consumer.

Re-introducing reusable plates into the dining hall and ideally making them the default option for patrons was identified as a possible opportunity to minimise was. A nudging experiment was conducted to see whether consumers would conform to this change in the process by using subtle prompts from catering staff to encourage plate usage over compostable containers. Three trials were conducted during the dinner service for five nights each in May 2017. Trial I, considered the control of the experiment, examined status quo and the current dining hall operations whilst not changing any details or prompts for the students by staff. Trial II examined what happened when staff asked students whether they would like to dine in or take away, and this corresponded with either a plate or container being given to eat with. Additionally, if students were dining in and requested a container, they were given this instead of a plate. Trial III was examined what happened when staff used a plate as a default to serve the students dinner unless otherwise requested by the student themselves that they would like a container instead.

The results from each trial are shown in Figure 2 where the proportion of usage was calculated for students using plates, and using containers either dining in or taking away. The most significant finding from these three trials is that the usage of plates rose from 4.2% in Trial I to 25.1% in Trial II and 37.2% in Trial III which supports the application of the nudge theory to change consumer behaviour predictably. Although there was still a larger proportion using containers, over time it is expected that plate usage would increase even more over time with further use of nudging prompts.

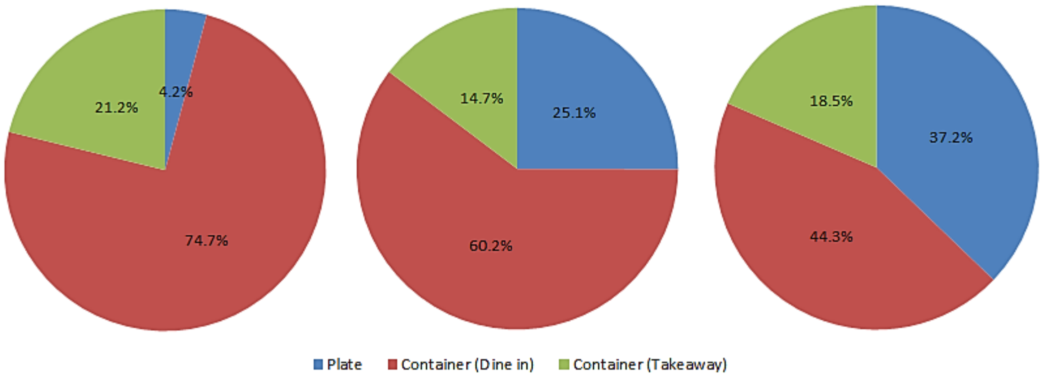


Figure 2: Proportion of plate and container usage in Trial I (left), Trial II (middle), and Trial III (right)

A subsequent analysis was then conducted four months after the trials in September 2017 to determine whether the status quo had shifted. The results of this analysis are shown in Figure 3 compared to the previous status quo examined in Trial I. Plate usage is now significantly higher than all three previous trials at 71.7% and it is clear that status quo has shifted with use of nudging prompts.

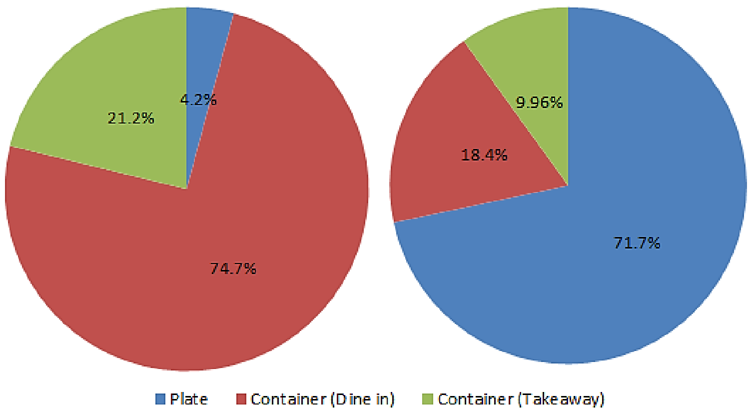


Figure 3: Proportion of plate and container usage in Trial I (left) and subsequent analysis (right)

## IMPLICATIONS

Currently, the FW from the dining hall is sent to a centralized composting facility run by the Palmerston North City Council and is diverted from landfilling. The systematic review results support the waste treatment method of animal feed production for FW. With concerns surrounding bovine spongiform encephalopathy (BSE), otherwise known as 'mad cow disease', any FW with ruminant-based proteins cannot be used as animal feed for ruminants, and any FW containing meat must be sterilized to meet regulations for other animal feed (MPI, 2017). As the dining hall consumer FW contains meat and other animal products, this would limit opportunities in how this would be treated and distributed to farms, and further research would need to be conducted to assess the viability of this option. Following this, anaerobic digestion, also known as biogas, is another viable option mainly due to benefits received from energy recovery. With the growing biogas industry in New Zealand, limited awareness and necessary technology not being as advanced as other countries, such as the Australia, UK, and countries within the EU, this would require further research regarding the viability in the context of the dining hall and wider New Zealand. In regards to waste minimisation in the dining hall, application of the nudge theory can be used to facilitate this and further improve processes in the dining hall. Taking into consideration the findings discussed in this paper, it is recommended that the dining hall continues composting all FW and compostable eating utensils, and changes in processes made through the use of nudging prompts should remain in use, and future opportunities should be sought to address other potential issues within the dining hall.

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# Outline

- Issues associated with global food waste
- Food waste in New Zealand
- Project design
- Findings of systematic review
- Findings of nudging experiment
- Conclusion

# Global food waste

- One third of all food produced is wasted[1]
  - Wasted inputs in food production[2,3]
  - Greenhouse gas emissions[4]
  - Soil and water pollution[3]
  - Land degradation and deforestion[4]
  - Food insecurity[5]


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# Waste in New Zealand

- 3.156 million tonnes sent to landfill in 2006[1]
  - 28% of this was organic waste

- New Zealand waste policy
  - NZ Waste Strategy 2002
  - Waste Minimisation Act 2008


[1]Ministry for the Environment. (2007). Environmental New Zealand 2007. Wellington, New Zealand: Author.

# Project design

**Aim**

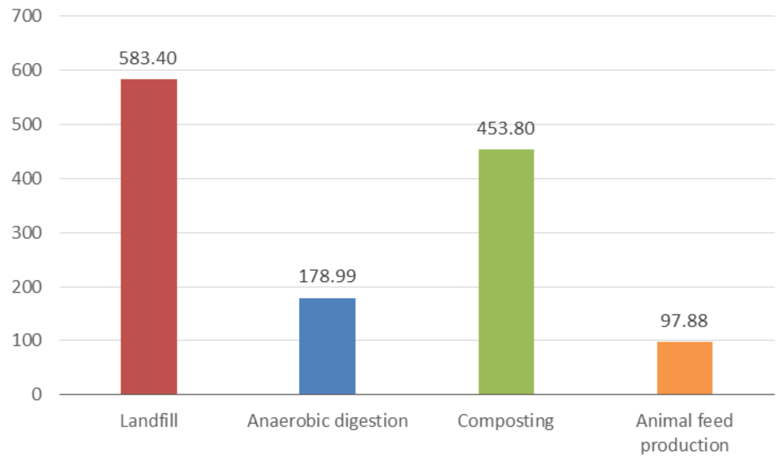
- To assess current and potential food waste management technologies
- To investigate the environmental and cost trade-offs for plates vs. compostable containers

**Methods**

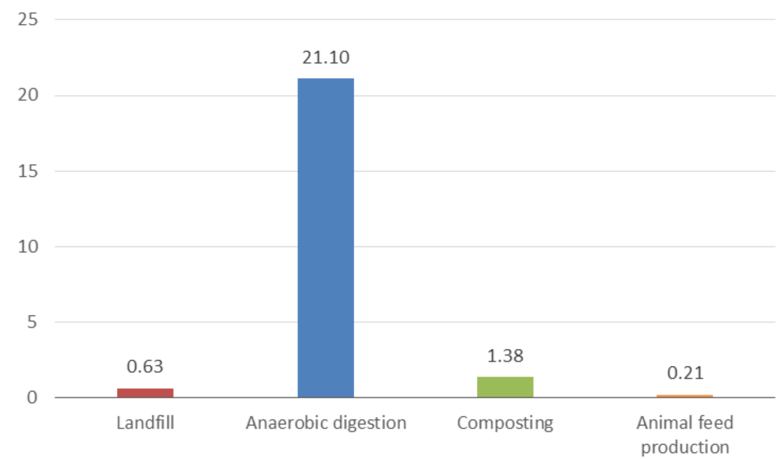
- Systematic review of existing LCA studies
- Nudging experiment

# Systematic review

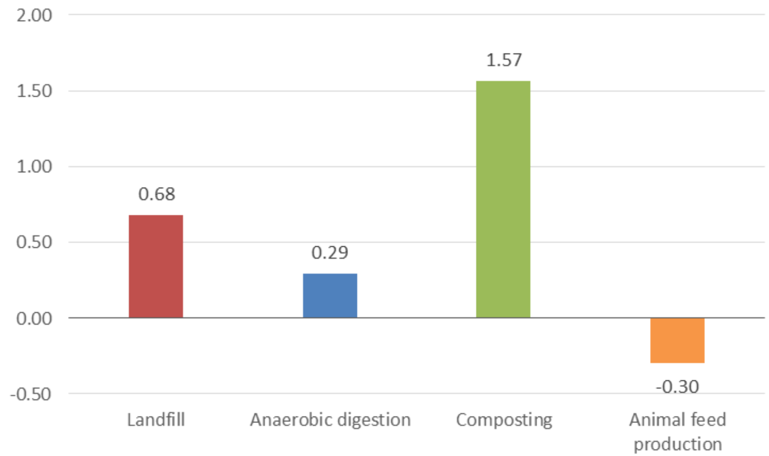
- 12 LCA studies were reviewed, and 11 impact categories associated with four food waste management technologies were assessed:
  - Global Warming Potential
  - Acidification Potential
  - Eutrophication Potential
  - Human Toxicity Potential
  - Ozone Depletion Potential
  - Freshwater Aquatic Eco-toxicity Potential
  - Marine Aquatic Eco-toxicity
  - Terrestrial Eco-toxicity Potential
  - Photochemical Oxidant Formation
  - Photochemical Ozone Creation Potential
  - Abiotic Depletion Potential



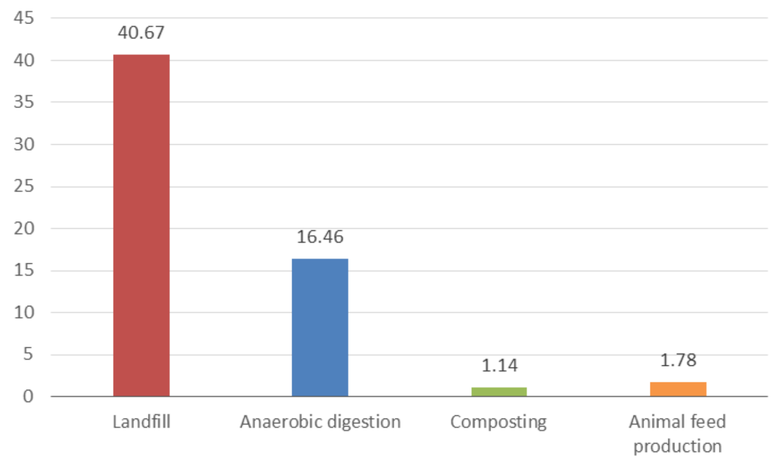

Average results for Global Warming Potential (kg $CO_2$-eq)




Average results for Eutrophication Potential (kg $NO_3^-$-eq)




Average results for Acidification Potential (kg $SO_2$-eq)



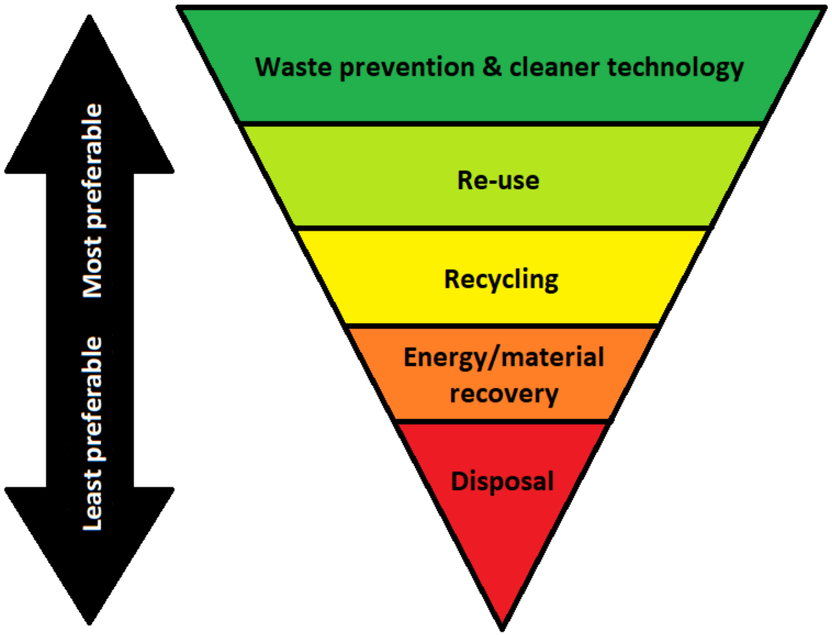

Average results for Human Toxicity Potential (kg 1,4-DB-eq)

# Summary of systematic review

| Waste technology | Mean ranking score (out of 4) |
|---|---|
| Landfilling | 3.4 |
| Anaerobic digestion | 2.2 |
| Composting | 3 |
| Animal feed production | 1.4 |

# Nudge theory

- Nudge theory provides a useful framework to promote waste minimisation



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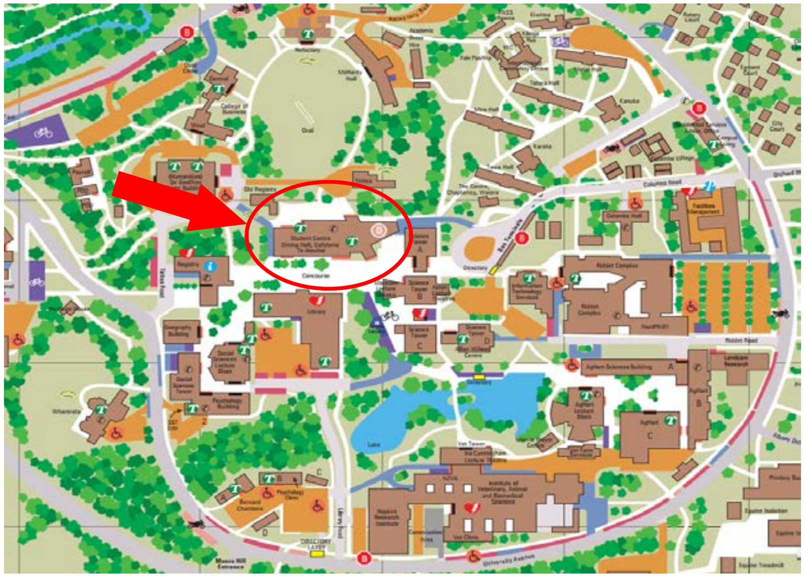
Palmerston North



Massey University Manawatu Campus

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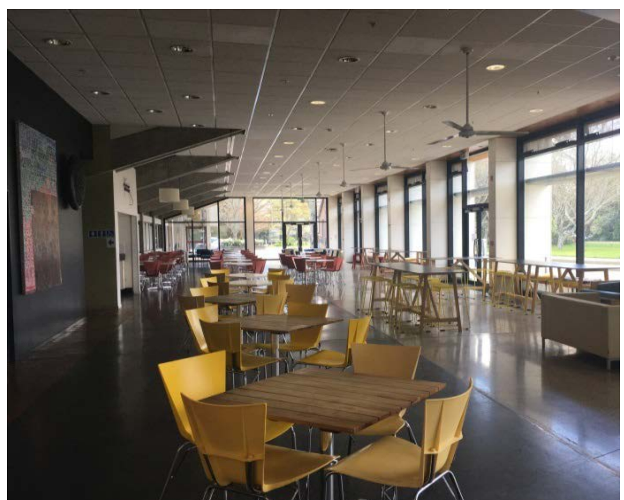
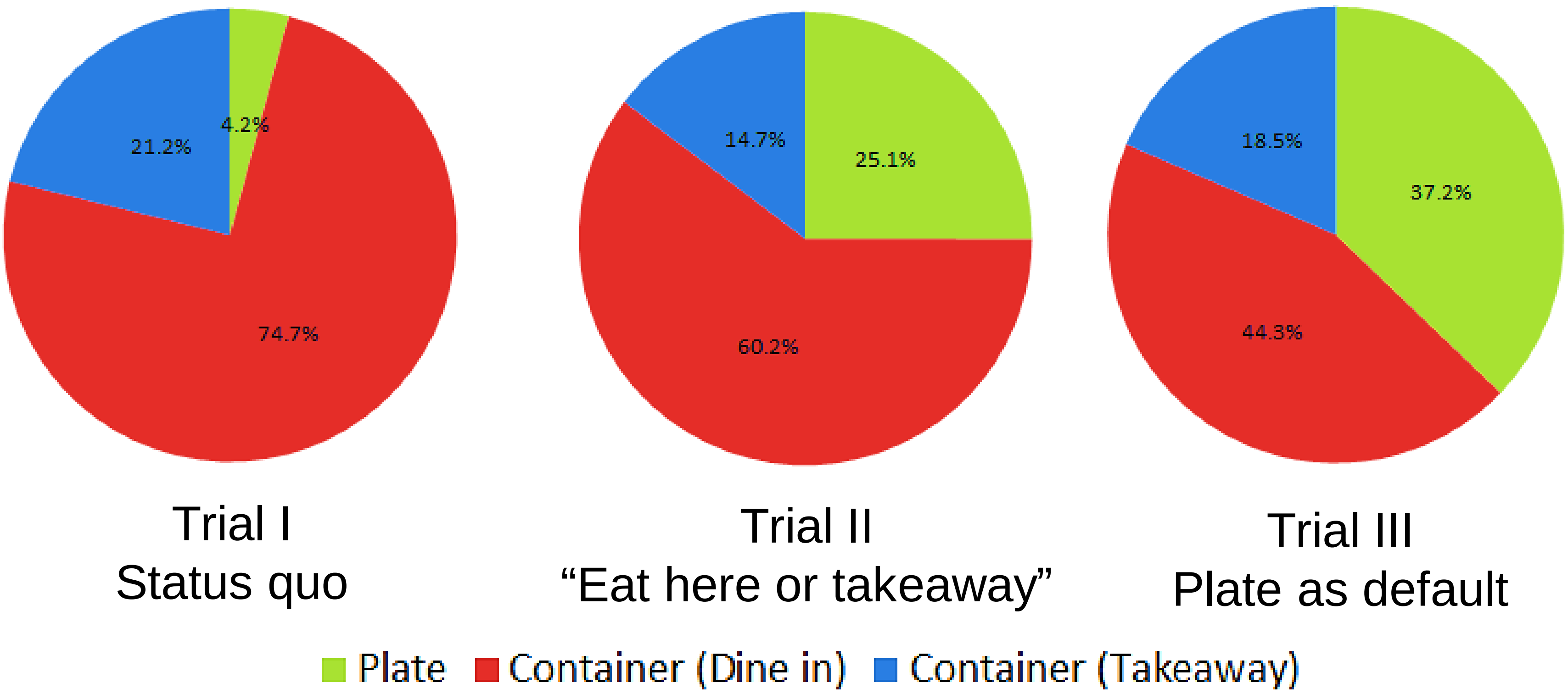
TIME
BREAKFAST
HOT MEALS
SALADS
PAY




WASTE
GLASS

# Nudging results

- Two hours each night (approx. 5 – 7 pm), Wednesday to Sunday
- 272 people on average

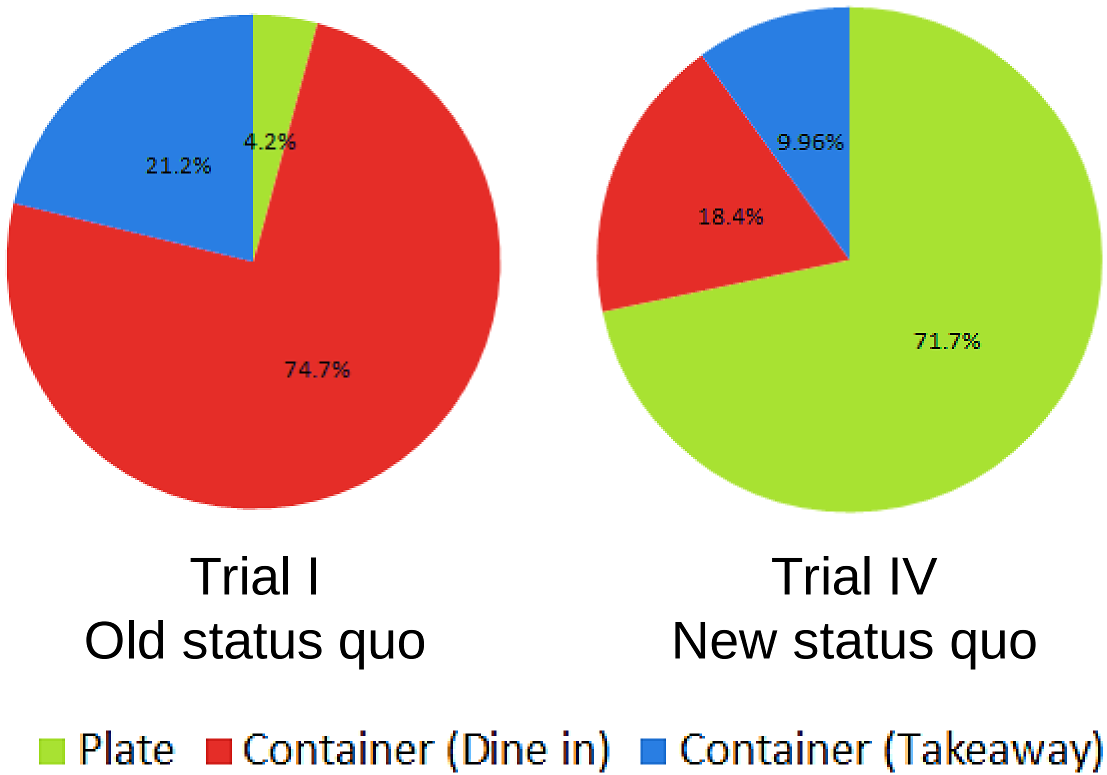


# Changes in the dining hall



# Subsequent analysis

- Approximately 4 months later, using the same methodology
- New average: 283 people



# Conclusion

- Food waste needs to be diverted from landfill
- Currently, composting is the optimal method for managing food waste at the Massey University dining hall
  - Further research is needed into other waste management methods
- Nudging theory was used to inform a successful behaviour change
  - A range of techniques significantly reduced waste to landfill
  - Has the potential to help address other wicked problems

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