Household Treatment of Food Waste in Dorset

Results of 52-Week Trial of the Green Cone Food Waste Digester

Rebecca Gysin

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Executive Summary

The highly putrescible nature of food waste, coupled with a range of environmental and public health concerns, has limited the development of options and strategies for diverting household food waste from landfill. There are two basic approaches for dealing with food waste, namely treatment at a centralised facility and household treatment using a Food Waste Digester (FWD). The FWD is a complementary system to the traditional garden composter. The latter produce compost from green waste whereas the FWD degrades all organic matter unacceptable to garden composters on health and environmental grounds.

FWDs range in size, applicability, efficiency, ease of use and price. The following claims are made about the Green Cone FWD, which is used in a number of counties across the UK:

- Takes virtually all household food waste, including vegetable scraps, raw and cooked meat or fish, bones, dairy products and other organic food waste such as bread and pasta;
- Waste is reduced to natural components of water, carbon dioxide and small amount of residue;
- The system is suitable for households with small and large gardens and those who do not want compost;
- Residual waste is dry and easier to recycle as it is not contaminated with food waste;
- Facilitates alternative weekly collections by removing food waste;
- Use tends to limit growth in waste as the householder takes ownership of their own food waste;
- Reduced transport pollution and major savings on collection and disposal costs, particularly in rural areas and with rising oil costs;
- Can make a significant contribution to meeting landfill targets;
- Meets all relevant health, safety and environmental legislation.

Although a number of independent assessments have been carried out of the Green Cone system, no diversion measurements have extended over a full year to take account of seasonal variations. Therefore, in 2004, Dorset County Council commissioned a study of the effectiveness of the Green Cone FWD over a 52-week period.

The key objective of the study was to measure the average quantity and composition of waste diverted to Green Cone FWDs in about 100 Dorset households over a period of a year (52 weeks). A secondary objective was to put the measured results in the context of the participant's habits and attitudes related to waste. Finally, based upon the data and views from the participating households, the study aimed to assess the overall effectiveness of the Green Cone system.

A total of 103 households were provided with Green Cones FWDs by Dorset County Council, of which 95 participated in the trial and provided measurement returns. The trial commenced Monday 31 May 2004 and ended Sunday 29 May 2005.

The trial methodology adopted was relatively successful in maintaining participation levels, with an overall participation level of 84% and 59% of households providing returns for all 52 weeks of the trial. In addition to the information from the weekly measurement returns, a 30-point Questionnaire was sent to each household in February 2005. A total of 85% of all participating households, and 98% of those who provided returns for all 52 weeks, completed the Questionnaire.

The Dorset Green Cone Trial successfully met its key objectives. The main results relevant to the system's performance and effectiveness can be summarised as follows:

- The average annual amount of waste diverted to the Green Cone was measured to be 204 kg/year/household, which compares closely with previous studies;
- 63% of participants put out for collection up to 1 less bin bag after using the Green Cone, 23% saw no reduction, 11% 1-2 bag reduction and 3% more than a 2 bag reduction. These particularly large reductions are greater than the quantity of food waste alone and may reflect an increase in recycling rates for these participants;
- 70% of participants agreed with the statement that using Green Cone "has reduced the amount of rubbish collected from my house";
- 69% of participants agreed with the statement that using Green Cone "has increased my commitment to reduce rubbish";
- 65% of participants agreed with the statement that using the Green Cone "has increased my commitment to recycling";
- 73% of participants agreed with the statement that the Green Cone "should be made available to every household with a garden";
- Although a majority of households experienced some issue with the Green Cone, only 4% had a problem that caused them to stop using it entirely;
- 81% of participants would recommend the Green Cone to a friend.

This study has demonstrated that the Green Cone system has the potential to divert significant quantities of food waste from landfill. Given the rural nature of Dorset, there could be cost benefits over the approach of centralised kerbside collection and treatment. Although participants in this trial were self-selecting there appears to be public acceptance of such a system, with the additional potential benefits of limiting the growth in waste and increasing recycling rates.

Contents

List of Figures

List of Tables

1 Introduction

1.1 Background

The decomposition of waste within landfill is a major source of the greenhouse gas methane. The methane is generated from biodegradable waste decomposing in the absence of oxygen. In response to growing concerns over the impact of greenhouse gases, the EU Landfill Directive (Reference 1) requires member states to progressively reduce the amount of biodegradable waste going to landfill by specified dates. The UK must reduce the amount of biodegradable waste going to landfill in the target years of 2010, 2013 and 2020 to 75%, 50% and 35% respectively, of the amount landfilled in 1995.

Biodegradable waste and municipal waste are defined separately in the EU Landfill Directive and these definitions are carried through into UK legislation. Municipal waste is defined as "waste from households, as well as other waste, which because of its nature or composition, is similar to waste from households" and biodegradable waste as "any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard". Household waste makes up approximately 90% of the 30 million tonnes of municipal waste generated each year in the UK. The food waste fraction of household waste represents about one quarter of the 20 million tonne biodegradable component of municipal waste, which is equivalent to about 0.2 tonne/household/year (Reference 2).

The highly putrescible nature of food waste, coupled with a range of environmental and public health concerns, has limited the development of options and strategies for diverting household food waste from landfill. There are two basic approaches for dealing with food waste, namely treatment at a centralised facility and household treatment using a Food Waste Digester (FWD). The FWD is a complementary system to the traditional garden composter. The latter produce compost from green waste whereas the FWD degrades all organic matter unacceptable to garden composters on health and environmental grounds.

FWDs range in size, applicability, efficiency, ease of use and price (References 3 to 5). Although a number of independent assessments have been carried out of the Green Cone system (References 6 to 8), no diversion measurements have extended over a full year to take account of seasonal variations. Therefore, in 2004, Dorset County Council commissioned a study of the effectiveness of the Green Cone FWD over a 52-week period.

1.2 The Green Cone Food Waste Digester

The company that manufactures and promotes the Green Cone (Reference 5) makes the following claims regarding the design and benefits of its FWD, several of which were tested during the study:

- Takes virtually all household food waste, including vegetable scraps, raw and cooked meat or fish, bones, dairy products and other organic food waste such as bread and pasta;

- Disposes of about 5 kg of food waste a week, which is over 25% greater than that produced by the average household;

- Design prevents surface and top-soil contamination and ensures that animals, birds and humans cannot readily access the composting material;
- Design prevents waste dispersion and eliminates odours so as not to attract vermin;
- No requirement for user intervention such as the mixing or turning of the waste;
- Waste reduced to natural components of water, carbon dioxide and small amount of residue;
- The system is suitable for households with small and large gardens and those that do not want compost;
- In a well operating system the residue will occupy the bottom 25cm of the digestion basket after the decomposition of about a tonne of food waste;
- Residual waste is dry and easier to recycle as it is not contaminated with food waste;
- Facilitates alternative weekly collections by removing food waste;
- Use tends to limit growth in waste as the householder takes ownership of their own food waste;
- Reduced transport pollution and major savings on collection and disposal costs, particularly in rural areas and with rising oil costs;
- Can make a significant contribution to meeting landfill targets;
- Meets the EU principles of proximity and self-sufficiency;
- Meets all relevant health, safety and environmental legislation.

A diagrammatic view of the Green Cone system is given in Figure 1. The FWD is a four-part plastic injection moulded system comprising a digestion basket that is installed below ground and which forms the base for an above ground double-walled solar chamber with an access lid. The design of the Green Cone utilises solar heating in the double-walled chamber to facilitate and accelerate the aerobic decomposition process within the digestion basket. A 4.5 litre receptacle ("kitchen caddy"), which can be sealed, is provided for collecting and carrying the household food waste to the Green Cone.

A detailed description of the Green Cone FWD has been reproduced from Reference 9 in Appendix 1, which also includes an outline of the digestion process, an overview of the relevant legislation and the health, safety and environmental impact of the system.

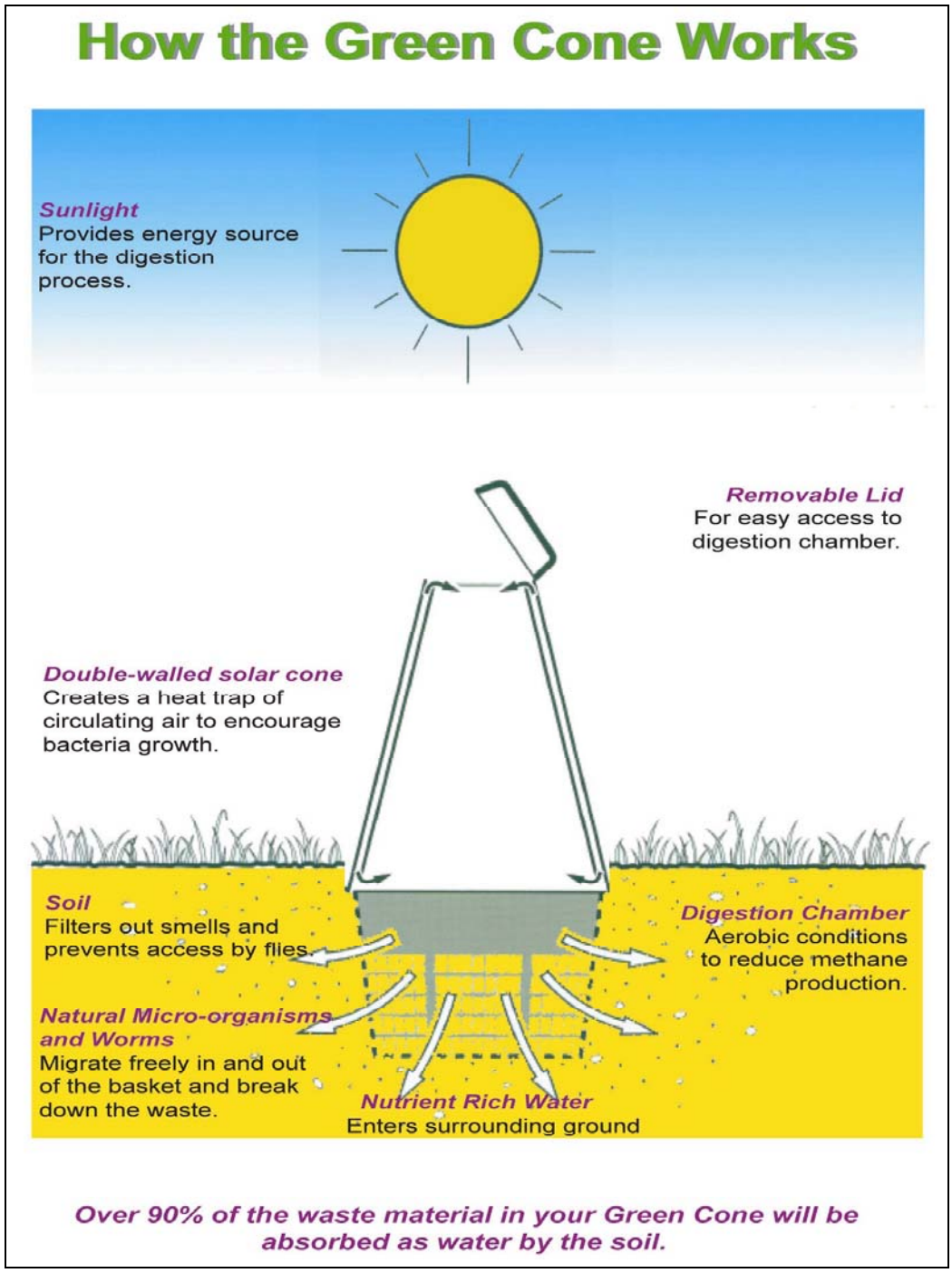

Figure 1: Diagrammatic View of the Green Cone System

1.3 Study Objectives

The key objective of this study was to measure the average quantity and composition of waste diverted to Green Cone FWDs in about 100 Dorset households over a period of a year (52 weeks). A secondary objective was to put the measured results in the context of the participant's habits and attitudes related to waste. Finally, based upon the data and views from the participating households, the study aimed to assess the overall effectiveness of the Green Cone system.

2 Methodology

A total of 103 households were provided with Green Cone FWDs by Dorset County Council, of which 95 participated in the trial and provided measurement returns. The trial commenced Monday 31 May 2004 and ended Sunday 29 May 2005.

The requirement for participating households to quantify the waste diverted into their Green Cone each week over a full year made it essential that the trial measurement protocol was simple and quick. The approach adopted was relatively successful in maintaining participation in the trial, with an overall participation level of 84% (81 households) and 59% (56 households) providing returns for all 52 weeks of the trial. The level of returns do show a general reduction over the year (Figure 2), with the average level of 94% for the first half of the year reducing to 74% over the second half. A detailed description of the measurement and analysis methodology is provided in Appendix 2. The measurement instruction sheet given to each participant is reproduced in Appendix 3.

In addition to the information from the weekly measurement returns, a 30-point Questionnaire was sent to each household in February 2005. The Questionnaire is reproduced in Appendix 4. A total of 85% of all participating households, and 98% of those who provided returns for all 52 weeks, completed the Questionnaire.

The objectives of the Questionnaire were to:

- Support the waste diversion analysis and provide cross-check information;
- Quantify additional benefits from using the Green Cone;
- Identify issues arising from the installation and positioning of the Green Cone in the household's garden;
- Identify issues with the day-to-day use of the Green Cone system;
- Gather information on the eating, food preparation and food disposal habits of participants.

The main results from the analysis are presented in graphical form in Section 3. Full responses from the trial participants to Questions 7, 21 and 26 of the Questionnaire are provided in Appendices 5 to 7.

In addition to the standard telephone support line provided to customers by Green Cone Ltd, a dedicated local support service was established for the Dorset Trial. The feedback gained through these support lines provided some additional information to interpret the results from the trial and in particular those from the Questionnaire.

3 Results

3.1 Food Waste Weight Diversion

The quantity of food waste diverted for each household to the Green Cone FWD was analysed using the methodology described in Appendix 2. The average kg/week values for all 95 participants are given in Figure 3 and for the 56 of participants who provided returns for all 52 weeks in Figure 4. Both sets of data are compared in Figure 5, where the effect of changes in the level of participation on the average amount of food waste put into the Green Cone each week is shown to be relatively small.

The average annual amount of waste diverted for all 95 participants was 205.5 kg/year/household and for the 56 participants who provided continuous measurements over the 52 weeks, which must be considered the more meaningful result, was 204.4 kg/year/household. This result compares well with other studies, as demonstrated in Section 3.2.

The variation shown in Figure 4 of the average amount of weekly waste diverted to the Green Cone throughout the trial may be due to a number of factors:

- Seasonal effects, such as the weather, the relative abundance of fruit and vegetables in August, particularly home grown, (weeks 11 to 15) and Christmas (week 30);
- Variations in the number of people in the household due to changed circumstances, school holidays and vacations away from home;
- Behavioural modification as a result of using the Green Cone and gaining an understanding of the quantity of household food wasted. The results of the Questionnaire (Section 3.3) showed that 69% of the respondents agreed that using the Green Cone had increased their commitment to reduce rubbish and 65% that it had increased their commitment to recycling;
- Initial novelty of the Green Cone, particularly in the first week;
- Measurement accuracy changing throughout the trial;
- Issues related to the operation of the Green Cone. These were identified through specific questions in the Questionnaire. 4% of households encountered a problem that caused them to stop using the Green Cone completely. Overall, the results of the Questionnaire (Section 3.3) indicated that participants were positive about the Green Cone, with 81% stating that they would recommend it to a friend and 73% believing the system should be made available to every household.

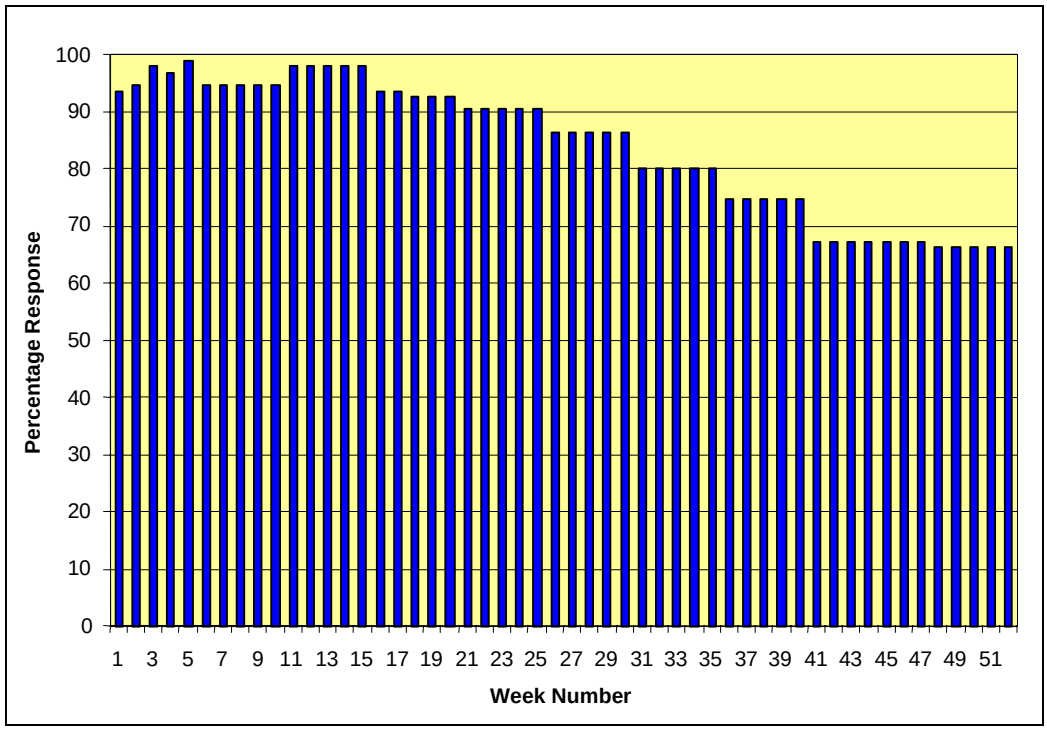

Figure 2: Response Rate

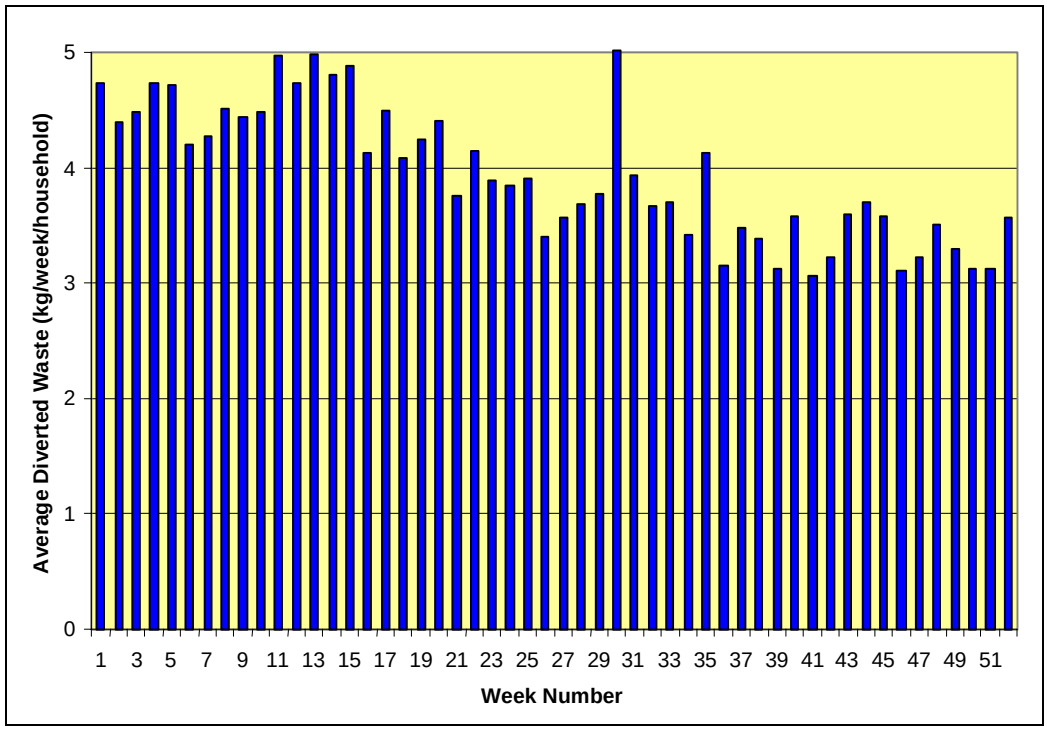

Figure 3: Average Diverted Waste for all 95 Participants

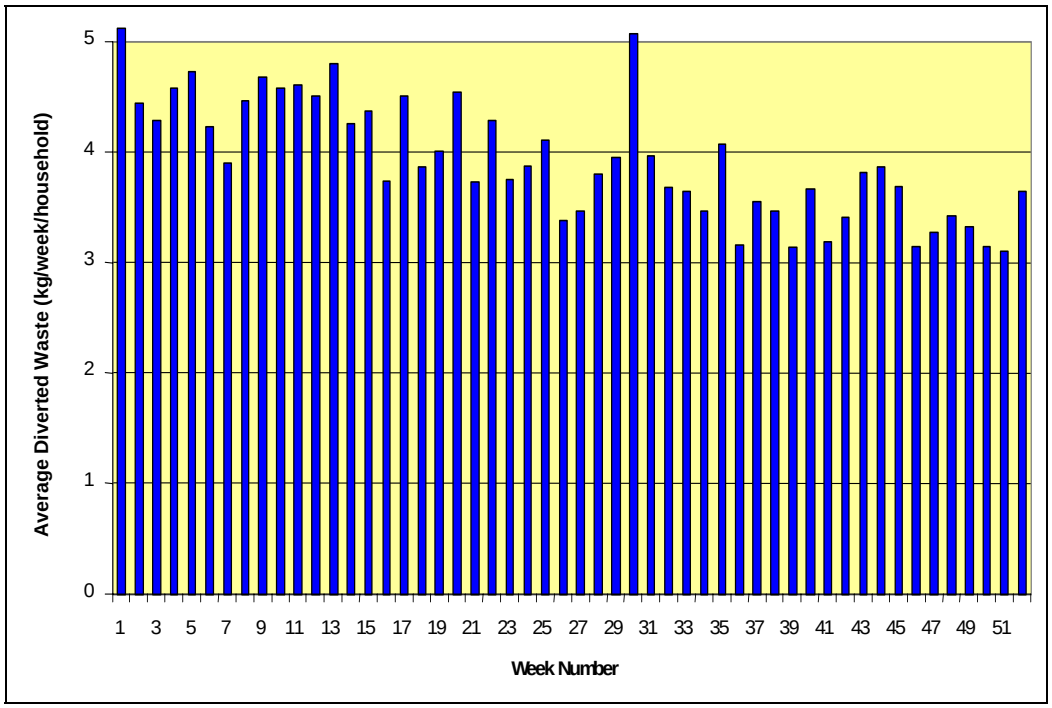

Figure 4: **Average Diverted Waste for 56 Participants that Provided Returns for all 52 Weeks**

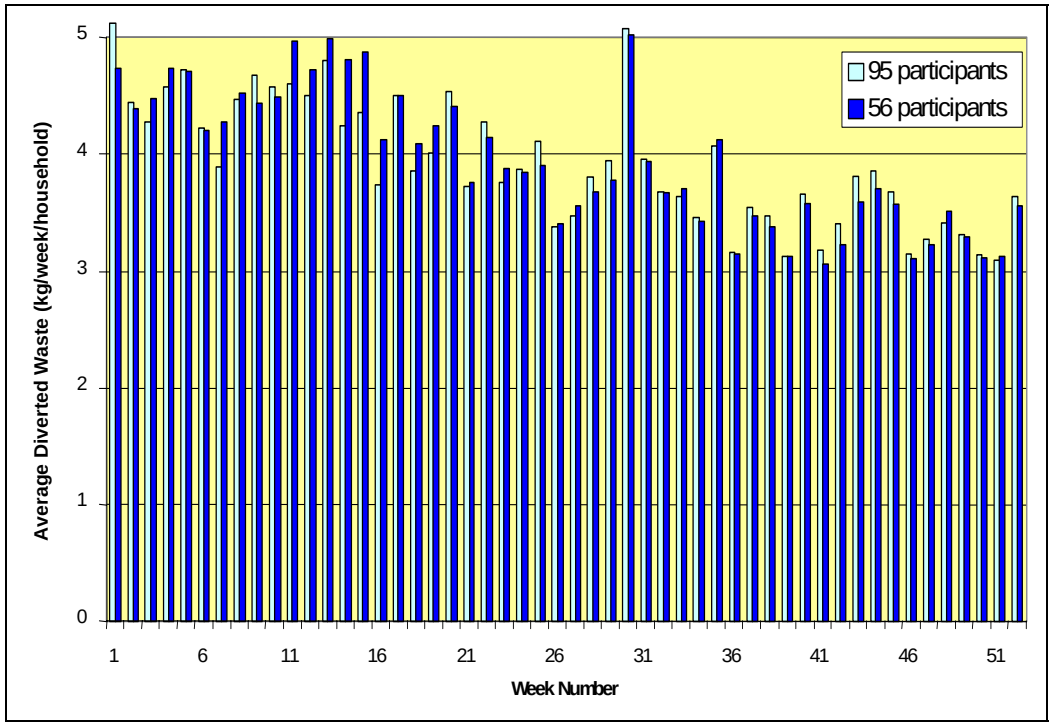

Figure 5: **Average Diverted Waste for all 95 Participants & 56 Participants that Provided Returns for all 52 Weeks**

3.2 Comparison of Measured Weights with Other Studies

The main uncertainties associated with the measurements carried out during this trial, and the extrapolation of the trial sample to Dorset as a whole, are as follows:

(a) The accuracy of the weekly caddy load returns.

(b) The accuracy of the measured caddy load weights.

(c) The appropriateness of the assigned caddy load weights.

(d) The appropriateness of using an average caddy load weight.

(e) How representative the sample is of the Dorset population of households with gardens.

Whilst it is possible to provide a broad estimate of the uncertainties for each component, it is considered more appropriate to estimate an overall uncertainty based on comparisons with other studies. The most similar study to this one was a six-week trial in West Sussex involving 48 households (Reference 6). With such a short study it was possible to ask the participants to weigh everything they put into the Green Cone, which provided an average result of 185 kg/year/household.

Another source of data is the compositional analyses of the bulk sampling of dustbin waste carried out by Local Authorities. Parfitt (Reference 2) has carried out a detailed analysis of the best available data sets to derive the most definitive value for the average quantity of kitchen waste in household collections in England of 194 kg/year/household.

Gale (Reference 10) provides kitchen waste values from three studies of 177 kg/year/household for Burford, Shropshire, 182 kg/year/household from a University of Leeds study and about 211 kg/year/household for Wales. These have not been included in the following comparison table because the results are either from small samples or are preliminary results.

Table 1: Summary of Household Food Waste Values

Region & Source of Data	Quantity (kg/year/household)
England (Parfitt WRAP)	194
West Sussex (University of Brighton)	185
Dorset (This Study)	204

Whilst the results in Table 1 are for different geographic regions and employed different sampling methods, the comparison suggests that the level of uncertainty for the Dorset study is less than 10% at the three-sigma level.

3.3 Results from Questionnaire

The results from the Questionnaire are presented in graphical form where possible (Figures 6 to 34). Full written responses from the trial participants to Questions 7, 21 and 26 of the Questionnaire are provided in Appendices 5 to 7.

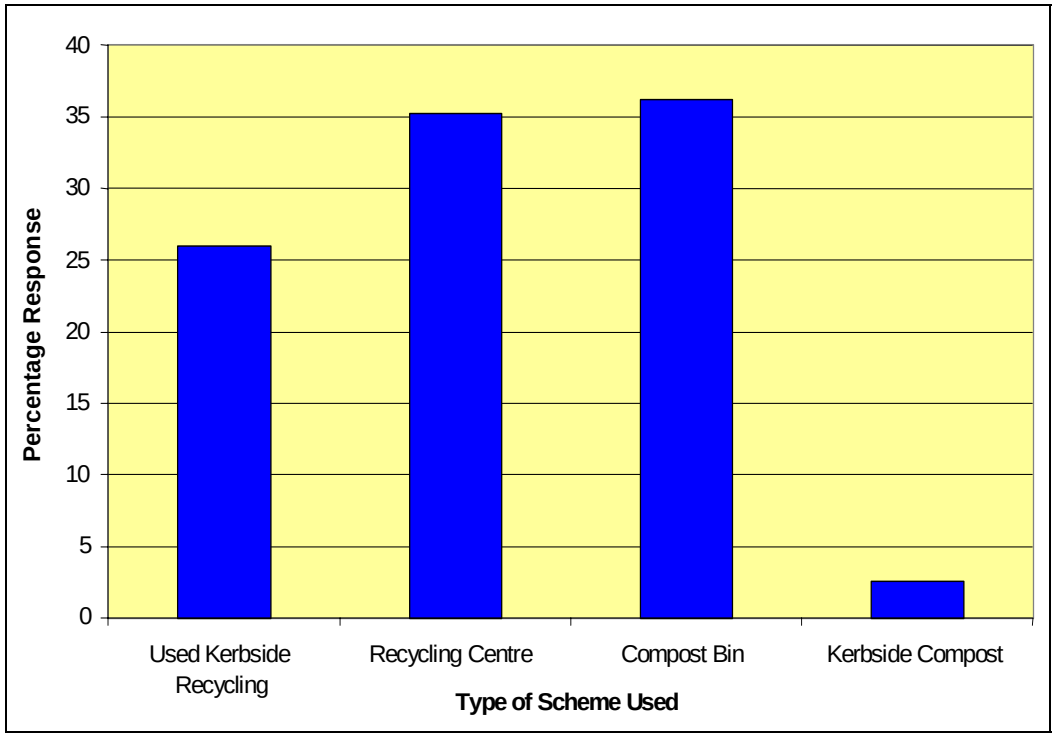

Figure 6: Participant's Recycling and Composting Habits (Q1)

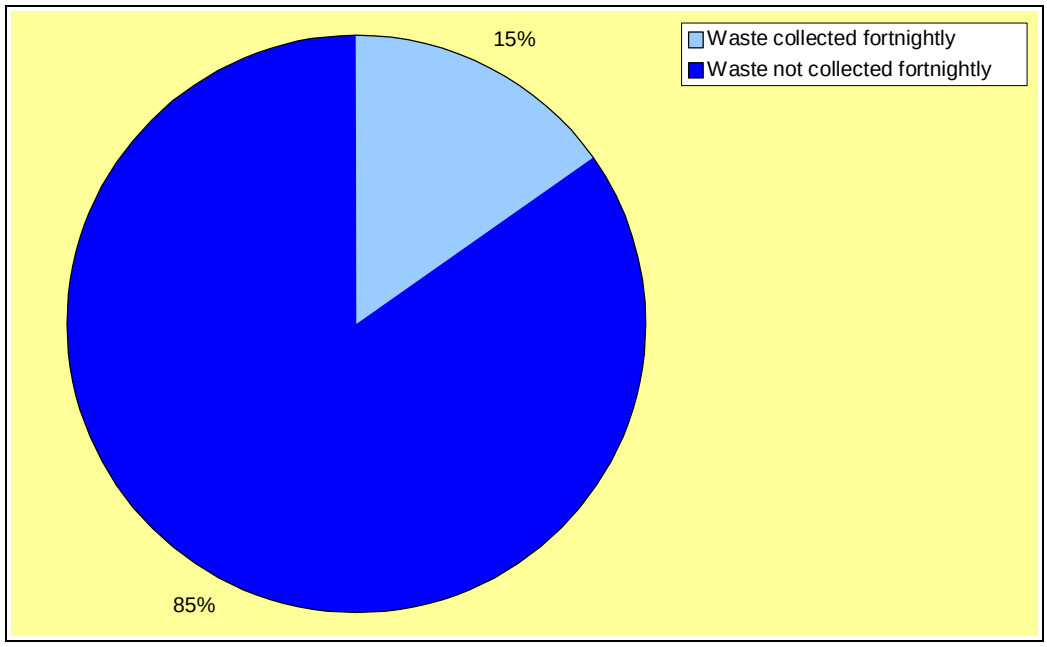

Figure 7: Participant's Kerbside Collection Frequency (Q2)

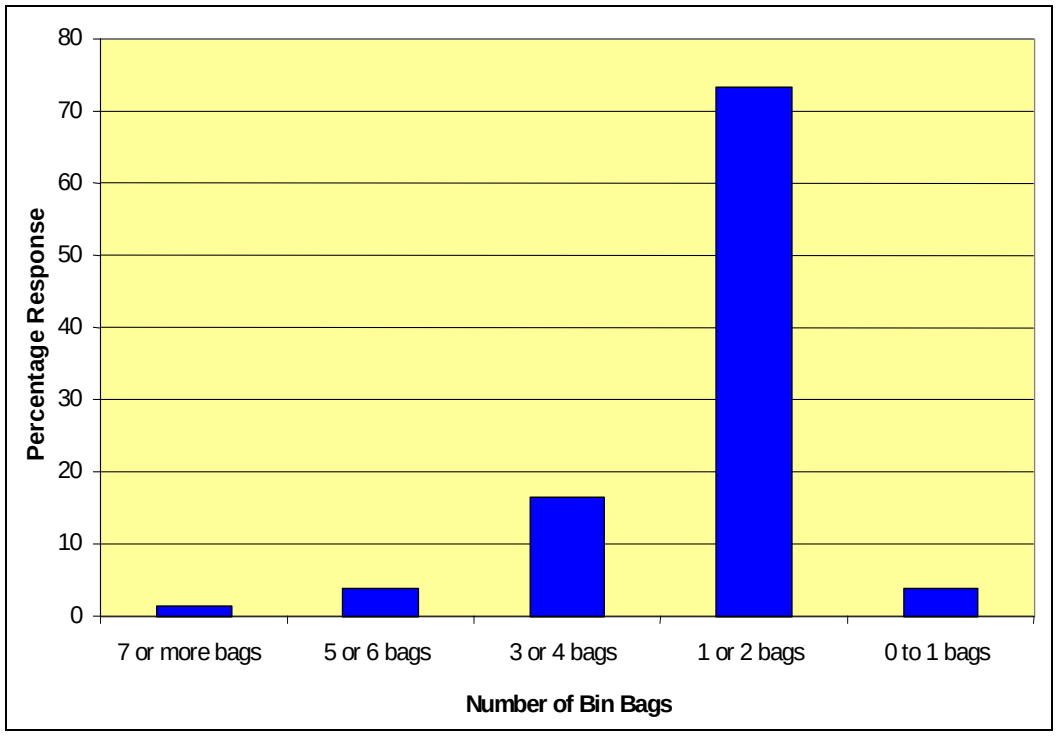

Figure 8: Number of Bin Bags Collected Prior to Having a Green Cone (Q3)

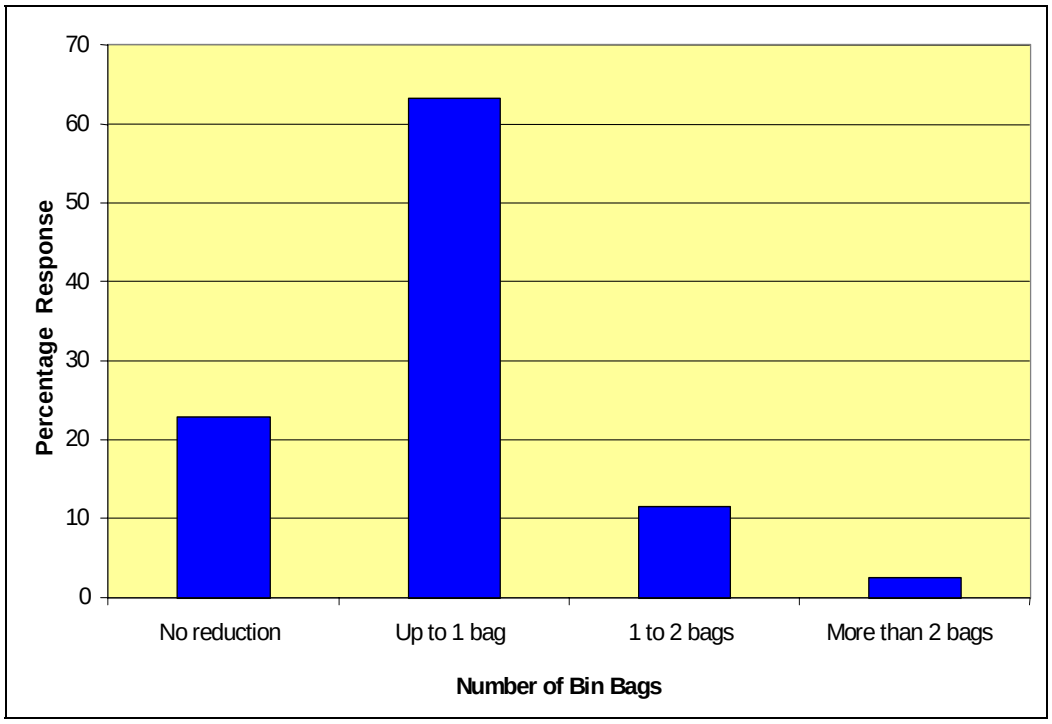

Figure 9: Reduction in Bin Bags After Using a Green Cone (Q4)

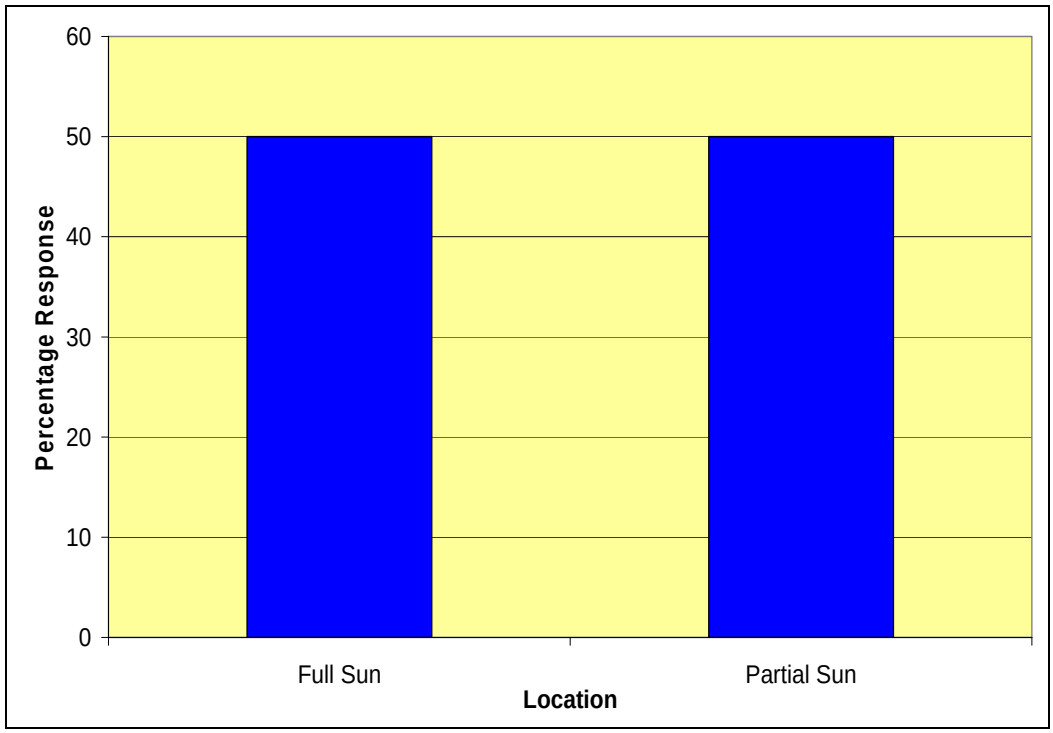

Figure 10: Location of Green Cone (Q5)

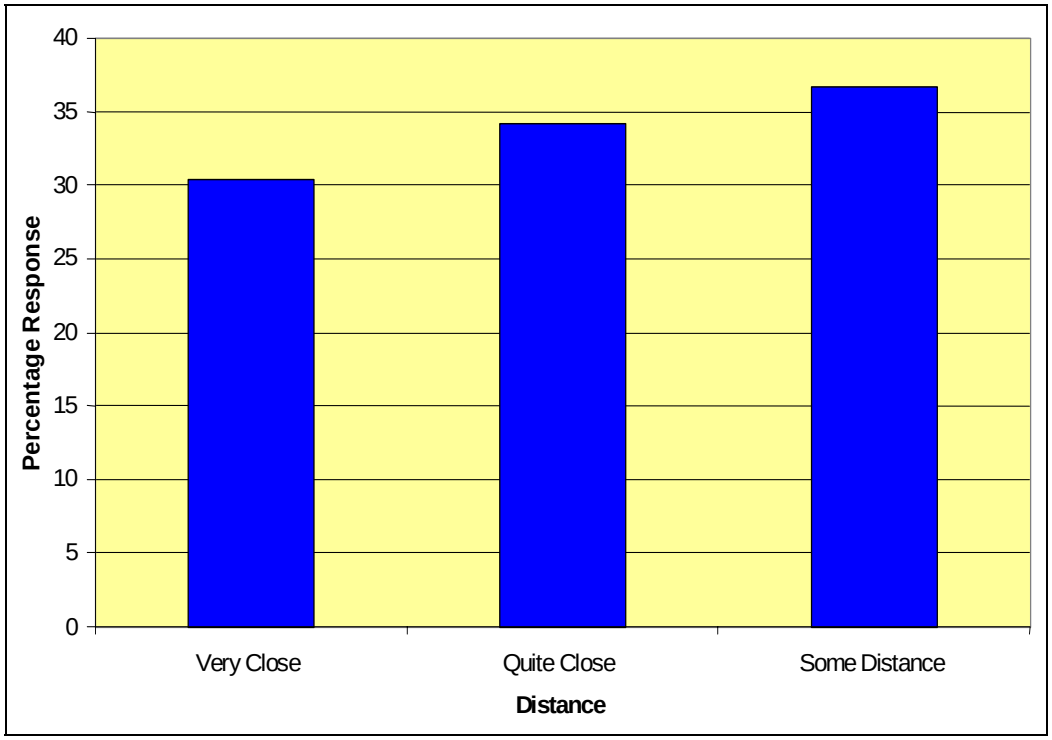

Figure 11: Distance of Green Cone from Kitchen (Q6)

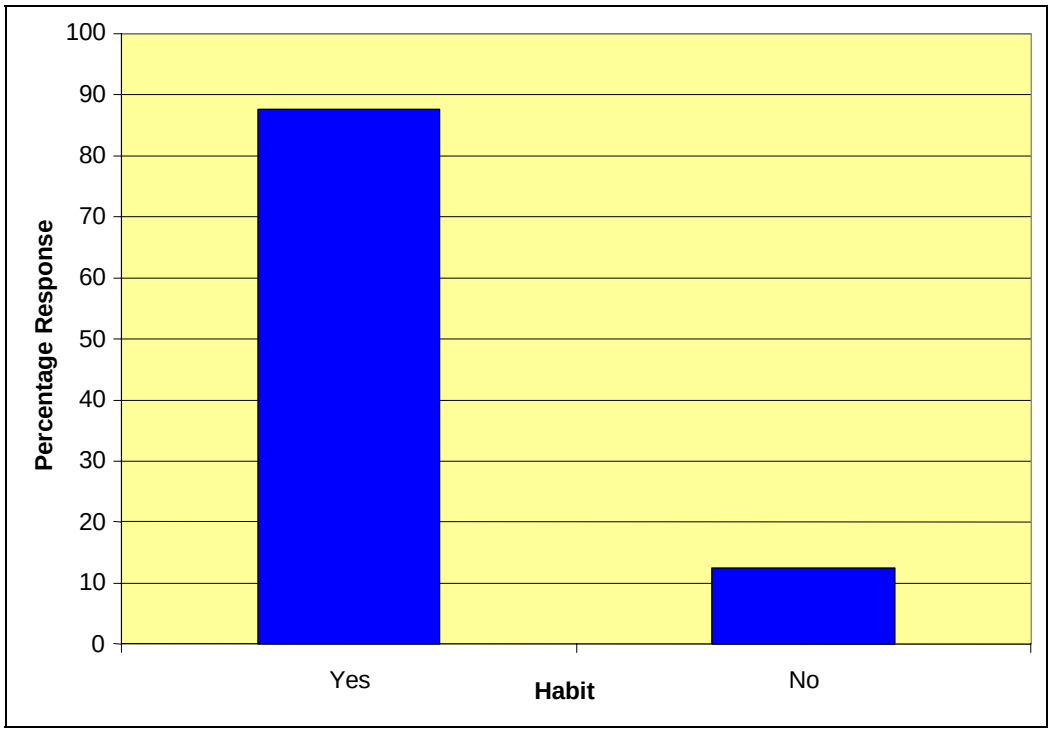

Figure 12: Whether Supplied Caddy is Used (Q7)

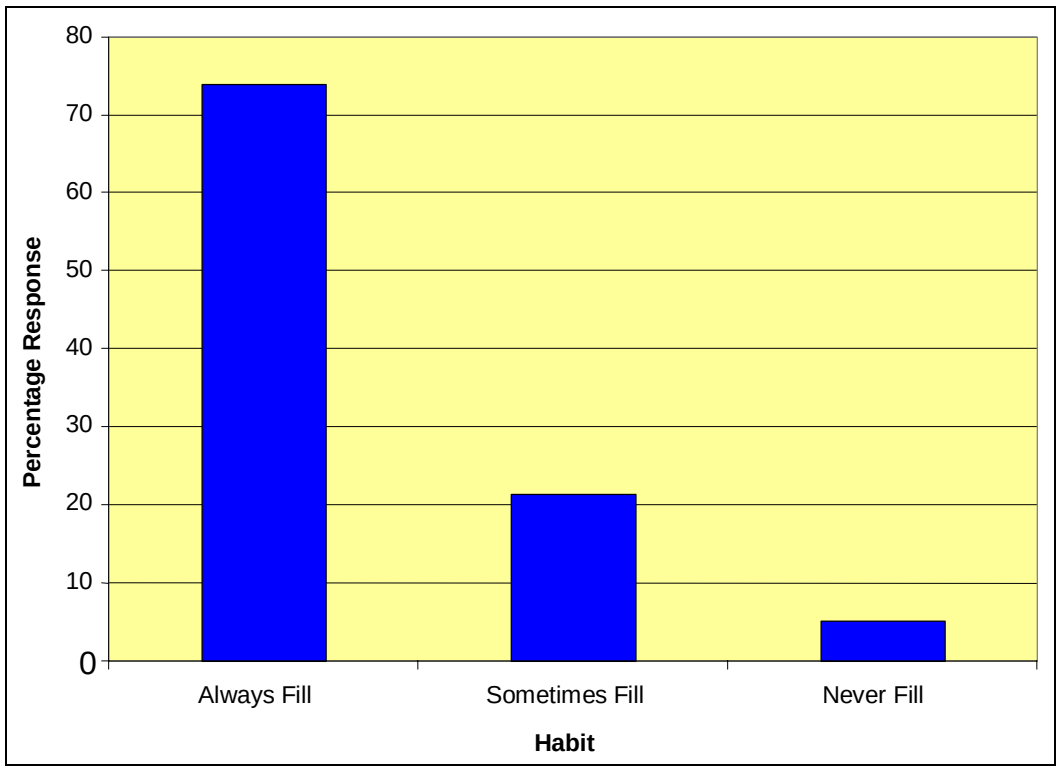

Figure 13: How Much Kitchen Caddy is Filled (Q8)

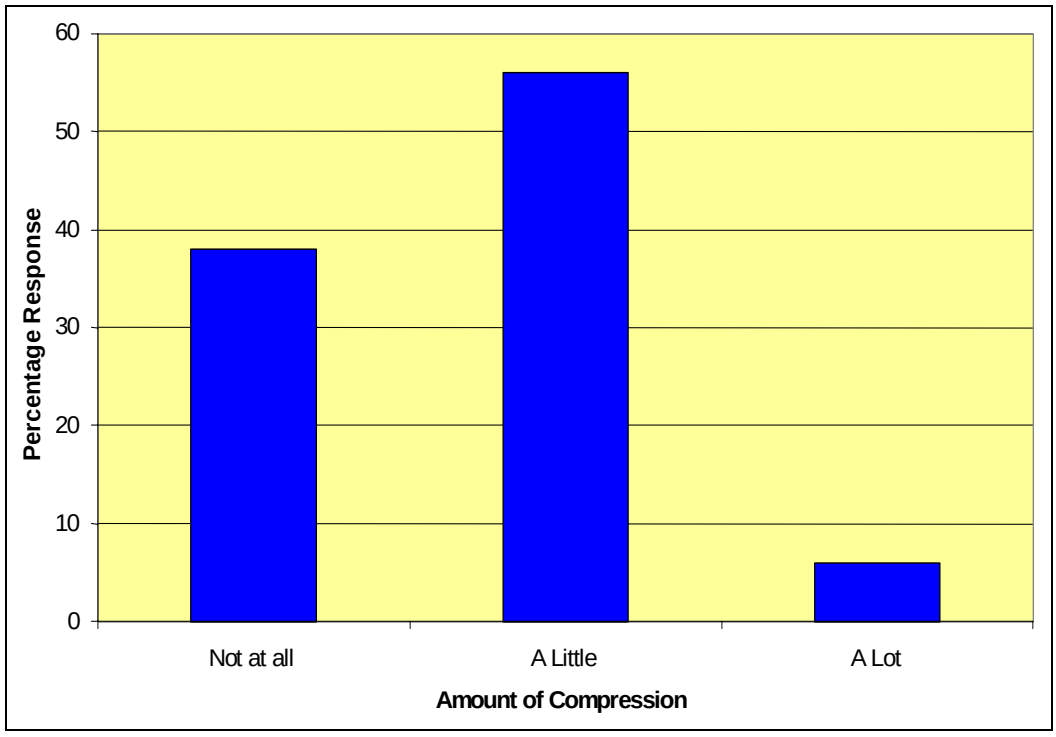

Figure 14: How Much Food Waste is Compressed in the Kitchen Caddy (Q9)

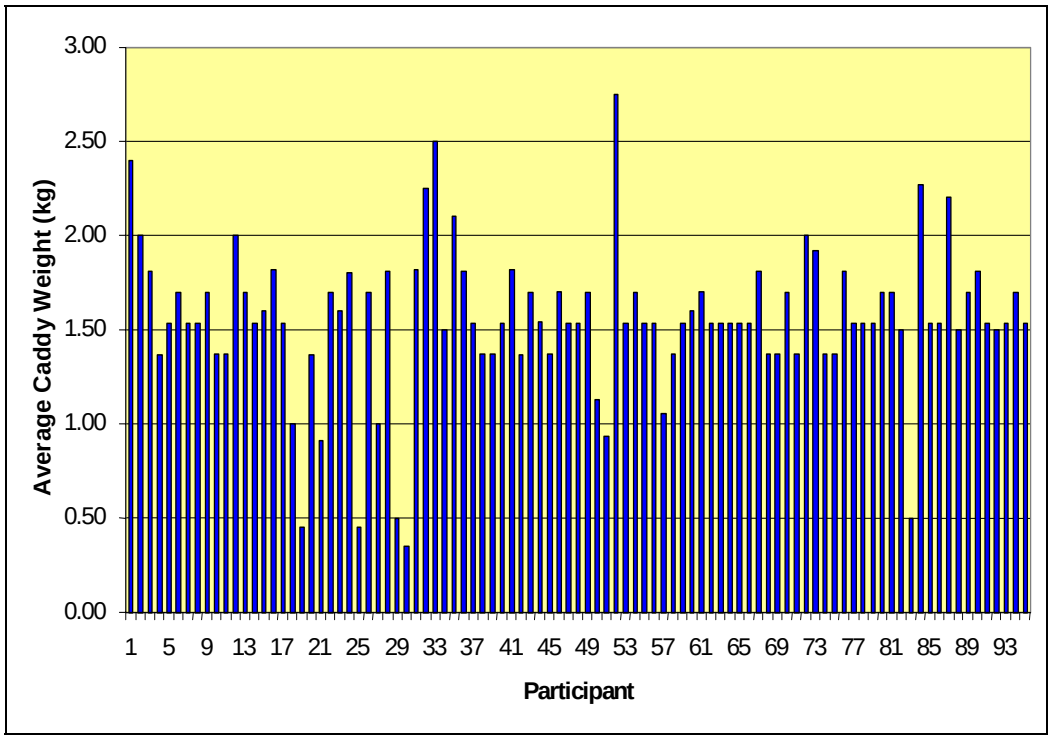

Figure 15: Average Caddy Weights for all 95 Participants (Q10)

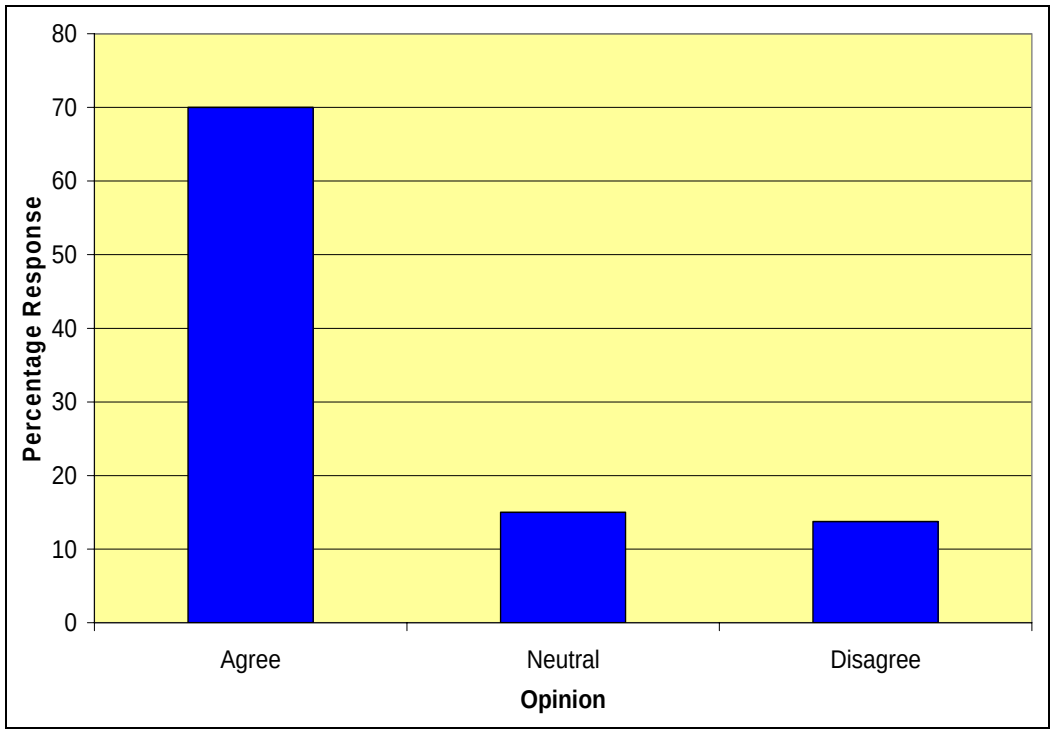

Figure 16: Whether the Amount of Rubbish Collected is Reduced Because of Green Cone (Q13)

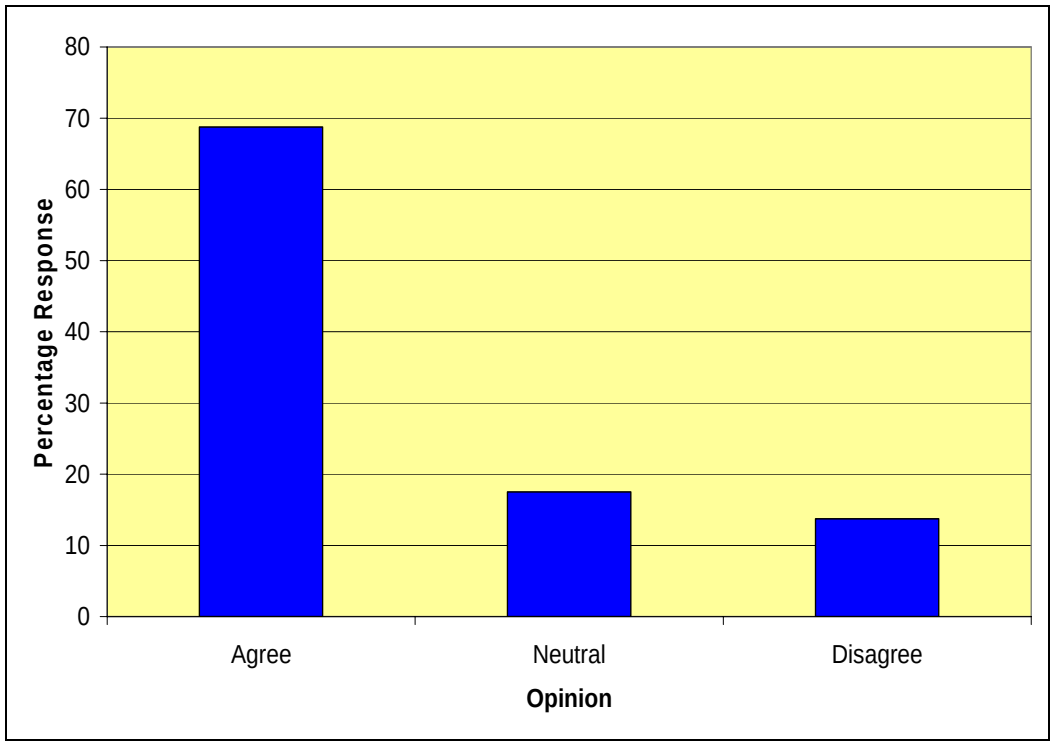

Figure 17: Increased Commitment to Reduce Rubbish Because of Green Cone (Q13)

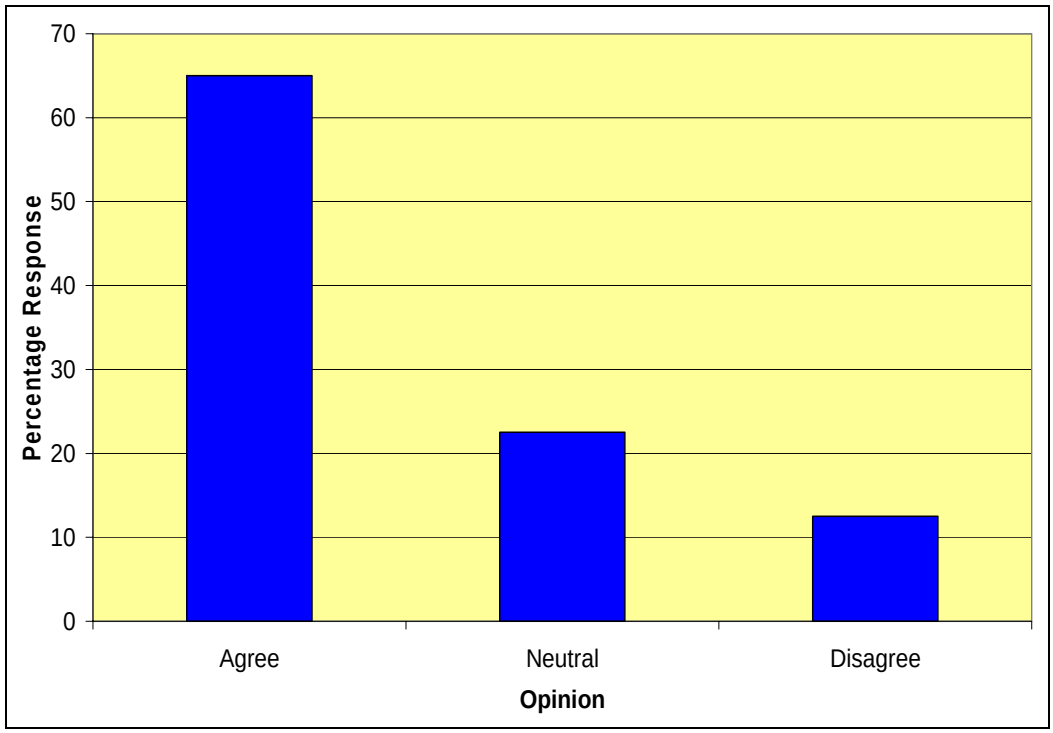

Figure 18: Increased Commitment to Recycling Because of Green Cone (Q13)

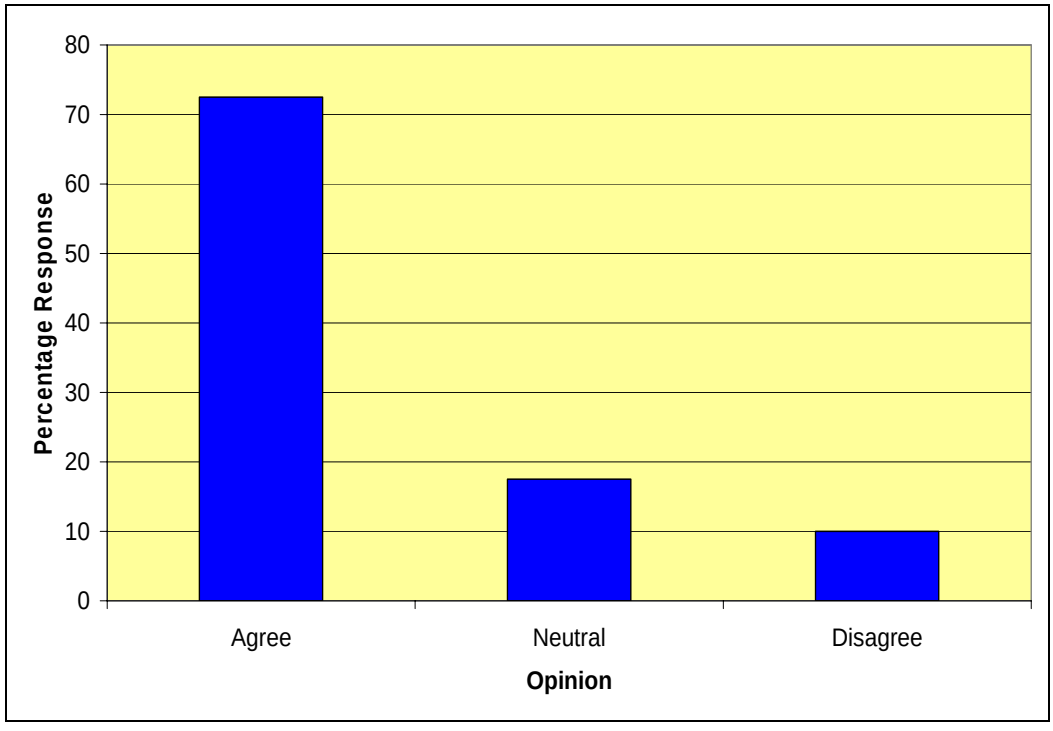

Figure 19: Whether Green Cone Should be Made Available to Every Household (Q13)

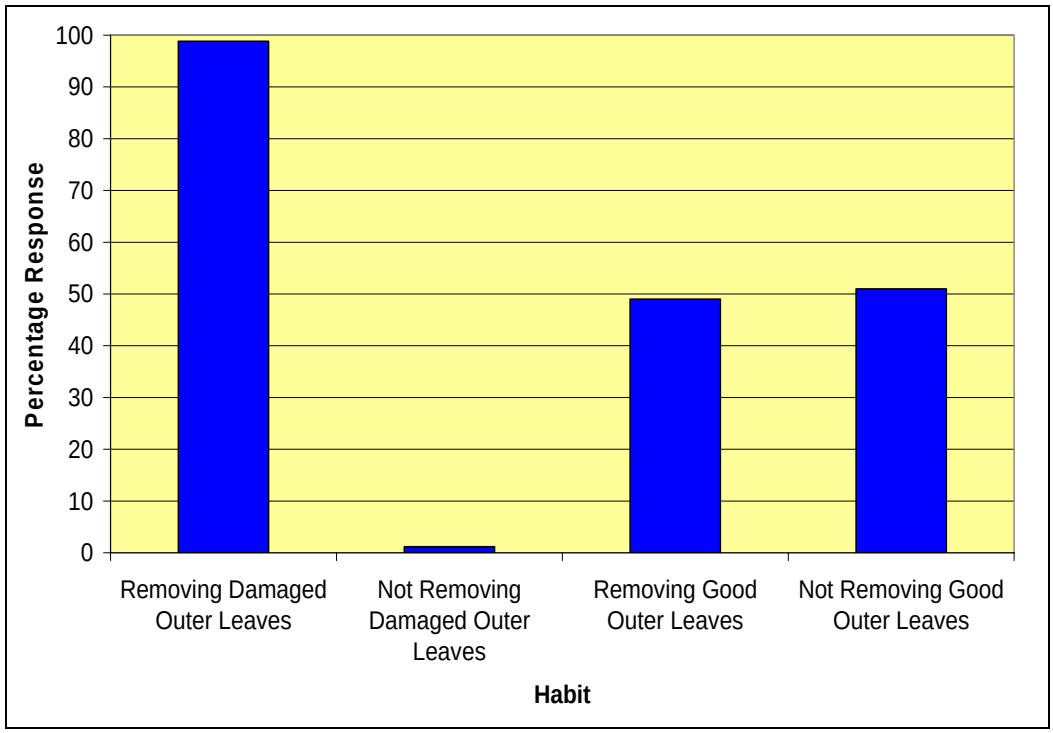

Figure 20: Cabbage Preparation Habits (Q14)

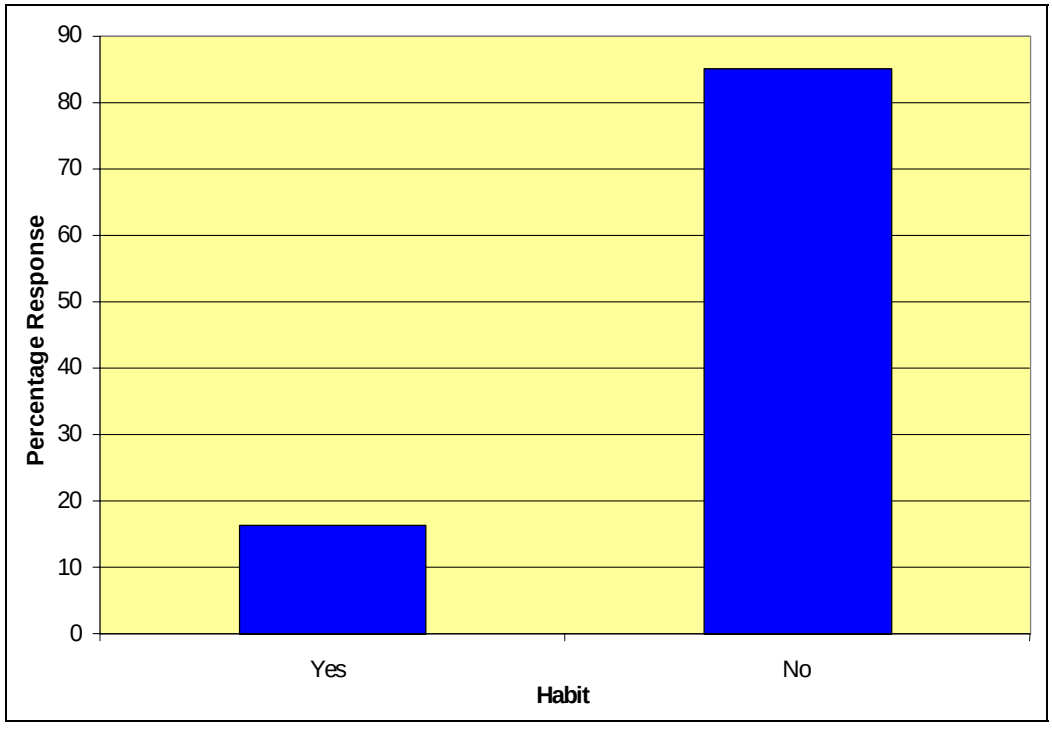

Figure 21: Peeling an Apple Before Eating (Q15)

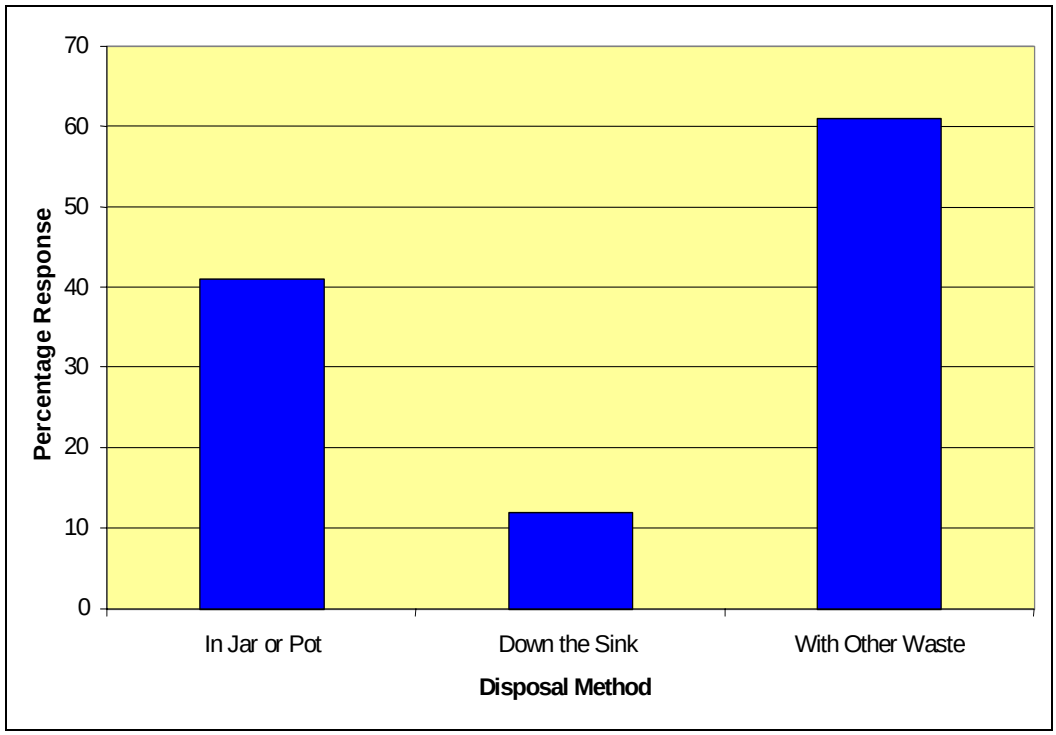

Figure 22: Disposal of Liquid Fat (Q16)

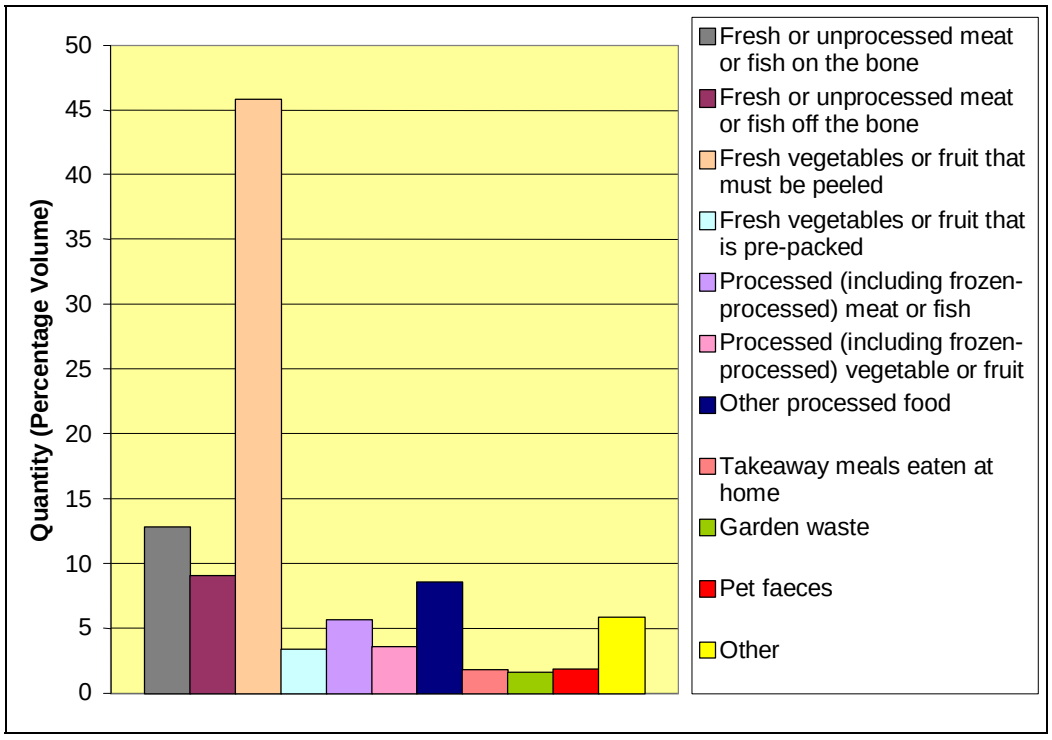

Figure 23: Average Composition of Waste (Q17)

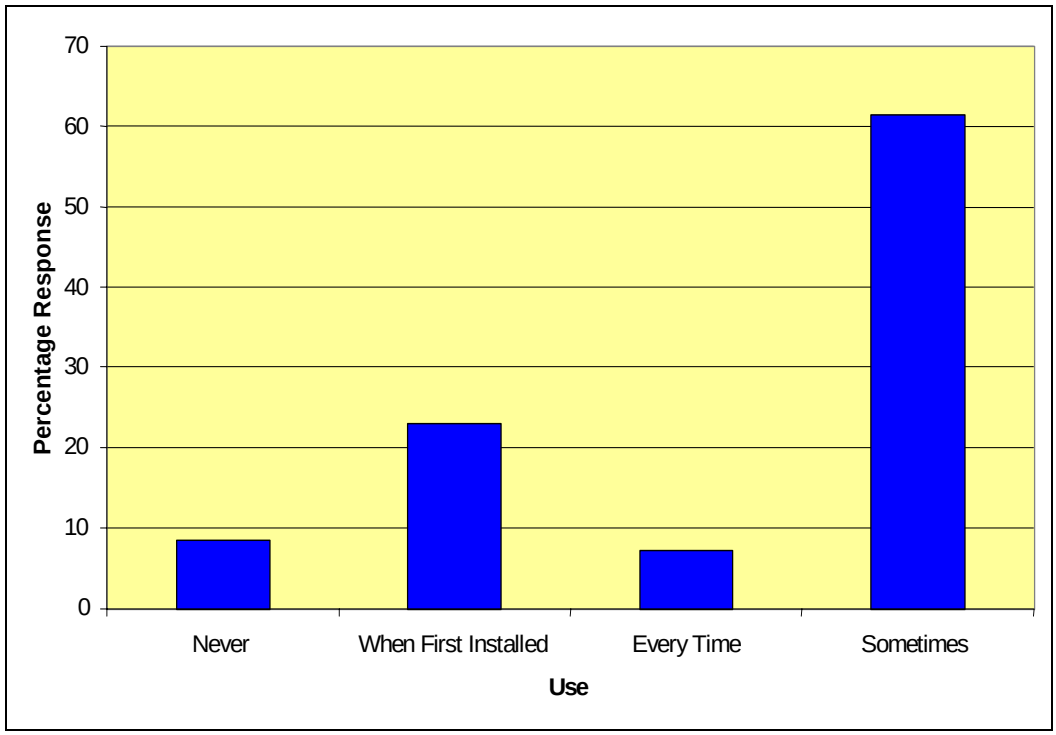

Figure 24: Participant's Use of Accelerator Powder (Q18)

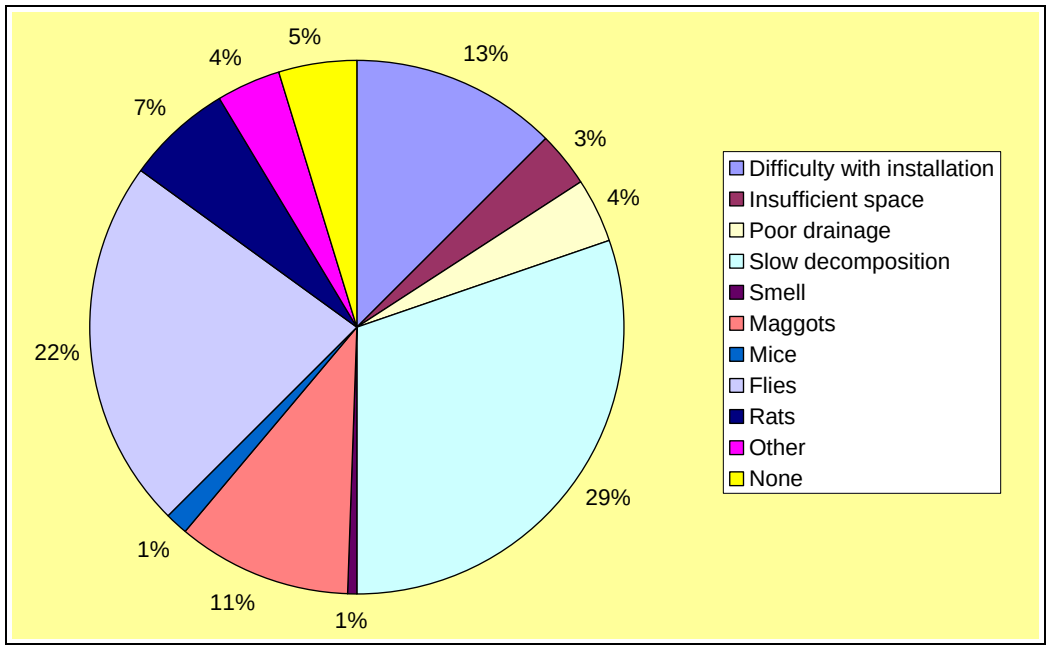

Figure 25: Participant's Experiences (Q19)

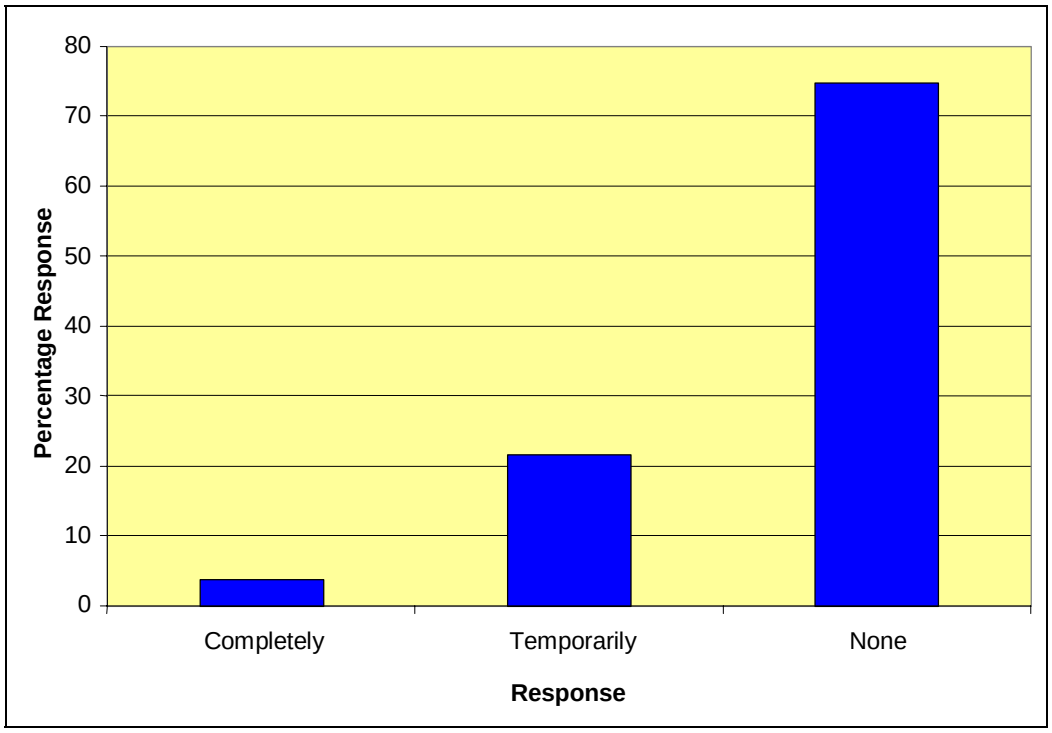

Figure 26: Problems Stopping the Use of Green Cone (Q20)

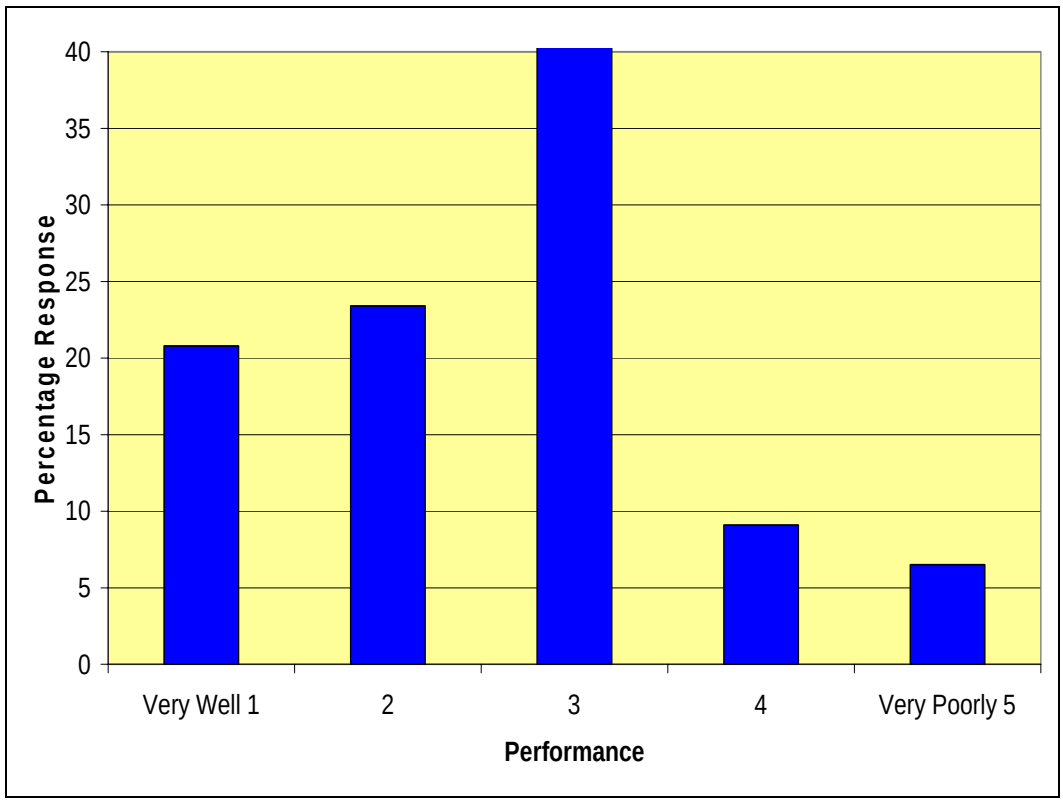

Figure 27: Green Cone Performance (Q23)

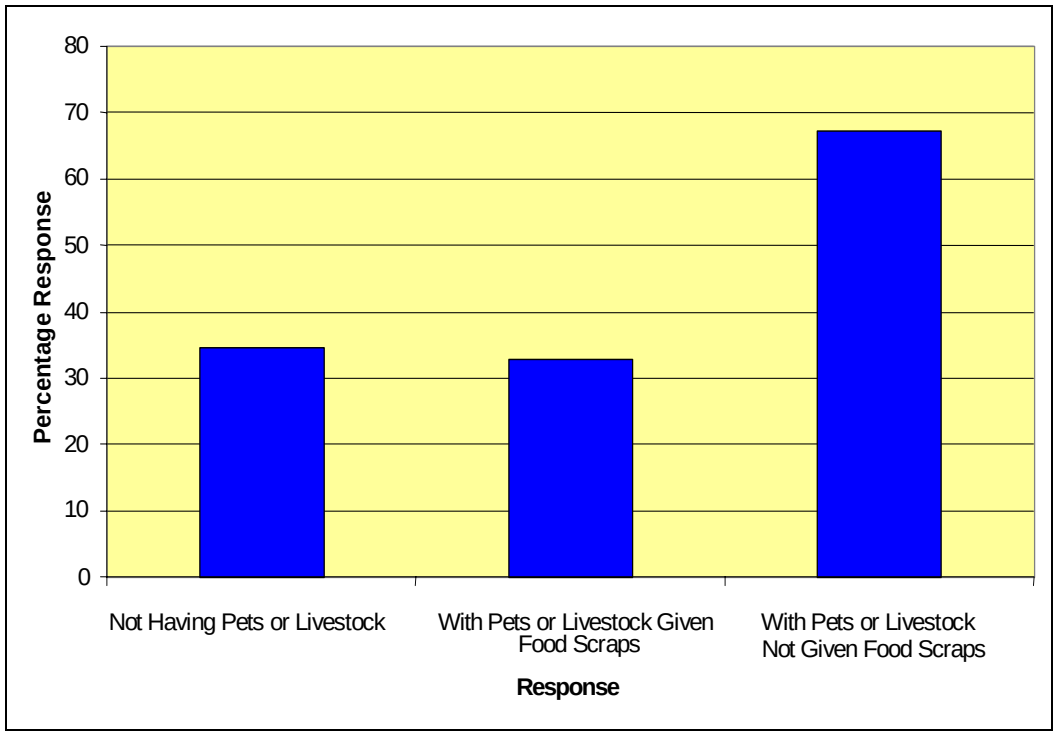

Figure 28: Pets or Livestock (Q24)

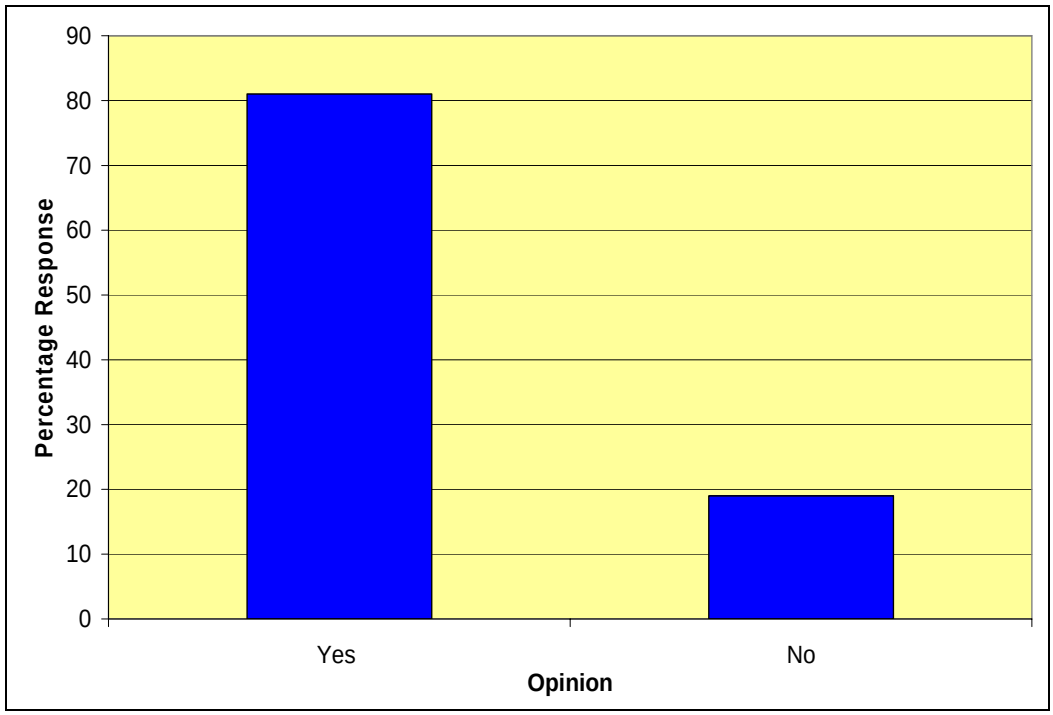

Figure 29: Recommendation of Green Cone to a Friend (Q25)

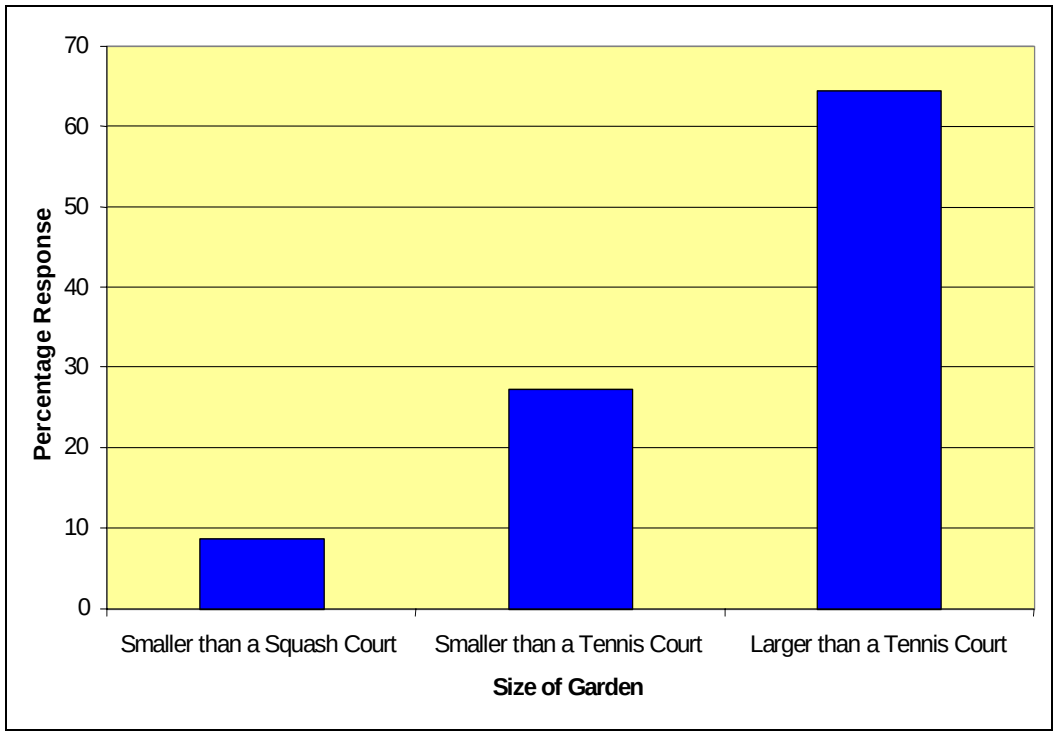

Figure 30: Size of Participant's Garden (Q27)

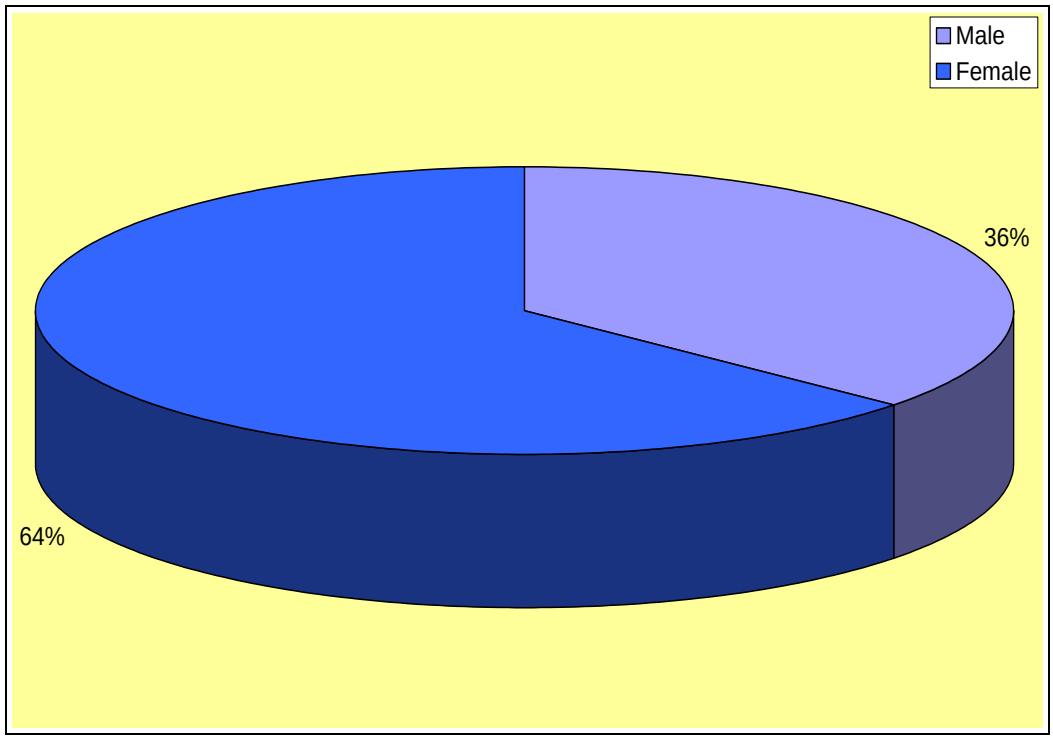

Figure 31: Gender of Respondent (Q28)

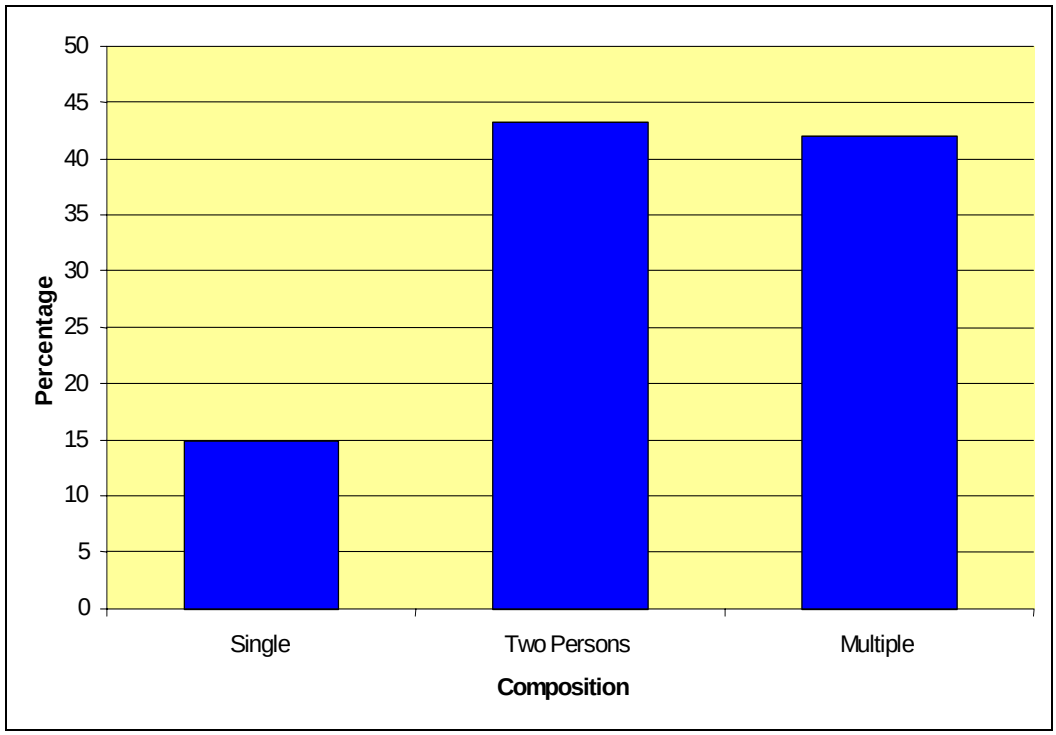

Figure 32: Household Composition (Q29)

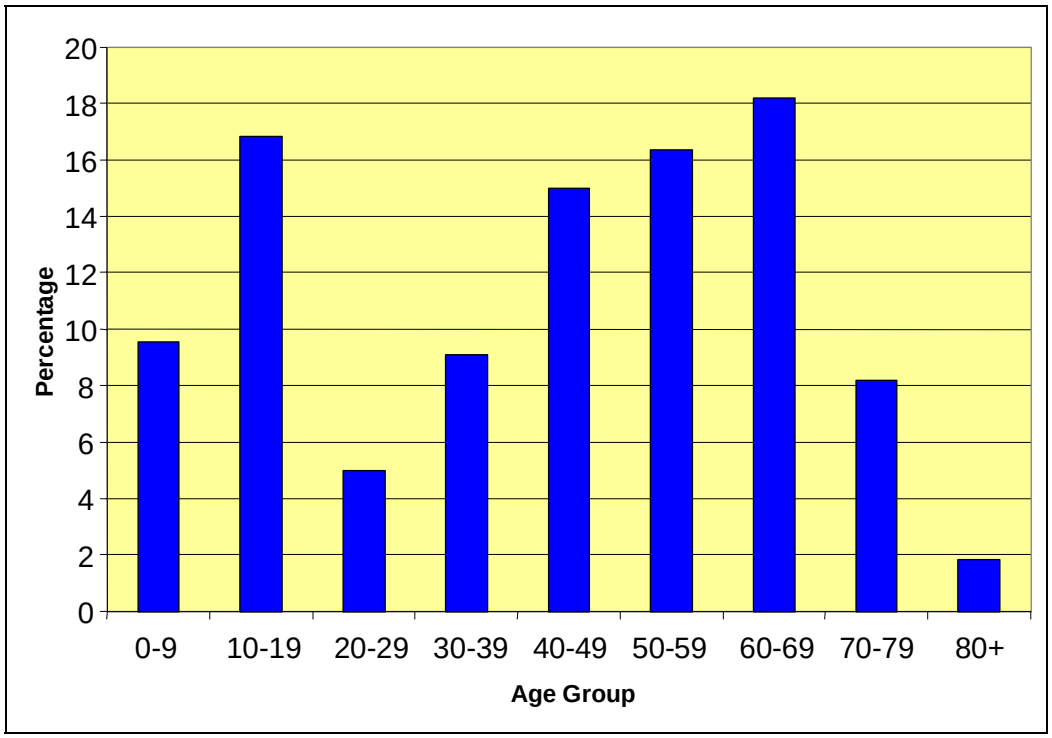

Figure 33: Age Groups as Percentage of all Occupants in Participating Household (Q29)

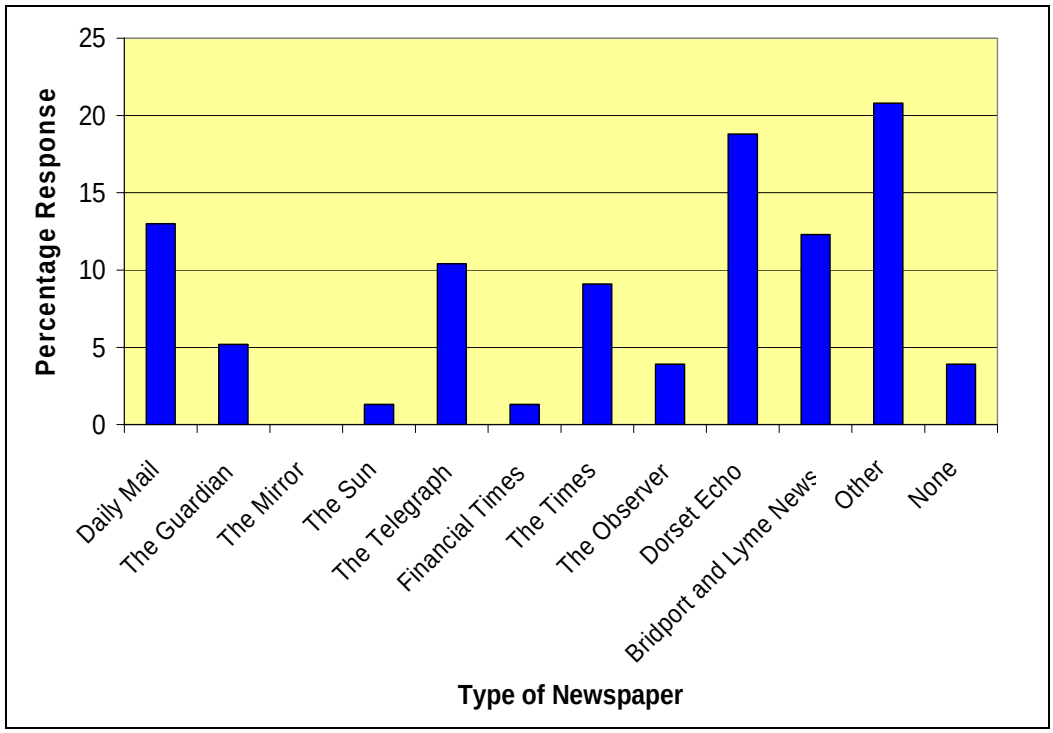

Figure 34: Newspapers Regularly Read by Participating Households (Q30)

The information acquired through the Questionnaire can be summarised as follows, which is provided in question order:

1) All participants in the Dorset Trial were already involved in composting and recycling to some extent;

2) 85% of participants had their waste collected weekly and 15% fortnightly;

3) 73% of participants put out 1-2 bin bags for collection prior to using the Green Cone, 17% 3-4 bags, 4% 5-6 bags, 4% 0-1 bags and 1% 7 or more bags;

4) 63% of participants put out for collection up to 1 less bin bag after using the Green Cone, 23% saw no reduction, 11% a 1-2 bag reduction and 3% more than a 2 bag reduction. These particularly large reductions are greater than the quantity of food waste alone and may reflect an increase in recycling rates for these participants as a result of using the Green Cone;

5) 50% of participants located their Green Cone in a position where it received full sunshine and 50% in a partially shaded position;

6) 37% of participants located their Green Cone some distance (over 20m) from the kitchen, 34% quite close (10-20m) and 30% very close (less than 10m);

7) 88% of participants used the supplied kitchen caddy to collect and carry their food waste to the Green Cone. Typical methods used by the remainder of participants are given in Appendix 5;

8) 74% of participants always filled the kitchen caddy before emptying it into their Green Cone, 21% sometimes filled and 5% never filled;

9) 56% of respondents compressed the food waste in the kitchen caddy a little, 38% not at all and 6% a lot;

10) Caddy load weights ranged from 0.35 kg to 2.75kg, with an average value of 1.55kg for all 95 participants;

11) There was significant misinterpretation of the question regarding the number of meals eaten at home each week. This data has therefore not been included because it is considered unreliable;

12) The average number of individuals at home during the week was 2.59 (from question 12) and the average number of occupants living in the participating households was 2.74 (from question 29);

13) Participant's views:

- 70% of participants agreed with the statement that using Green Cone "has reduced the amount of rubbish collected from my house";
- 69% of participants agreed with the statement that using Green Cone "has increased my commitment to reduce rubbish";
- 65% of participants agreed with the statement that using the Green Cone "has increased my commitment to recycling";
- 73% of participants agreed with the statement that the Green Cone "should be made available to every household with a garden";

14) 99% of participants usually remove the outer leaves of a supermarket cabbage that are damaged or discoloured and 49% even if they look in good condition;

15) 85% of participants do not usually peel a supermarket apple before eating it;

16) 61% of participants put their excess liquid fat with their other food waste, 41% kept it for cooking and 12% poured it down the sink. 14% of participants used more than one method;

17) 46% of the average kitchen waste going into Green Cone was fresh vegetables or fruit that required preparation, followed by fresh or unprocessed meat or fish on the bone (13%) and off the bone (9%);

18) 62% of participants used the provided accelerator powder sometimes (on average 1.5 times per month), 23% only when the Green Cone was first installed, 8% never and 7% every time;

19) 29% of the issues experienced by participants were related to slow decomposition at some stage through the year, with up to 4% of these due to poor drainage. 33% of issues were related to maggots and flies, 13% with the installation and 8% with vermin of some kind. These findings are consistent with the West Sussex Trial (Reference 6). There was little comment regarding difficulties installing the Green Cone in response to the question requesting views on disadvantages of the system and possible improvements. The local support service provided the following additional information:

- Three households with elderly or incapacitated occupants contacted the support service because they could not dig the hole for the digestion basket. Based upon previous experience and the fact that 92% of households provided with a Green Cone for the Dorset Trial are known to have actually installed and used the system, it is anticipated that most of the installation issues were minor;

- As described in Appendix 1, decomposition in the Green Cone is a slow process but a well operating system is capable of treating 5 kg of food waste a week. The participant's response to being asked whether they experienced slow decomposition is somewhat subjective as there was no specific reference point. For those participants who contacted the local support service, decomposition problems had largely resulted from the installation and operating instructions not being followed. For example, the digestion basket was located below the water table or in areas of very poor drainage, the cone was positioned in partial shade receiving very little direct sunshine and the system was overfilled above ground level with garden waste such as grass cuttings;

- In general, flies and maggots were accepted as a minor annoyance and participants understood that fruit flies, which were the main culprit, cannot be avoided as they are in the skins of some fruits. Only 16% of participants bothered to use a recommended insect control method, although a few contacted the local support service with suggestions such as putting waste into the cone in late evening;

- If properly installed, the Green Cone should not attract vermin as no smells come from the system. Vermin could be attracted if food is spilt near the cone. In every case that the local support service was contacted regarding vermin, participants admitted that the offending animal already came into the household's garden. This was particularly true where food or food scraps were put out for birds or livestock. For most of those unlucky enough to have a rat run crossing their Green Cone the solution was simply to move the cone. It is worth commenting that in one case, rats stopped visiting the traditional compost bin because food waste was transferred to the security of the Green Cone. In another case the problem of aggressive seagulls attacking and removing food waste from rubbish sacks was solved by the use of the Green Cone. A badger was a problem for one participant, which had not been previously experienced by Green Cone Ltd;

20) 4% of households encountered a problem that caused them to stop using the Green Cone completely;

21) Written responses in Appendix 6;

22) 16% of participants used a an insect control method;

23) 84% of participants believed the Green Cone gave an average or above average performance;

24) 65% of participating households had pets, chickens or other livestock and 33% of these households gave food scraps to their animals;

25) 81% of participants would recommend the Green Cone to a friend;

26) Written responses in Appendix 7;

27) 64% of households had gardens larger than a tennis court (35mx17m), with 9% having gardens smaller than a squash court (10mx6m);

28) Females completed 64% of the Questionnaires. This probably either indicates that, as found in previous research, females are more environmentally conscious than males or that the females in this sample are generally responsible for meal preparation and clearing up;

29) 43% of participating households comprised two persons, 42% were more than two people and 15% where single occupant. 31% of occupants in the participating households were in the age group 40-59, 28% were 60 or more, 27% were under 19 and 14% were 20-39;

Due to the size of the trial and the small number of responses related to particular issues, only a limited number of correlations were feasible. For example, no geo-demographic analysis could be carried out or relationships established between the quantities of waste put into the Green Cone and participants having compost heaps or pets. Responses to the range of questions on performance and satisfaction showed good general consistency. No correlation could be found between the amount of sunshine received by the Green Cone and its decomposition rate, although this was proven to be a factor for a few households.

The average amount of waste diverted for the 56 households that provided continuous measurements over the 52 weeks was 3.9 kg/week/household. Based on the household occupancy data provided by question 29 of the Questionnaire, this is equivalent to 1.9 kg/week/household occupant. The relationship between the amount of waste per household occupant and the number of occupants is shown in Figure 35, where the general trend is for a decrease in the amount of waste per person with increasing household occupancy. It should be noted that both the two largest household groupings were only single samples.

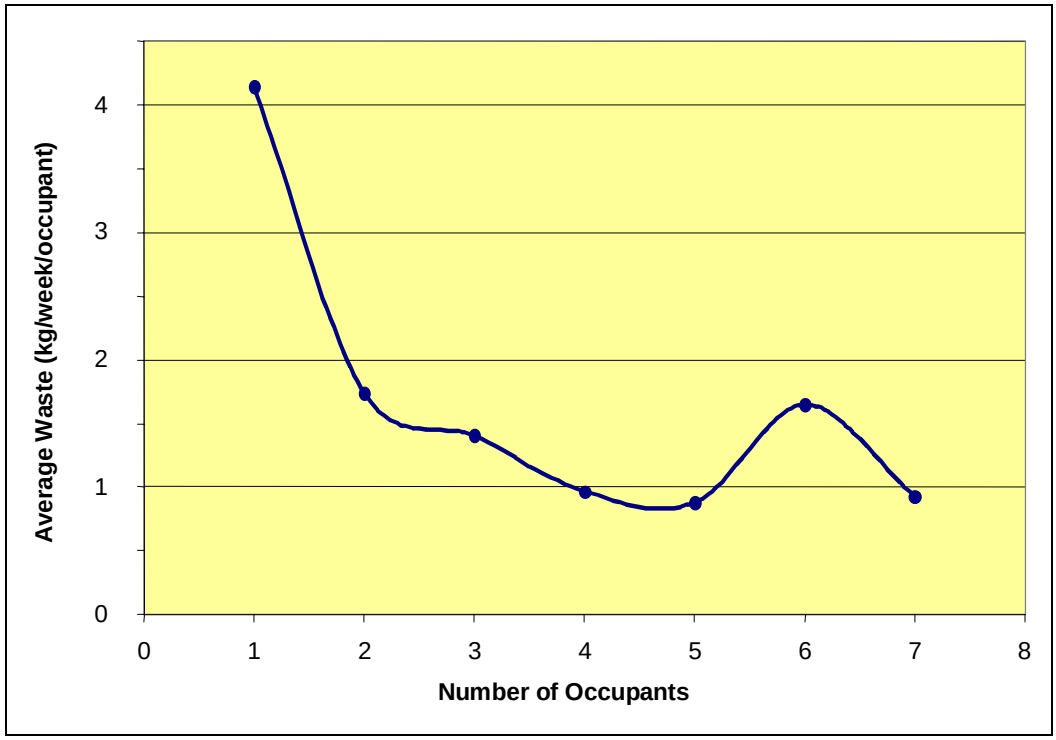

Figure 35: Average Waste per Week per Household Occupant

4 Conclusions

The Dorset Green Cone Trial successfully met its key objectives. The main results relevant to the system's performance and effectiveness can be summarised as follows:

- The average annual amount of waste diverted to the Green Cone was measured to be 204 kg/year/household, which compares closely with previous studies;
- 63% of participants put out for collection up to 1 less bin bag after using the Green Cone, 23% saw no reduction, 11% 1-2 bag reduction and 3% more than a 2 bag reduction. These particularly large reductions are greater than the quantity of food waste alone and may reflect an increase in recycling rates for these participants as a result of using the Green Cone;
- 70% of participants agreed with the statement that using Green Cone "has reduced the amount of rubbish collected from my house";
- 69% of participants agreed with the statement that using Green Cone "has increased my commitment to reduce rubbish";
- 65% of participants agreed with the statement that using the Green Cone "has increased my commitment to recycling";
- 73% of participants agreed with the statement that the Green Cone "should be made available to every household with a garden";
- Although a majority of households experienced some issue with the Green Cone, only 4% had a problem that caused them to stop using it entirely;
- 81% of participants would recommend the Green Cone to a friend.

This study has demonstrated that the Green Cone system has the potential to divert significant quantities of food waste from landfill. Given the rural nature of Dorset, there could be cost benefits over the approach of centralised kerbside collection and treatment. Although participants in this trial were self-selecting there appears to be public acceptance of such a system, with the additional potential benefits of limiting the growth in waste and increasing recycling rates.

5 References

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2) *Parfitt, J. (2002), Analysis of Household Waste Composition and Factors Driving Waste Increases. WRAP Report for Strategy Unit, December 2002*

3) *Green Johanna (2005), Retrieved: 23 July 2005 from http://www.greenjohanna.se/*

4) *Bokashi (2005), Retrieved: 23 July 2005 from http://www.livingsoil.co.uk*

5) *Green Cone (2005), Retrieved: 20 June 2005 from http://www.greencone.com*

6) *University of Brighten (2003), Minimisation of Food Waste through Home Digestion – Results of Trials in West Sussex. Report for West Sussex County Council by the University of Brighton Waste and Energy Research Group, December 2003*

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8) *Roslyn Associates (2002), The Waste Away Scheme Phase Two: A Quantitative Survey of the Effectiveness of The Moray Council's Waste Minimisation Scheme to Reduce Organic Kitchen Food Waste Going to Landfill. Report by Roslyn Associates for Ecolinc, ISBN 0-9539959-1-7, November 2001*

9) *Green Cone (2005), Retrieved: 10 October 2005 from www.greencone.com/in_depth_look.asp*

10) *Gale, P. (2002), Risk Assessment: Use of Composting and Biogas Treatment toDispose of Catering Waste Containing Meat. Report by WRc-NSF Ltd., Contract No. 12842-0 for Defra, May 2002*

Appendix 1: Description of the Green Cone Food Waste Digester

Function

The function of the Green Cone food waste digester is to:

- Accelerate the natural decomposition process by
    - raising temperatures;
    - maintaining aerobic conditions; and
    - encouraging the growth of micro-organisms.
- Contain and enclose the food waste to prevent dispersion and eliminate odours.
- Create barriers to human, farm animal, wild animal, pet and bird activity.
- Prevent surface and top soil contamination.
- Meet all relevant health, safety and environmental legislation.

The system takes all household food waste, including vegetable scraps, raw and cooked meat or fish, bones, dairy products and other organic food waste such as bread and pasta.

Design

The Green Cone is a four-part plastic injection moulded system comprising a digestion basket that is installed below ground and which forms the base for an above ground double-walled solar chamber with an access lid. The design of the Green Cone utilises solar heating in the double-walled chamber to facilitate and accelerate the aerobic decomposition process within the digestion basket. The system should therefore be installed to obtain the maximum sunlight in a household's garden. A 4.5 litre receptacle, which can be sealed, is provided for collecting and carrying the food waste to the Green Cone.

The diameter of the 440 mm deep digestion basket is 550 mm at the top and 400 mm at the bottom. A series of slots designed into the basket commence 190 mm below ground level and effectively remove about half of the side wall and base material. The inner and outer walls of the conical solar chamber are 20 mm part, providing an internal gap that is open at the top and bottom of the unit. The diameter of the outer chamber reduces from 550 mm at its base to 285 mm at the lid end. The chamber is 680 mm high but when assembled and installed, the Green Cone stands 650 mm above ground level and extends 460 mm below ground level. Access is through a 200 mm diameter hole in the top of the solar chamber, which is sealed by a hinged lid with a twistlock security catch.

The Green Cone will dispose of about 5 kg of food waste a week, which is over 25% greater than that produced by the average household. The food waste is converted into water, carbon dioxide and a small amount residue, without the need for user intervention such as the mixing or turning of the waste. In a well operating system the residue will occupy the bottom 250 mm of the digestion basket after the decomposition of about a tonne of food waste. Thus, after about five years, this small quantity of residue must be removed and dug into the garden sub-soil.

Process

The decomposition of organic material is a natural process. Much of the dry weight of plant and animals is attributable to proteins and their remains are eventually converted into soil through a continuous cycle of activity by a wide range of interdependent organisms and micro-organisms. The distribution of these organisms follows that of organic matter and is therefore not uniform, with over ninety percent concentrated in the top 100 mm of the soil. By locating the digestion basket below ground, the Green Cone takes advantage of this distribution of soil organisms. The system works best in fertile, well-drained soil, which means that areas of solid rock or with a high water table are unsuitable. In heavy clay soils, drainage should be improved by using a mixture of gravel and compost around the digestion basket. Soil fertility can be enhanced by the addition of suitable natural bacteria, as described later.

The smallest and most numerous micro-organisms are bacteria, with one gram of fertile soil containing around a billion bacteria. Bacteria are unicellular micro-organisms and amongst the smallest living creatures known. There are three bacterial cell shapes, spherical (coccus), rodlike (bacillus) and spiral (spirillum). Under favourable conditions bacteria numbers grow rapidly. Some survive in a dormant or spore state when conditions are not suitable, reviving when they become favourable again.

On the basis of temperature requirements for growth, bacteria are grouped into psychrophiles (0 - 30^{o}C), mesophiles (15 - 45^{o}C) and thermophiles (45 - 60^{o}C). Bacteria within each group exhibit specific minimum, maximum and optimum temperatures for growth, where, for example, mesophiles grow best in the temperature range 25 - 40^{o}C. To ensure a healthy population of bacteria, the Green Cone is provided with a mixture of these natural, non-pathogenic bacteria for use when the system is first installed and if the decomposition process slows because of an imbalance of organic material and bacteria.

Most bacteria grow in a near neutral environment (neither acidic or alkaline) and without light. Atmospheric oxygen is required by some but not all bacteria, others are inhibited by its presence. Bacteria are classified as aerobes when they require oxygen to grow and anaerobes when they cannot grow in the presence of oxygen. Facultative anaerobes do not require oxygen but can grow in its presence; obligate anaerobes are poisoned by free oxygen. Under poor oxygen conditions some micro-organisms can produce toxins that inhibit the growth of higher plants and other micro-organisms. These toxins include methane, hydrogen sulphide, phosphine, skatole, indol and various organic acids. It is for this reason that the Green Cone is designed to maintain aerobic conditions through generating air movement, which results from the temperature gradients created by the double walled solar chamber.

In addition to bacteria, other soil micro-organisms are intimately involved in the natural decomposition process. Actinomycetes resemble both bacteria and fungi. Their spores, although similar to those of bacteria, germinate into very fine colourless threads (mycelia) that resemble those of fungi. Fungi such as moulds, mildews or mushrooms are usually more variable in form than either bacteria or actinomycetes. There are also algae, which are found as motile single cells or non-motile filaments.

Soil fauna ranges from microfauna, usually defined as animals less than 100 microns long, through macrofauna to megafauna, which are the largest soil organisms. Microfauna includes single-celled protozoans, some smaller nematodes, small flatworms, rotifers and tardigrades. Many microfauna only exist in the water films on the organic matter. The most common macrofauna are the small white segmented enchytraeidae that feed on fungi, bacteria and decaying matter. Soil macrofauna play a valuable role in fragmenting organic waste and increasing its surface area. In addition, with the help of symbiotic organisms in their guts, some also break down complex substances such as cellulose, keratin and chitin. Megafauna includes the larger earthworms, which also pass both soil and organic matter through their guts. The fragmented organic waste and soil fauna excretions create an environment suitable for the growth of micro-organisms. The continuous cycle of consumption, digestion and excretion by soil fauna alternates with increases in the population of micro-organisms.

Heterotrophic soil micro-organisms, which derive their carbon and energy from organic materials, are concerned mainly with the breakdown of organic matter, the carbon cycle and nitrogen fixation. Autotrophic micro-organisms, which obtain carbon from carbon dioxide and energy from the oxidation of simple organic compounds, form nitrites and nitrates and oxidise sulphur and iron compounds. Most micro-organisms produce carbon dioxide, which dissolves in water to form carbonic acid. Mineral elements such as sodium, potassium and magnesium are released to the soil during the decomposition process. The weak carbonic acid dissolves relatively insoluble soil minerals.

The different bacteria outlined above produce different enzymes, which are the protein catalysts responsible for the metabolism of organic waste. The principal enzyme types important in the decomposition of food waste are:

- Lipases to digest the fats in foods such as dairy produce, oil and meat.
- Amylases to digest the carbohydrates in foods such potato peelings, bread, biscuits, rice and pasta.
- Proteases to digest the proteins in foods such meat, milk and eggs.
- Cellulases, or cytases, to digest the cellulose in fruit and vegetable matter.

Where conditions are such that the decomposition process is very efficient, such as within the Green Cone, only a small residue of humic substances comprising lignin and protein remains.

Relevant Legislation

The UK has amongst the most comprehensive legislation and controls related to food waste and animal by-products in the world. The recent EU Animal By-Products Regulations and the UK's National Regulations introduced controls for the processing and end use of composted material derived from food waste. Under the legislation, all food waste that contains, or has been in contact with, meat or other products of animal origin must be disposed of so that animals and birds cannot gain access. This does not just apply to the collection, transportation and centralised treatment of food waste but also to household treatment. Detailed guidance on the treatment of animal by-products and catering (food) waste has been provided by the UK Department for Environment, Food and Rural Affairs (Defra).

Meat or other products of animal origin fit for human consumption are classified under legislation as low risk Category 3 animal by-products. Regulation 16 of the Animal By-Products Regulations states that the composting requirements for centralised treatments "do not apply to the composting of Category 3 catering waste on the premises on which it originates provided that (a) the decomposed material is only applied to land at those premises: (b) no ruminant animals or pigs are kept on the premises; and (c) if poultry is kept at the premises the material is composted in a secure container which prevents the poultry having access to it during decomposition." As a consequence, the household treatment of food can only take place in an enclosed container that prevents access by poultry, wild and domestic animals and birds. In addition, a household food waste digester must be physically separated from pigs or ruminants (e.g. sheep, cows, goats, deer) by a suitable barrier, such as a fence. This applies to both farmed and pet animals.

The design and operation of the Green Cone meets all the relevant legislation.

Health, Safety and Environmental Impact

The Green Cone is a benign technology and as such causes minimal health, safety and environmental impact. The below ground digestion basket and the sealed solar chamber provide sound physical barriers to odours, insects, birds and animals. With 40% of the unit below ground, the green conical solar chamber of the system creates negligible visual impact. The Green Cone is constructed from as much recycled material as possible, which in practice means that 100% of the digestion basket and inner solar chamber are made from recycled plastic.

Common to all handling of food and food waste, good housekeeping practises are the cornerstone of health and safety. Such practices include not spilling or leaving food uncovered in the home or elsewhere and the washing of hands before and after handling food. One advantage of the Green Cone is that no third party is involved in the collection and treatment of the waste, with householders handling their own food waste of which they know the provenance. In addition, the individual choices made in the home production or purchasing of food regarding organic growing and farming methods, GM derivatives, animal welfare and pesticide residues can be carried though to the household food waste disposed of in the Green Cone.

In use, food waste is transferred as soon as practical from the kitchen to the Green Cone, which allows food waste to be removed daily as opposed to weekly or fortnightly with a centralised collection approach. Once deposited in the below ground digestion basket, there is no possibility for unintentional access to the food waste by human activity. As with any gardening activity, particularly those involving soil or compost, gloves should be worn when removing the small amount of residue that accumulates in the digestion basket after several years of operation.

As noted in the previous section, much of the legislation relevant to the treatment of food waste is concerned with the risk to pigs, ruminants and poultry of infection from pathogens potentially present in meat and the subsequent risk to humans. A detailed risk assessment of the centralised treatment of food waste and land disposal of the compost produced has been carried out for Defra, which concluded that the approach is acceptable provided that a number of key conditions are met.

The derivation of reliable absolute risk values covering human intervention in environmental systems is extremely complex. The Green Cone has been assessed relative to the benchmark established by Defra, using both qualitative and quantitative information. Environmental risk assessment is not concerned with the complete elimination of a pathogen by any one barrier but relies on a multiple barrier approach. Many of the barriers involved in the centralised treatment of food waste are common to the household treatment using the Green Cone system. These include the reduction and elimination of by-pass to the treatment process using physical barriers, the effectiveness of the process itself, decay in the soil, dilution in the soil and the fact that only household food fit for human consumption is being treated, of which a few per cent is uncooked meat.

Temperatures in the solar chamber of the Green Cone reach up to 50^{o}C for long periods during summer months in the UK. Although temperatures are lower with natural decomposition in the Green Cone than in commercial centralised treatments, the indigenous micro-organisms can be preserved to grow at the expense of any pathogens present through competition for nutrients and predation. In addition, the process is performed over extremely long periods of up to five years, which allows for effective pathogen destruction.

Due to the effectiveness of the Green Cone in controlling process by-pass, the efficiency of the decomposition process itself and the inaccessibility to animals, birds and humans, the overall health, safety and environmental risk is extremely small and comparable to that for centralised treatments.