Identifying new products, uses and markets for Australian vegetables: A desktop study

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Identifying new products, uses and markets for Australian vegetables - a desktop study

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Applied Horticultural Research

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This project has been funded by HAL using levy funds from the Australian vegetable industry and matched funds from the Australian Government.

The broad objective of this project was to quantify the waste produced by the Australian vegetable industry, with a focus on waste at the farm level. The project then reviewed alternative uses for vegetable waste and presented uses with potential for adoption by growers or processors.

Contents

1 Media Summary

Waste is a significant issue for the vegetable industry. Waste can include the non-harvested parts of plants, off-cuts and by-products, product which does not meet retailer specifications and product that is abandoned before harvest due to low market prices.

This study has estimated the types and quantities of waste occurring in the Australian vegetable industry. The results suggest that over 277,000 tonnes of the major vegetable lines, representing around 25% of production, is wasted each year. Most waste is due to failure to meet strict retail quality specifications. This otherwise edible product is usually dumped, used for stock feed, or rotary hoed back into the soil. The cost of this waste to growers is estimated at close to $155million annually.

The best way to reduce waste would be to increase demand for fresh vegetables. Most Australians eat less than 3 serves of vegetables a day and only 8% eat the recommended 5 daily serves. There are therefore major opportunities to increase consumption, with corresponding benefits for public health.

Other options for using vegetable wastes include;

- Extraction of bio-active compounds for use in nutritional supplements and nutraceuticals, or as natural food colourants
- Extraction of volatile compounds to use as natural flavourings in food manufacturing
- Dietary fibre production, potentially including bio-active compounds, for use in fortified foods and supplements
- Producing insects such as mealworms or black soldier fly larvae as high protein ingredients in feeds for aquaculture
- High quality animal feed production through silage or aerobic fermentation
- On farm electricity generation using biogas produced from anaerobic digestion of organic materials
- Combustion without oxygen (pyrolysis), producing electricity as well as a stable form of carbon (biochar) which can be used to increase soil fertility
- Composting with earthworms (vermicompost) production to improve soil structure and fertility

A number of these options would appear to offer economic opportunities for Australian vegetable growers.

2 Executive Summary

There is significant waste from the vegetable industry, including product off-cuts and by-products, product which does not meet retailer specifications and product that is not harvested due to low prices in the market. In many cases this produce is dumped, used for stock feed, or rotary hoed back into the soil.

This desktop review and survey of growers and processors was undertaken to characterise and quantify waste produced by the vegetable industry in Australia.

Waste comes in many forms, and at different locations within the supply chain. In many cases, it is the observer who defines what is considered waste. For example, non-harvested, non-edible plant material would only be counted as organic waste if the focus were the potential production of biofuel.

In addition, most studies of waste have focused on losses due to processing or examined food thrown out by consumers, rather than evaluated what is lost at the farm level. Waste may therefore be considered as recoverable versus non-recoverable waste. That is, waste which can be physically recovered and profitably recycled versus waste that is difficult or impossible to recover and re-use.

Carrots produce the most waste at 93,000 tonnes per year, which represents 31% of total production. In order of the amount of waste produced, the crops are: carrots, capsicums, cauliflower, sweet corn, cabbage, baby leaf (transplanted), lettuce, broccoli, beans, beetroot, and baby leaf (direct-seeded). Although baby leaf transplants have a relatively low level of waste, the value of this crop means that the resulting financial losses are the highest of those studied.

Total annual production of the vegetables studied was 1,116 kt per year. Total waste from these crops was estimated at 278 kt, representing 25% of production. The value placed on this waste, even taking into account savings from reduced harvest and packing requirements and the green manure value of crops ploughed into the ground, still approaches $155 million annually (Table 1).

Table 1 - Summary of production volumes, waste volumes and resulting loss to producers of a number of key vegetable lines.

Crop	Total production (kt)	Total waste (%)	Value of waste ($ million)
Carrots	93.0	31	24.0
Capsicums	31.1	26	13.8
Cauliflower	27.8	37	19.6
Sweet corn	26.9	27	14.3
Cabbage	19.8	27	9.7
Baby leaf - TP	19.4	12	38.8
Lettuce	17.0	14	7.4
Broccoli	15.4	31	16.7
Beans	12.8	25	2.2
Beetroot	10.2	28	1.2
Baby leaf - DS	3.5	12	6.9
Totals	**276.9**	**25**	**154.7**

Alternative uses for vegetable waste in Australia include:

Increasing consumption of vegetables: The best solution for the vegetable industry and consumers is clear - increase demand. The obvious way to do this is to clearly communicate the essential role of vegetables in promoting health and wellbeing. Consumption of vegetables needs to be doubled just to achieve the recommended 5 serves a day. Options are investigated for funding such a campaign given that vegetables do not currently have a marketing levy.

On farm electricity generation from vegetable waste: On farm power generation using biogas produced from the anaerobic digestion of vegetable waste is a viable option for larger vegetable growers producing at least 10 t of waste per day. The levelised cost of energy (LCOE) for Biogas is generally $80 - $160 / MWh, with farm wastes at the lower end due to their suitability for this process. This compares favourably with the average retail cost of electricity ($230 / MWh).

Bio-Active compound extraction from vegetables: Many of the special benefits that come from eating vegetables are due to the various chemical compounds they contain. These include sulfur compounds, phenolics, betalains and carotenoids. While the sulfur compounds found in *Brassicas* such as broccoli are less suitable for extraction and use in supplements, many phenolics and carotenoids remain stable during processing and consumption and maintain their activity in the body. Although it is not currently economically viable to extract bio-active compounds from Australian vegetables, this is an area which is continuing to develop. Moreover, plant extracts developed for other purposes – such as dietary fibre – which also contain bio-active compounds, are likely to find ready use in manufactured 'nutraceutical' products.

Extraction of volatile compounds and food flavours: Aromatic compounds extracted from fruit or vegetable waste can be used as flavourings by the food processing industry. Appropriate vegetables include celery, herbs, capsicums, chillies, garlic and onions. The economic viability of using SCC technology or perhaps even other process extraction methods would need to be assessed. There is expertise available in Australia. For example, the company Flavourtech located in Griffith NSW specialises in providing innovative processing solutions to the Food & Beverage and Pharmaceutical industries.

Dietary fibre from vegetables: Diets rich in dietary fibre (DF) are associated with reduced rates of cancer (especially colon cancer), cardiovascular disease, constipation, irritable colon and diabetes. Many vegetables and vegetable wastes (eg outer cabbage leaves, corn cobs) are rich in both insoluble and (the more valuable) soluble dietary fibre. For example, carrot and beetroot wastes both have total DF contents of 6 - 8g/100g fresh weight split between soluble and insoluble DF. Beetroot also contains betalains, while carrots contain carotenoids (β-carotene, anthocyanins), potent (soluble) antioxidants. This could further enhance the market value of DF from these sources as additives to functional foods.

Other specialist vegetable opportunities: In general, the vegetables with the least waste are those for which there are multiple different uses, and where these different uses have been anticipated and planned for. Lettuce provides an example where careful crop scheduling, predicting market demand, and vertical integration with fresh cut product manufacturing have reduced wastage to as little as 5% for some grower / processors. Some potential uses in this area include:

- Carrots for additives to fruit juice and bakery
- Corn cobs for biofiltration
- Celery and parsley for oil flavour
- Chillies for sauces, purees and semi-dried products
- Black carrots for natural food colouring

Biochar from crop waste: Biochar involves high temperature combustion of organic materials to produce energy and a stabilised form of carbon (char) that can be used as a soil amendment. Equipment remains relatively expensive and large volumes of raw materials are required. Biochar production is most likely to be economically viable if it becomes eligible for carbon credits under the CFI, and the price of carbon increases. Viability would also be increased if sources of carbon such as timber wastes could be combined with vegetable wastes to produce the char.

Fish food from vegetable waste: As fish stocks in the worlds oceans continue to dwindle, aquaculture appears to offer a solution to the growing demand for seafood. However, production is hampered by a continuing reliance on fish meal, produced from lower value wild caught fish, as a food source. While much research has focussed on crop plants and animal wastes as protein sources for fish, there is increasing interest in the use of insect-based protein meals. Vegetable wastes are ideal food sources for insects such as black soldier fly and mealworms, which can then be dried to use as a component in fish food. Although there are still too many unknowns to determine whether this is an economically viable option for the Australian vegetable industry, this may be an area worthy of further investigation.

Animal feeds: Fruit and vegetable wastes are rich in many bioactive and nutraceutical compounds, such as polyphenolics, carotenoids and dietary fiber and have potential to be used in the production of animal feed products. Potential areas include processing vegetable waste into high protein, high nutritional value stock feeds for cattle and dairy cows, and turning waste into silage through a process of assisted fermentation.

Biofertilisers and vermicompost: Vegetable waste can be converted into bio fertilisers or vermicompost, which can have disease suppressive and bio insecticidal properties. Vermicomposting involves the use of earthworms to convert biodegradable solid waste into a product with excellent soil conditioning properties, reported disease suppression and enhanced nutrient availability. The vermicompost can either be sold, as can the liquid "worm juice" produced, or used directly on the farm as a soil amendment.

This project covers levy paying crops only. The following vegetable industries do not pay the National Vegetable Levy, and were therefore not included in this review: asparagus; garlic; hard onions; herbs (other than fresh culinary shallots and parsley); melons; mushrooms; potatoes (other than sweet potatoes); seed sprouts and tomatoes.

3 Introduction

There is significant waste from the vegetable industry. This waste includes product off-cuts and by-products, product which does not meet retailer specifications and product that is not harvested due to low prices in the market. In many cases the produce is dumped in the paddock or landfill, or put to potentially lower-value uses such as feed for cattle, or rotary hoed back into the paddocks.

New value-added vegetable-based products and by-products can help create new markets and new demand for vegetables, including secondary product and waste product. This helps underpin market values and profitability for levy payers.

Whilst new product development is often the domain of commercial entities, there can be a role for the national research and development levy in supporting novel and underpinning technologies and in assisting levy payers to identify, develop and introduce new products. Examples of new uses of vegetables and vegetable by-products include nutraceuticals, biofuels and nutrient recovery from vegetable waste.

The purpose of this study is to review the data available on vegetable waste in Australia and overseas, estimate the actual quantities of waste produced by growers and processors in Australia and review new, innovative and economically feasible uses for that waste.

This project covers levy paying crops only. The following vegetable industries do not pay the National Vegetable Levy, and were therefore not included in this review: asparagus; garlic; hard onions; herbs (other than fresh culinary shallots and parsley); melons; mushrooms; potatoes (other than sweet potatoes); seed sprouts and tomatoes.

4 The International issue of food and vegetable waste

4.1 Introduction

The economic value of any program to develop new uses for vegetable industry wastes will depend largely on the quality and quantity of materials available. In addition to conducting original local research, it is therefore useful to review what is known and already published about waste within the vegetable supply chain.

This desktop study focuses on published information on volumes of vegetable waste in markets overseas as well as within Australia. Where local information is not available, studying comparable markets in other countries might indicate approximate wastage rates within the Australian system, although this cannot be assumed. In addition, vegetables tend to be grouped as a category, rather than studied as discrete product lines. Nevertheless, the published data does provide some guidance as to the scale of this issue and potential volume of material available.

4.2 International food losses

The Food and Agriculture Organisation (FAO) recently conducted an extensive study of world food losses[1]. Perhaps surprisingly, the biggest losses were in North America and Oceania, followed by Europe. Regions with relatively high incomes wasted more food than did developing parts of the world (Figure 1), despite their better infrastructure and efficient supply chains. The study suggested that up to 1/3 of all food produced is wasted, with the majority of this wastage occurring between the farm and the retail store.

[1] Gustavsson, J. Cederberg, C., Sonesson, U. van Otterdijk, R., Maybeck, A. 2011. Global food losses and food waste: extent, causes and prevention. Food and Agriculture Organisation of the United Nations, Rome, 2011.

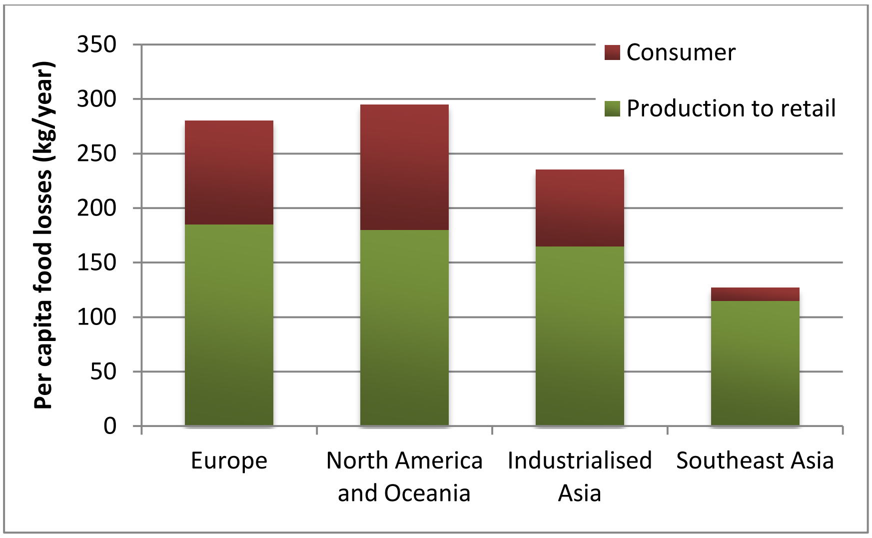

Figure 1. Per capita food loss in different regions of the world (source[8]).

Other reviews of food waste in the global supply chain have estimated that as much as half of all food produced is wasted either before or after it reaches the consumer[2,3]. A study of food waste in the UK[4] indicated that consumers throw away about one-third of the food they buy, while other countries vary between 8% (Netherlands) and 25% (USA)[5]. A recent survey of seven European countries suggested that consumers throw away 20% of their food purchases[6].

Disturbingly for the fresh produce industry, about 50% of what is thrown away is fruit and vegetables, although this category represents closer to 20% of food purchases[6].

A study in South Africa found that fruit and vegetables accounted for 46% of food waste even though the sector represented only 27% of food produced. Much of the waste occurred before the product reached the consumer, with 18% waste during production and postharvest handling and a further 31% waste during processing, packaging and distribution[7].

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[2] Parfitt, J., Barthel, M., Macnaughton, S. 2010 Food waste within food supply chains: quantification and potential for change to 2050. Philosophical Transactions of the Royal Society: Biological Sciences. 365:3065-3081.

[3] Lundqvist, J., de Fraiture, C., Molden, D. 2008. Saving Water: From Field to Fork – Curbing Losses and Wastage in the Food Chain. SIWI Policy Brief.

[4] WRAP. 2008. Household food and drink waste in the UK. Waste and Resources Action Program. www.wrap.org.uk. accessed March 2013.

[5] Parfitt, J., Barthel, M., Macnaughton, S. 2010 Food waste within food supply chains: quantification and potential for change to 2050. Philosophical Transactions of the Royal Society: Biological Sciences. 365:3065-3081.

[6] Cofresco. 2013. Pan European study reveals disturbing numbers on European food waste. www.cofresco.de/en/unternehmen/save-food/verschwendung.html accessed March 2013.

[7] Oelofse, S.H.H., Nahman, A. 2012. Estimating the magnitude of food waste generated in South Africa. Waste Management Resources 31:80-86.

While losses occur across all food groups, waste from fresh produce certainly dominates the total. This is not due necessarily to issues with pests and disease, but to quality standards which grade out imperfect product[8]. Partly as a result, it was estimated that more waste occurs at the farm, where product is either left in the field or discarded soon after harvest, than at any other point in the supply chain (Figure 2).

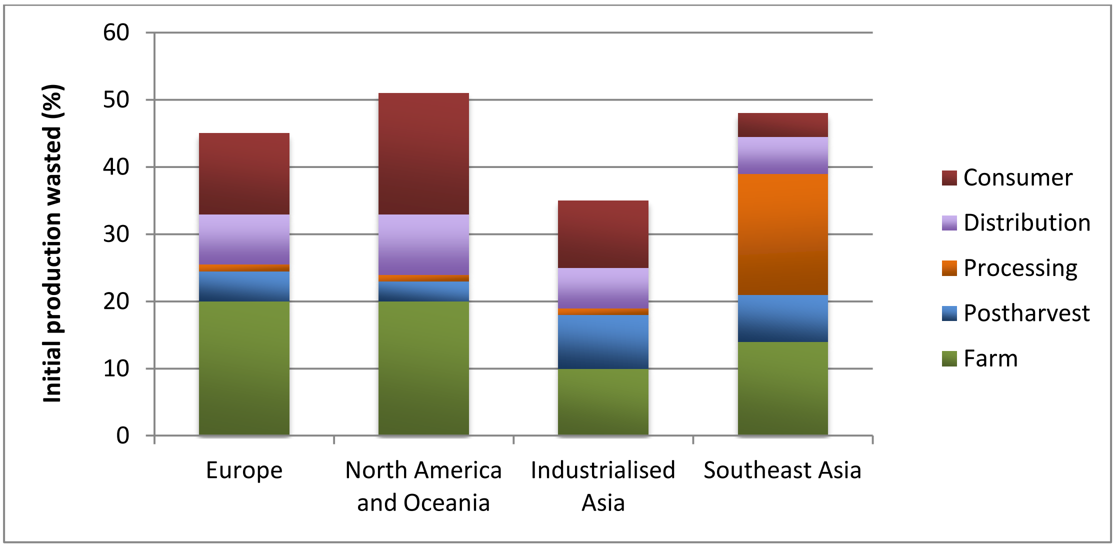


Figure 2. Percentage of initial production of fresh produce wasted at different points through the supply chain (source[8]).

Moreover, food waste appears to be increasing. A study of the progressive increase of food waste in America and its environmental impact estimated food waste by comparing food produced in the USA to the calorie demands of a growing population[9]. They found that food waste had increased by ~50% since 1974, reaching around 1,400 kJ per person per day. This waste has been produced using an estimated 25% of the freshwater supply (given that 70% of water is used for agriculture) and 4% of total USA oil consumption.

[8] Gustavsson, J. Cederberg, C., Sonesson, U. van Otterdijk, R., Maybeck, A. 2011. Global food losses and food waste: extent, causes and prevention. Food and Agriculture Organisation of the United Nations, Rome, 2011.
[9] Hall, K.D., Guo, J., Dore, M., Chow, C.C. 2009. The progressive increase of food waste in America and its environmental impact. PLoS ONE 4:e7940.doi10.1371.

4.3 USA data on vegetable waste

The Economic Research Service within the United States Department of Agriculture (USDA-ERS) tracks the availability of food in the USA. Unfortunately on-farm losses are not included. Nevertheless, the data indicates that losses between the farm gate and the consumer are well above 40% and increasing (Figure 3), consistent with the results of the American food waste study[9].

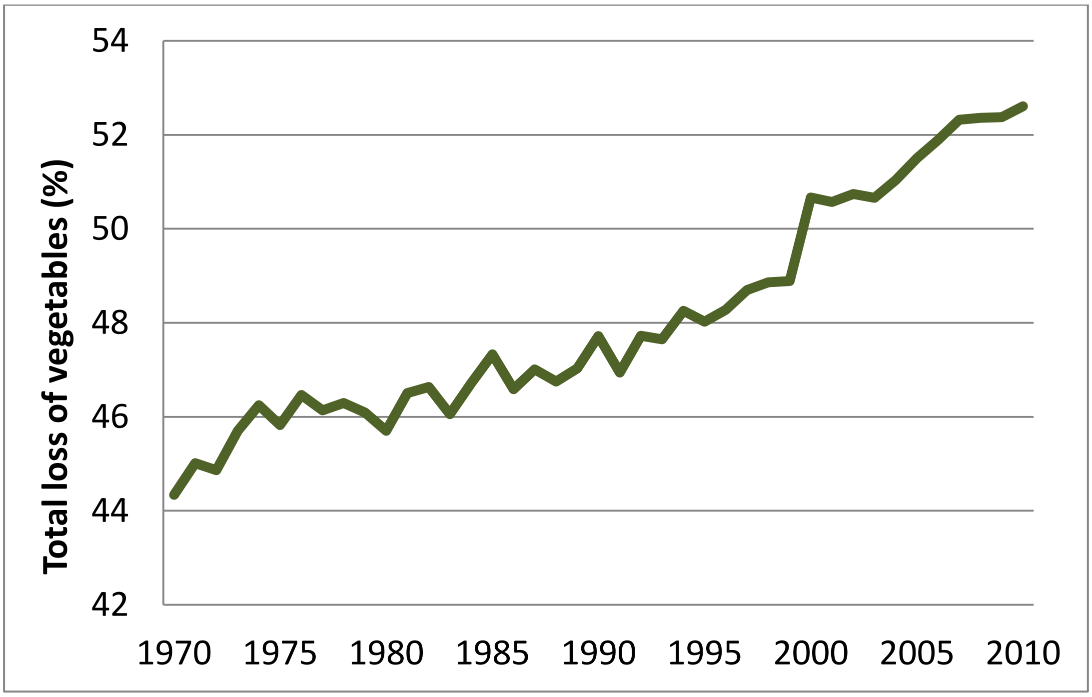


Figure 3. Total loss of vegetables between the farm and consumer in the USA (source: USDA-ERS[10]).

As part of the USDA's dietary assessment of the US food supply, Kantor[11] estimated food losses based on the average reduction in weight between the farm and when it is eaten. It therefore includes the non-edible parts that are normally discarded (peel, core, stem etc) as well as product waste. Although Kantor's figures do not include on-farm losses, it is interesting to note the considerable portion of many products that cannot be eaten but which nevertheless is still harvested, transported and sold.

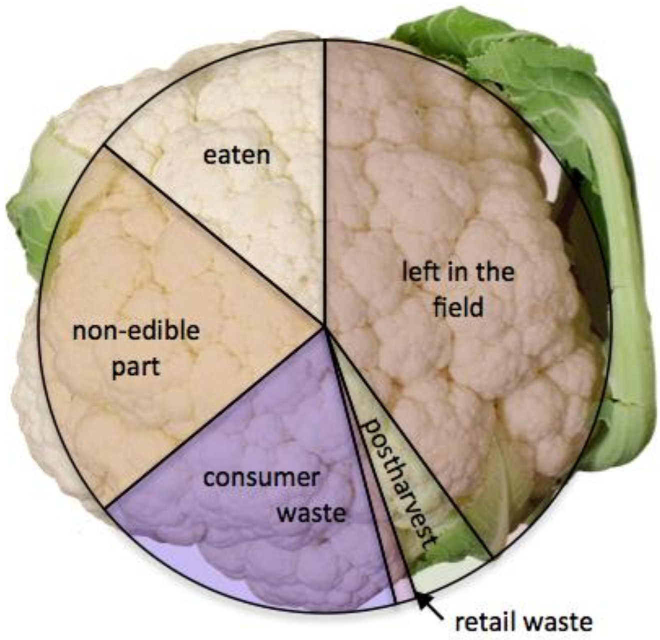
[10] USDA National Agricultural Statistics Service. 2013. Vegetables 2012 Summary. January 2013. ISSN: 0884-6413.

[11] Kantor, L.S. 1998. A dietary assessment of the US food supply (AER-772). US Department of Agriculture, Economic Research Service, Washington, D.C. 52 pp.

Table 2 - Inedible portion of vegetables[11].

	Inedible portion (%)
Brussels sprouts	10
Carrots	11
Green beans	12
Lettuce (iceberg)	16
Capsicums	18
Cabbage	20
Lettuce (leaf)	21
Broccoli	39
Cauliflower	61
Sweet corn	64

Dhruba *et al*.[12] estimated that 40% of the total mass of an individual cauliflower plant is harvested, the rest being left in the field. According to Kantor[13], approximately 24% is lost between the farm and the consumer, while 61% of what is left of the product is considered non-edible (Figure 4).



[12] Dhruba, D., Shah, S.C., Gautam, D.M., Yadav, R.N. 2009. Response of Cauliflower (Brassica oleracea var. Botrytis) to the Application of Boron and Phosphorus in the Soils of Rupandehi District. Nepal Agric. Res. 9:139-149.
[13] Kantor, L.S. 1998. A dietary assessment of the US food supply (AER-772). US Department of Agriculture, Economic Research Service, Washington, D.C. 52 pp.

Figure 4. Estimated portion of cauliflower that is eaten compared to that which is waste (sources: Kantor[13] and Dhruba[12]).

Another guide to wastage on farms can be extrapolated by comparing the area planted with the area harvested. For example, the USDA recorded that 84,440 acres were planted with carrots in 2012 but 82,610 were harvested, a drop of about 2%. Jones and Ndiaye[14] also found that field losses of carrots were low compared to other crops. Field losses for other crops were close to 10%, while additional significant waste occurred due to postharvest trimming, especially for lettuce.

Table 3 - Field and processing losses (source: Jones and Ndiaye[14]).

	Field loss (%)	Processing loss (%)
Broccoli	11	3
Cauliflower	10	3
Celery	10	1
Leaf lettuce	6	9
Head lettuce	4	16
Carrot	1	1

This same study found that postharvest losses from the Salinas Valley were negligible[14]. This is in contrast to the USDA-ERS data (2010), which reports losses between the farm gate and retail ranging from 7-10% for most vegetables and 12% for leafy greens.

Estimates of loss at retail vary considerably, ranging from only 2%[11] to up to 20% for perishable products such as brussel sprouts and snap beans[15]. While robust products such as pumpkins and carrots are generally likely to have lower loss at retail, discrepancies exist. Buzby[15] found that although packaged salads typically have a longer shelf life than head lettuce, loss of pre-packs is often greater. They suggest that this may be due to the large range of products available and the higher cost of such products.

[14] Jones, T., Ndiaye, N. 2004. Food Loss in Fresh Fruit and Vegetable Farming, Storage and Processing. USA. Report to the United States Department of Agriculture, Economic Research Service.

[15] Buzby, J.C., Wells, H.F., Axtman, B., Mickey, J. 2009. Supermarket Loss Estimates for Fresh Fruit, Vegetables, Meat, Poultry, and Seafood and Their Use in the ERS Loss-Adjusted Food Availability Data. USDA Economic Research Service (USDA-ERS), Economic Information Bulletin Number 44, March 2009.

4.4 European data on vegetable waste

Reducing food waste has a high priority in Europe due to concerns about environmental sustainability. As well as rising disposal costs, there is interest in using vegetable wastes in ways that add value, going beyond composting or simple animal feeds[16]. The European Union is funding an ongoing project aimed at reducing food waste. The objective is to reduce environmental impacts (landfill, noxious residues and odours), improve sustainability and provide natural ingredients for the food and feed industries[17].

Despite this, little data is available, especially for waste occurring during production, processing and postharvest management. Henn[18] estimated that potato, vegetable and fruit processing in Germany generate 380,000 tonnes of organic waste annually. Similarly, Eurostat figures suggest that more than one million tonnes of vegetable trimmings are produced in the European Union every year[17]. Stuart[19] suggests that somewhere between 20-40% of UK-grown fruit and vegetables are rejected between harvest and retail, mainly due to failure to meet strict quality specifications.

As in the USA, more is known about what consumers throw away than what is lost or abandoned on the farm. A UK study found that vegetables accounted for 23% of food thrown away by consumers[20]. This represents about 46% of all vegetable and salad purchases or about 1.9 million tonnes annually of waste. While it is acknowledged that about 60% of this waste is unavoidable (peelings, cores etc), the report also notes that this is likely to be a considerable underestimation of the amount of waste produced.

[16] Laufenberg, G., Kunz, B., Nystroem, M. 2003. Transformation of vegetable waste into value added products: (A) the upgrading concept; (B) practical implementations. Bioresource Technology 87:167-198.
[17] The Food Navigator, 2012
[18] Henn, T., 1998. Untersuchungen zur Entwicklung und Bewertung funktioneller Lebensmittelzutaten aus Restoffen am Beispiel von Mohrentrestern und ihrer Anwendung in Gertranken (Thesis, Bonn, 1998) Cuvillier Verlag Gottingen.
[19] Stuart, T. 2009. Waste: Uncovering the Global Food Scandal. W.W. Norton and Co. Inc. London.
[20] WRAP. 2008. Household food and drink waste in the UK. Waste and Resources Action Program. www.wrap.org.uk. accessed March 2013.

4.5 Australian data on vegetable waste

Like their contemporaries in the USA and Europe, Australians waste much of the food they purchase.

A report by the Australia Institute suggested that Australian consumers threw away $5.3 billion worth of food in 2004, more than half of which was fresh food such as fruit and vegetables[21].

Many such studies have been conducted on food waste; a total of 1,262 reports on Australian food waste were recently collated and reviewed by the Department of Sustainability, Environment, Water, Population and Communities (DSEWPC)[22]. However, 87% of this information related to waste by consumers, with less than 2% of studies including pre-farm gate or postharvest losses. Additional complications are due to differences in the methods used to measure waste[23], the reluctance of some companies to disclose proprietary information[24], and climate and weather variability that can cause wide fluctuations in waste from year to year.

The report notes that there is a major gap in knowledge regarding on-farm crop wastes, with almost no data available. Also, there was little information on volumes of waste from food manufacturing and processing, supermarket distribution chains and fresh produce retailers. This is unfortunate as waste from processing may be considerable; e.g. in the early 1990s the Australian pineapple processing industry alone produced 400,000 tonnes per annum of peel[25].

The DSEWPC[22] report appears to confirm the lack of Australian information on the quantities and value of vegetable waste in the food chain. Few references seem to be available. The following summarises what could be gleaned from known sources.

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[21] Hamilton, C., Denniss, R., Baker, D. 2005. Wasteful consumption in Australia (Discussion Paper Number 77). Canberra: The Australia Institute.

[22] Department of Sustainability, Environment, Water, Population and Communities http://www.environment.gov.au/

[23] Mason, L., Boyle, T., Fyfe, J., Smith, T., Cordell, D. 2011. National Food Waste Data Assessment: Final Report for the Department of Sustainability, Environment, Water, Population and Communities.

[24] Morgan, E. 2009. Fruit and vegetable consumption and waste in Australia. Final Report for VicHealth. www.vichealth.vic.gov.au.

[25] Tran, C.T. & Mitchell, D.A., 1995. Pineapple waste – a novel substrate for citric acid production by solid state fermentation. Biotechnology letters 17:1107-1110.

Table 4 - Departments of Sustainability, Environment, Water, Population and Communities summary of vegetable waste (source: DSEWPC[22]).

Crop or Situation	Comment	Source
WA cauliflowers	Incorrect harvest maturity caused 14% cauliflowers to be discarded immediately postharvest in WA.	Shellabear[26]
WA cauliflower field and postharvest waste	Another project on WA cauliflower reported an export packout rate of 54% for cauliflowers when considered from seed to finished product. The remainder were wasted due to: • Seedling death – 14% • Harvest rejects – 9% • Packing rejects – 8% • Not harvested – 15%	Phillips[27]
Carrots in Tasmania	Under Tasmanian conditions the high productivity of carrot growing is counterbalanced by a low packout rate of 60%, equivalent to around 28 tonnes per hectare of graded out carrots.	Brown and Gracie[28]
Processing, Tasmania	A Tasmanian study estimated that fruit and vegetable packing and processing operations produce 10,600 tonnes and 17,000 tonnes of waste respectively in that State. Processing additionally produces 19,000 tonnes of sludge. The packing operations data does not include graded out materials sold for processing or as animal feed, which explains the low figures. *NB The majority of this waste is from potatoes and onions.*	McPhee[29]
Processing - Simplot	Simplot Australia stated that close to 100,000 tonnes of waste were produced annually by its processing sites. The major waste streams were: • Bathurst - corn cob, cores and husks. • Devonport - beans, peas, carrots, broccoli, cauliflower. • Ulverstone - potato peelings and flesh.	Heap[30]

[26] Shellabear, M. 1995. Export cauliflower improvement project 1993-1994. Horticulture Australia Final Report.
[27] Phillips, D. 1997. Export cauliflower improvement. Horticulture Australia Final Report VG221
[28] Brown, P., Gracie, A. 2000. Factors influencing carrot size and shape. HAL final report VG97019.
[29] McPhee, J. 2002. Increasing the opportunities for use of organic wastes in the Tasmanian vegetable industry. Horticulture Australia Final Report VX99002.
[30] Heap, M. 2008. Innovative approaches to adding value to vegetable waste - Phase II. Horticulture Australia Final report MT06053.

5 Quantities of waste produced as part of vegetable production in Australia

5.1 Introduction

The results of the desktop study (section 3) demonstrate that little has been documented on vegetable waste in Australia. Moreover, what is known about vegetable waste has focused on waste by consumers. The role of such studies has been to highlight concerns about the environmental cost of wasting food and the impacts of organic matter going to landfill.

In contrast, the focus of this study is to find ways of recovering and recycling vegetable wastes so as to improve vegetable industry profitability. Only materials produced near the grower / packer are likely to be recoverable, with the cost and practical issues with recycling unwanted materials increasing as product moves through the supply chain (Figure 1).

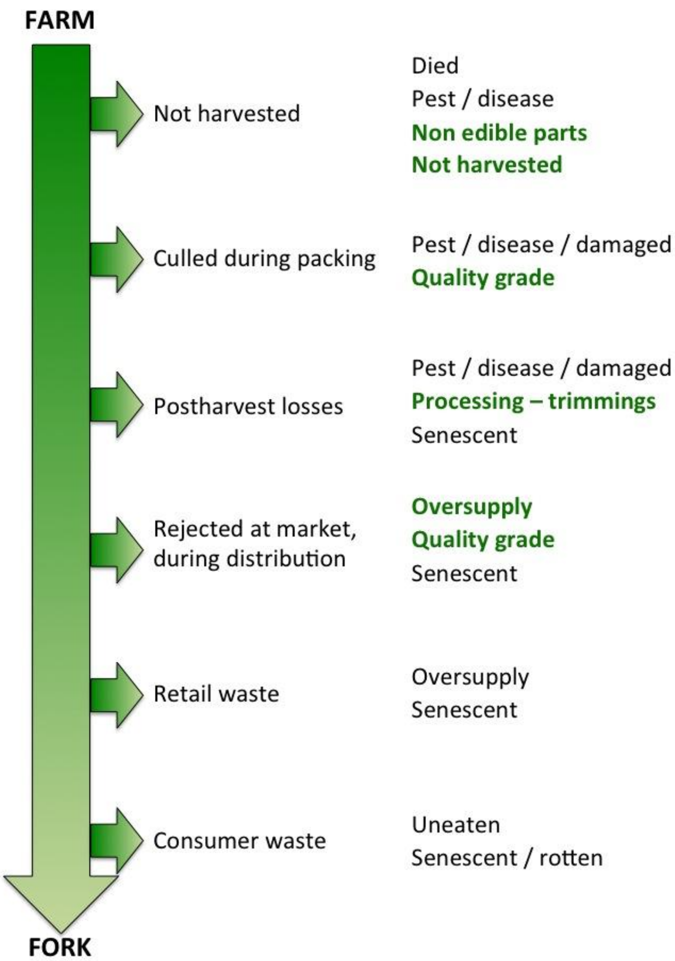

Figure 5. Sources and causes of waste within the vegetable supply chain. Green text indicates those wastes that are most likely to be financially viable to recover and re-use for another purpose.

This report seeks to quantify and qualify vegetable waste available for re-use for a number of major vegetable lines. This has been based on interviews with growers and processors as well as published information. While such figures are estimates only, they will provide some indication of what types of materials should be the focus of further studies into finding new uses for vegetable wastes.

5.2 Forms of pre-harvest vegetable waste

What farmers and other supply-chain members regard as "waste" varies greatly. For many farmers, waste is product abandoned before harvest or discarded during packing due to quality issues or oversupply in the market. However, waste can also include those non-edible plant parts that are left in the field after the saleable part is harvested. For some crops this may be the majority of the total biomass produced[31].

In most cases, field waste is generally simply worked back into the soil as green manure. However, there may be other uses for this material, such as production of biofuels, biochar or extraction of compounds which can be used in manufacturing.

There is surprisingly little data on the biomass of vegetable crops left in the field after the saleable part of the plant is harvested. Yield data generally refers only to the portion with market value, despite the fact that the unharvested part may contain valuable organic material. Table 5 shows the approximate percentage of some crops remaining after the saleable portion has been harvested.

Table 5 - The percentage of some crop plants generally regarded as inedible and left in the field after the saleable part is harvested.

	Non-saleable part of plant (%)	Estimated biomass left in field (kt/yr)	Reference
Broccoli	70*	114	Zebarth *et al.*, 1995[32]
Capsicum	56	153	Jolliffe & Gaye, 1995[33]
Cauliflower	65	139	Phillips, 1997[34]
Sweet corn	40	67	Williams, 2008[31]

** New varieties are likely to be more efficient.*

[31] Williams, M. M. (2008) Sweet corn growth and yield responses to planting dates of the North Central United States. HortScience Volume: 43 Issue: 6 Pages: 1775-1779

[32] Zebarth, B. J.; Bowen, P. A.; Toivonen, P. M. A. (1995) Influence of nitrogen fertilization on broccoli yield, nitrogen accumulation and apparent fertilizer-nitrogen recovery. Canadian Journal of Plant Science Volume: 75 Issue: 3 Pages: 717-725.

[33] Jolliffe, P. A.; Gaye, M. M. (1995) Dynamics of growth and yield component responses of bell peppers (Capsicum annuum L.) to row covers and population density. Scientia Horticulturae Volume: 62 Issue: 3 Pages: 153-164

[34] Phillips, D. 1997. Export cauliflower improvement. Horticulture Australia Final Report VG221

5.3 Methodology

The following vegetables were selected for this study:

1. Brassicas (cabbage, cauliflower, broccoli)
2. Sweet corn
3. Carrots
4. Beetroot
5. Lettuce
6. Baby leaf crops
7. Capsicums and chillies
8. Beans

This project covers levy-paying crops only. The following vegetable industries do not pay the National Vegetable Levy, and therefore have been excluded from this review: asparagus; garlic; hard onions; herbs (other than fresh culinary shallots and parsley); melons; mushrooms; potatoes (other than sweet potatoes); seed sprouts and tomatoes.

There are a large number of vegetable growers in Australia; AusVeg put the 2010/11 number of growers at 5,753[35], but many of these farming operations are small. In Australia 80% of the vegetables are produced by a small number of large growers, estimated to be about 200 growers nationally[36].

The project team considered a broad survey approach as a way of collecting the data. However, this approach was unlikely to get any meaningful response from the top 200 growers, and would at-best collect data from a number of smaller growers. Given the stricture of the industry, the project team thought data collected in this way would be unreliable.

The following approaches to quantifying waste were developed.

[35] http://ausveg.com.au
[36] Mike Titley, pers. comm.

5.4 Quantifying waste from growers

A survey form was designed (see appendices 10.4) and key growers from each of the major crops and regions were selected, contacted personally and interviewed. The list of growers who participated in the interviews is included in the appendix 10.1. Their responses have been disaggregated so that individual answers cannot be identified.

The interviewer asked growers questions about each crop they had grown in the past 12 months:

- Area planted.
- Harvested % (or area).
- Yield marketed.
- Percentage of harvested crop that was wasted.
- Why was it wasted? (E.g. low price, out of spec.)
- What did you do with the waste?

This data was then collated to give a picture of waste for each of the crops studied. Next, the AusVeg / ABS data was used to extrapolate these results to give an industry-wide picture of waste for each of the crops studied.

The waste for each crop was then calculated as follows:

- Area planted (hectares)
- Gross yield (tonnes/ha)
- Total production (kt)
- Total waste (summer/winter/total)

5.5 Quantifying waste from processors

To estimate processing waste, a similar approach was taken to that used for estimating waste from growers. A survey form was designed (see appendix 10.5) and key processors (10.2) were asked:

- Crops processed
- Total throughput per year (tonnes)
- Percentage of waste
- Reason for waste
- What do you do with the waste?

They were also asked:

- Do you have any ideas on what could be done to reduce waste?

- Suggestions on alternative uses for waste?
- Other comments or suggestions.

The data was collated and a combination of AusVeg and ABS data were used to extrapolate the data collected to a national figure. The following data is reported:

- Area planted
- Gross yield
- Total production
- Postharvest waste
- Post-processing waste
- Total waste

Processing waste is summarised in appendix 10.3.

5.6 Waste from the major produce markets

The following waste estimates were obtained from the major wholesale markets. This waste currently either goes to landfill or is disposed of in other ways by waste collection companies. For example, Sydney Markets is serviced by Veolia, which takes wastes to a tip site south of Sydney. Some waste is recycled at the site using a liquid digester for methane production. Brisbane Markets is in the process of re-tendering for waste collection. Finding an innovative, environmentally sustainable solution to the issue of waste is considered an extremely high priority by the Brisbane Markets Ltd landlord.

Table 6 - Waste from the wholesale produce markets

Market	Waste per year	Waste per working day
Sydney	20,000 t general waste	80 t
Melbourne	6,000 t green waste	24 t
Brisbane	7,200 m^3 general waste	29 m^3
Adelaide	No central collection	No central collection
Perth	4,000 t general waste	20 t

6 Waste estimates for the main crop groups

6.1 Cabbage

Cabbage production is generally extremely variable, as are resulting losses. It is often used as a speculative crop, with the result that supply and demand fluctuate greatly. During periods of high demand virtually 100% of the crop may be sold, whereas at other times over production results in 40 – 50% being left in the field.

A significant volume of cabbage production (approx. 25%) is sent for processing (Figure 6). The main products are fresh coleslaw and inclusion in cooked items such as chiko rolls, spring rolls and other food service items. Previously there was a market for cabbage used in sauerkraut production, but this has disappeared in the last few years. Cabbage could potentially be used to make kim chee, but standard white cabbage is not the preferred variety for this use. There is some potential for fresh market growers to send out of specification product for processing. However, the processing market is dominated by growers who grow specifically for this purpose, so allow the cabbages to develop to a much larger size.

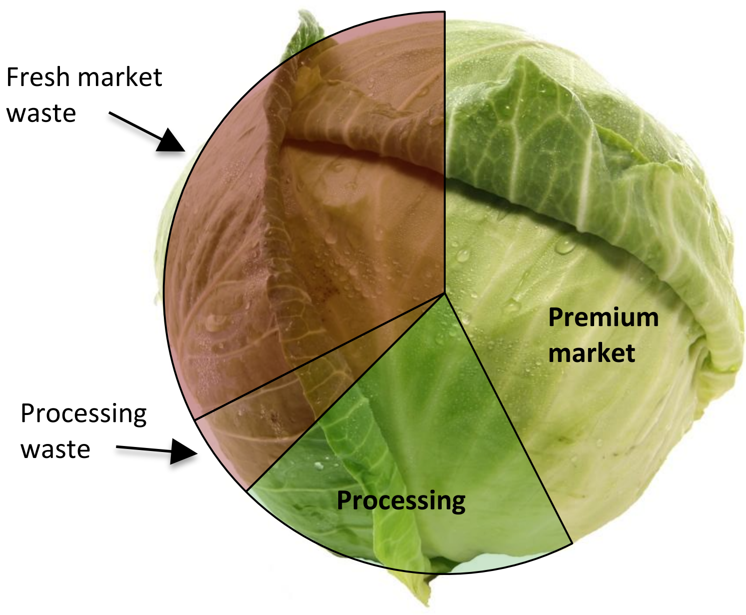

Figure 6. Cabbage uses and waste.

6.1.1 *Specifications*

There are many different varieties of cabbage, each with its own quality requirements. Standard green and savoy cabbages are usually required to be 1.5 – 2kg weight with a maximum of 3-4 outer leaves. There is also a market for "mini" cabbages 500g – 1kg weight. Red cabbages are generally a little smaller, being 0.8 – 1.8kg weight. Specifications for cabbages are (arguably) less demanding than those for some other vegetables, and may not be the major cause of loss.

6.1.2 ***Waste***

Area planted	2,000 ha
Gross yield	Fresh = 25 – 30 t / ha – 27.5 t / ha x 1,500 ha = 41.25 kt Processing = 60 – 68 t / ha – 64 t / ha x 500 ha = 32 kt
Total production	**73.25 kt / year**
Waste	Fresh = 5 – 60% – 10% postharvest culls – up to 50% left in the field according to supply and demand Processing = 20% – 15% discarded core + outer leaves – 5% rejected due to damage, pest or disease
Total waste	**19.8 kt / year** – 32.5% average waste for fresh market cabbage, year round – 20% average waste on processed cabbage

Cabbage wastes are generally used only as fresh animal feed or green manure.

6.2 Cauliflower

Cauliflower has suffered from a major downturn in export markets, particularly from western Australia. The result has been domestic oversupply and increasingly tight market specifications, resulting in relatively high levels of waste during harvest and packing.

Phillips[37] conducted an extremely detailed study of cauliflower waste on farms around Manjimup, WA. While varieties have changed, high market expectations make it seem likely that waste levels remain similar today (Figure 7). The major causes of rejection at that time were colour (pink, yellowed, browning) as well as maturity, size and physical damage.

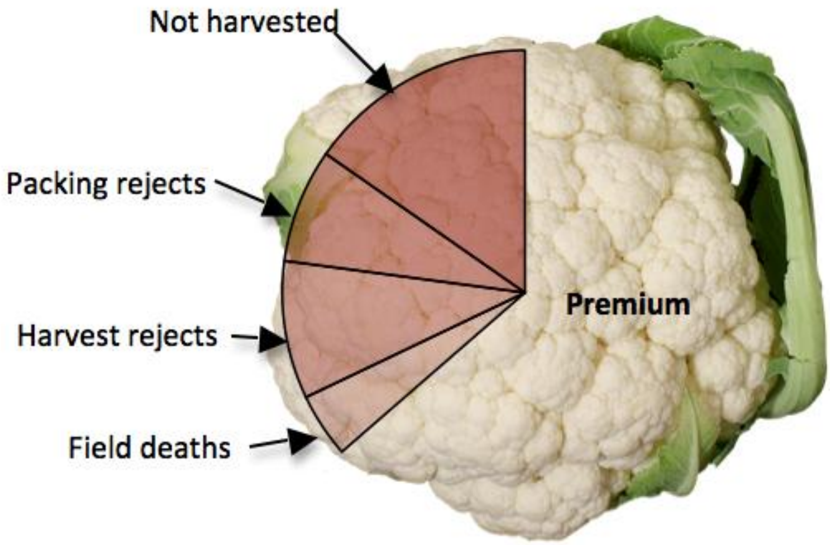

Figure 7. Cauliflower losses in WA, from Phillips, 1997[37].

6.2.1 *Specifications*

The preferred size for cauliflowers is 150 – 180mm diameter, with a few wrapping leaves to protect the outer curds. There are also minor markets for baby cauliflowers (80 – 120mm diameter) and fresh cut florets (30 – 130mm diameter) packed into punnets. Curds have to be free of sunburn or other discolouration of any kind, at the correct maturity, and with only very minor scuffing or bruising.

6.2.2 *Waste*

Area planted 2,500 ha

[37] Phillips, D. 1997. Export cauliflower improvement. Horticulture Australia Final Report VG221

Gross yield 30 t / ha

Total production **75 kt / year**

Total waste (plant) **112 kt / year**

- Only 40% of cauliflower plant is harvested, 60% remains in the field
- Gross yield non-harvestable material = (75 kt/40%) x 60%
- This is considered recoverable waste, as it could potentially be harvested and used, rather than ploughed back into the soil as is current practice.

Total waste (curds) **27.8 kt / year**

- 4% field deaths
- 10% rejected at harvest due to colour, maturity or size
- 7% rejected at packing
- 0 - 30% not harvested due to market supply and demand
- total losses (curds) = approximately 37%

According to Kantor[11] 24% of marketed material is lost between the farm and the end consumer, while only 60% of the harvested part is considered edible floret, the remainder being stalk and core. These are effectively non-recoverable wastes.

Total postharvest waste **11.3 kt / year**

- Total marketed product = 47.2 kt / year
- Postharvest wastage = 24%

Total waste (‘inedible’ curd) **18.9 kt / year**

- 40% edible portion (60% discarded before eating)
- 40% x (total marketed and potentially consumed product)

Total cauliflower eaten **17 kt / year**

- Total production – (waste on farm + postharvest waste + ‘inedible’ portion discarded by consumers)

Cauliflower wastes are currently used only as green manure or as animal feed.

6.3 Broccoli

The downturn in export markets and processing industries has increased supply of broccoli into domestic markets. Perhaps as a result, fresh market specifications have become increasingly demanding in terms of head size, shape and trimming. While new varieties have improved production efficiency and decreased head variability, tight product specifications have decreased packout rates (Figure 8).

Some broccoli is still grown specifically for processing, mainly in Tasmania (approx. 100 ha). Out-of-specification product is also occasionally used for processing, but this represents a minor market.

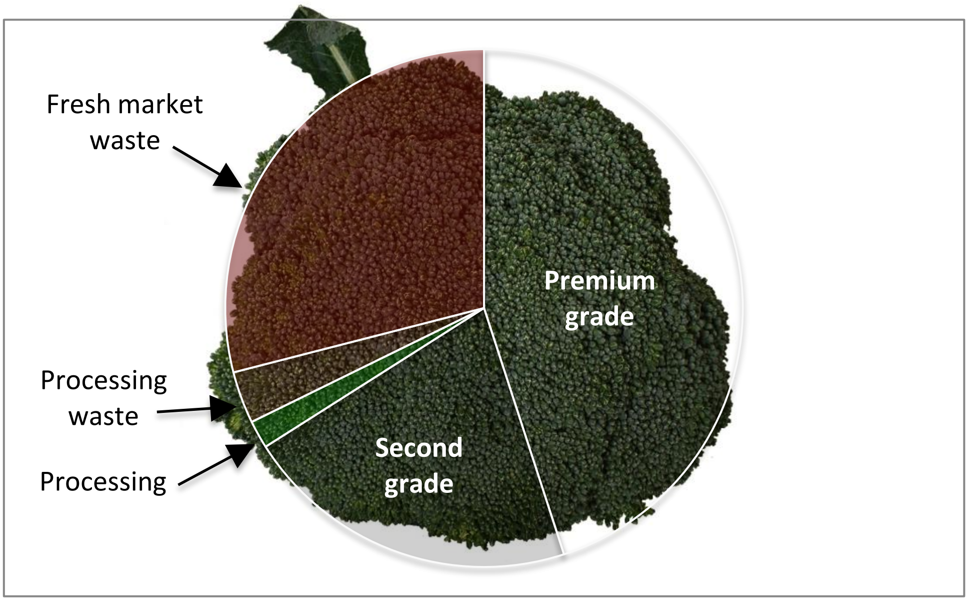

Figure 8. Estimated average broccoli waste from fresh market and processing sources.

6.3.1 *Specifications*

Specifications for broccoli are extremely tight. Size specifications vary, but generally give a range of around 40mm diameter variation within any consignment. Most demand is for medium sized heads approx. 100 – 140mm in diameter. There is also a small market for larger heads 140 – 180mm diameter. The stem should be no more than 50 – 70mm long. All florets have to be tight and green with only minor breakages, swollen buds or scuffing permitted.

6.3.2 *Waste*

Reports regarding levels of broccoli waste vary greatly. While some farms report minimal losses, others have packout rates that suggest >50% of the crop is discarded. Nearly all waste is due to failure to meet premium grade specifications, combined with a lack of outlets for 2nd grade products. Around 2/3 of broccoli which is processed into florets is also wasted due to discarding of stem material.

Area planted	7,000 ha
Gross yield	7 t / ha
Total production	**49 kt / year** – 90 – 95% intended for fresh market – Volume processed = 4.5 kt / year
Total waste (plant)	**73.3 kt / year** – Conservatively estimated that 40% of broccoli plant is harvested, 60% remains in the field – Gross yield non-harvestable material = (49 kt/40%) x 60% – This is considered recoverable waste, as it could potentially be harvested and used, rather than ploughed back into the soil as is current practice.
Waste (head)	Fresh = 20 – 50% – Premium grade = 40 – 50% – Second grade = 12 – 30% (not always saleable) – 10% rejected at harvest due to size, maturity etc – 10% postharvest culls – up to 35% left in field according to supply and demand Processing = 65% – base and stem material discarded, only florets used
Total waste (head)	**15.4 kt / year** – 28% average waste for fresh market broccoli – 65% waste for processed broccoli

The only known use of broccoli waste is as animal food or green manure. However, broccoli contains a range of compounds that have been strongly associated with reduced risk of certain cancers, cardiovascular disease and other disorders. It may be possible to explore options for extracting such compounds from broccoli wastes (or other brassica crops) to use in dietary supplements or nutritionally enhanced foods.

6.4 Sweet corn

Sweet corn in some ways appears to be a relatively inefficient crop; Williams (2008) found that only around 45% of the plant is edible kernel. However, sweet corn has the advantage that it can be sold fresh or processed, and that fresh market corn can be sold in a variety of different formats to maximize use of the crop. These include whole corn, trimmed pre-packs and "cobettes". Some packers have been able to minimize waste using innovative products and including some on-site processing.

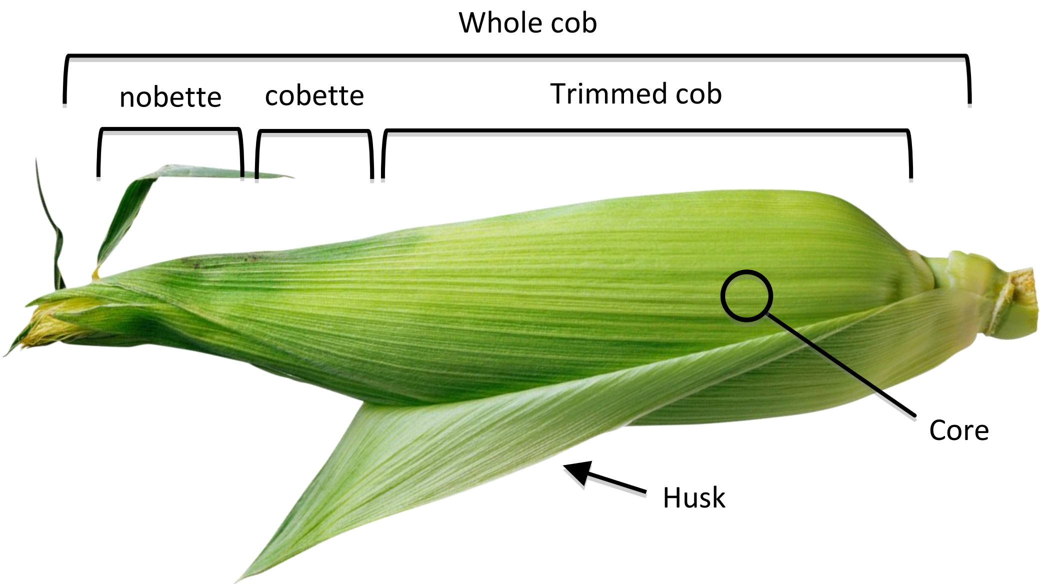

Figure 9. Sweet corn

6.4.1 *Specifications*

Premium grade sweet corn needs to have no unfilled kernels, evidence of insect attack (eg Heliothis caterpillars) or soil contamination. Trimmed corn should have the outer leaves removed with 20% of the kernel visible on the topside of the pack.

Cobettes	30-50mm long, >25mm diameter, total pack weight = 450g
Pre-pack	110—250g, weight per cob 180-250g, total pack weight 500g
Whole corn	>150mm long,
Baby corn	60-110mm long, 12-20mm diameter at widest point.

6.4.2 *Waste*

Area planted	6,700 ha.

Gross yield 15 t / ha

Total production **100.5 kt / year**

Waste Fresh = 20%

- 0 – 5% postharvest culls from cobs sold whole and fully husked
- 20% discarded tips (trimmed nobettes) and excess husk when sold as trimmed corn in pre-packs (some of this material may be repackaged and sold as mini-cobettes)

Processing = 32 – 55%

- 32 – 45% discarded husk, tips and base when processed into frozen whole cobs
- 50 – 55% discarded core, husk, and top and tail when processed into frozen kernels

Total waste **26.9 kt / year**

- Waste estimated according to the table shown below;

	Production (kt / year)	**Waste** (average %)	**Waste** (kt / year)
Whole (fresh)	13	5	0.65
Trimmed (fresh)	51.5	20	10.3
Cobs (processed)	20	38	7.6
Kernels (processed)	16	52	8.32

Waste generated includes husks, nobettes (tips) and, in the case of processing into kernels, corn cores. Corn cores are high in fibre, raising the possibility of extracting this for use as a dietary supplement. Nobettes, and other trimmings, are a valuable, high protein animal feed, currently sold for $8/t.

6.5 Carrots

The carrot industry is another industry that has had to adjust in the face of major lost export markets. At the same time as the market for premium grade carrots disappeared, so did the juicing market which previously offered an outlet for out of specification product. The market for processed carrots is now mainly shredded product for coleslaw, julienne and some "baby carrots" and represents only around 7% of the total market (Figure 10).

Specifications for fresh market carrots are precise, even when carrots are included in pre-packs. This causes significant rejections, despite modern precision growing techniques.

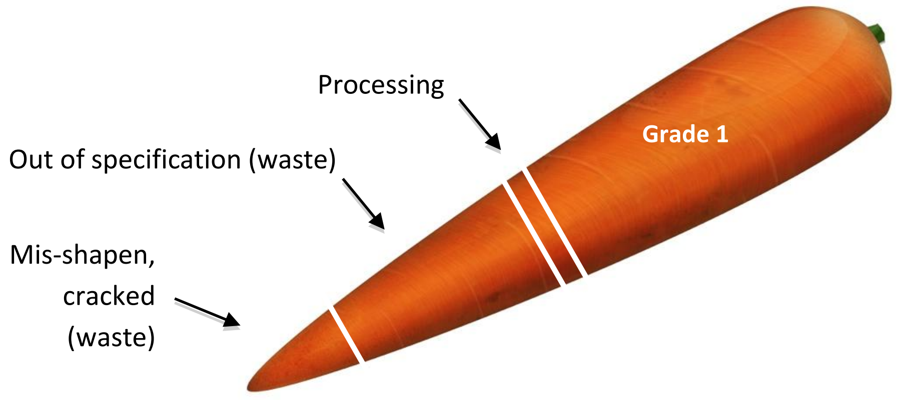

Figure 10. Carrot uses and waste.

6.5.1 *Specifications*

Pre-pack carrots; 25-43mm diameter, 120-220mm long

Baby carrots; 15-30mm diameter, 100-150mm long

Loose carrots;

Small - 33-45mm diameter, 100-150mm long

Medium - 38-45mm diameter, 150-200mm long

Jumbo - 45mm+ diameter, 180-210mm long

Broken carrots are not permitted, while only minor scuffing, scratches and chipping is allowed on shoulders and skin.

6.5.2 *Waste*

Area planted	4,600 ha
Gross yield	60 - 70 t / ha
Total production	**300 kt year** – 7% sent for shredding, processing – 93% fresh market
Total waste	**93 kt / year** – 10% culled postharvest due to being damaged, cracked – 23% culled postharvest due to being 'out of specification' – 5% waste on processed carrots

Carrot waste is currently used only as animal food. However, carrots are high in fibre, antioxidants (beta carotene) and other compounds of potential dietary or industrial use. There may be some potential to find new uses for carrot waste.

6.6 Beetroot

Only a few years ago, the majority of Australian beetroot was destined for processing. Beetroot processors generally have relatively tight specifications for size and shape, with very large, small or unevenly shaped bulbs unsuitable for canning. Added to the loss from trimming, peeling etc, this means that waste from canning processes has been a significant issue for the industry (Figure 11).

Demand for processed beetroot currently stands at around 9,000 - 10,000 tons annually. However, it is unclear how much of this market will continue to be supplied domestically given the recent major decline in the canning industry.

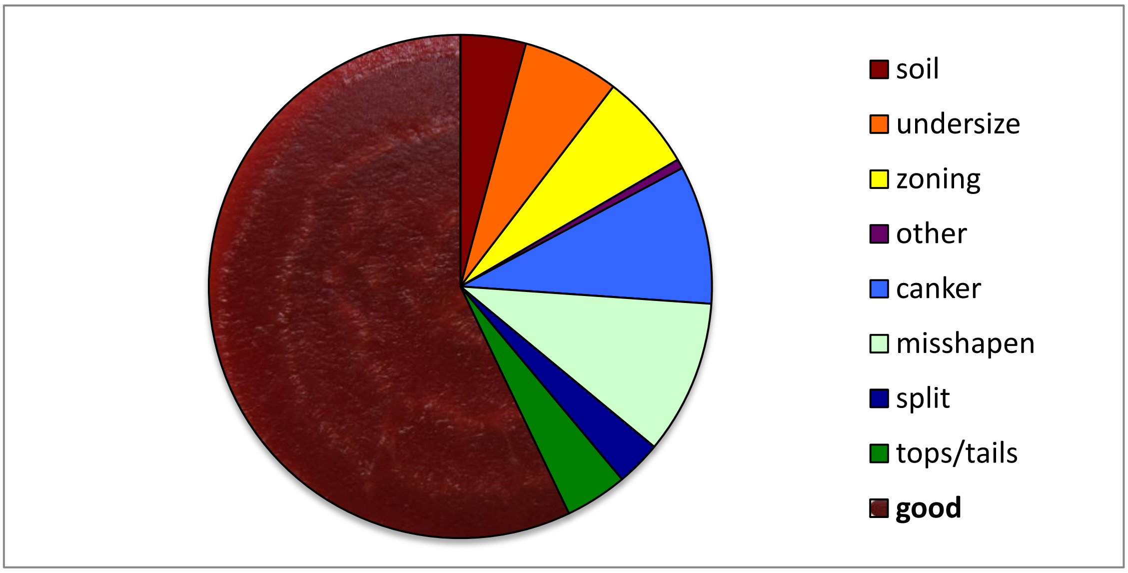

Figure 11. Beetroot waste during processing (from Wolens, 2011)[38]

Of some benefit to the industry, the fresh market for beetroot has increased in recent years as cooks discover that beetroot need not come solely from a can! Fresh market beetroot can be divided into bunched baby beets and large whole beets, allowing better use of the whole crop.

Beetroot is generally grown either for fresh market or for processing; fresh market beetroot that is outside of specification is not likely to be suitable for sending to processing as an alternative.

[38] Wolens, T. 2011. Development of integrated strategies for sustainable processing beetroot production. Horticulture Australia final Report VG05083.

6.6.1 ***Specifications (fresh market)***

Fresh market beetroots must be smooth skinned, free of dirt or insects and evenly shaped. A range of sizes can be acceptable, so long as bunches are well graded, with <20% size variation within each bunch.

Baby beets - 35-55mm diameter, stems and foliage <20cm long

Standard beets - 70-90mm diameter, stems <10cm long, total foliage <30cm

Minor amounts of scuffing, rubs and blemishes are allowed, but must not exceed 4cm^2/bulb

6.6.2 ***Waste***

Area planted	Processing = 400 ha Fresh market = 500 ha
Gross yield	40 t / ha
Total production	**36 kt / year**
Waste	Processing = 43% – 17% postharvest culls – 4% top and tail trimmings – 22% culled after cooking and preparation Fresh = 20% (early season) to 15% (mid season) – 5 – 10% postharvest culls – 10% 'out of specification'
Total waste	**10.2 kt / year** – 43% waste on 16 kt / year processed beetroot – 20% waste on 7 kt / year early season fresh beetroot – 15% waste on 13 kt / year mid season fresh beetroot

This suggests that total beetroot waste is around 10.2 kt annually. This is currently used only to produce compost, green manure and good quality animal food. However, beetroot is rich in dietary fibre and antioxidants (betalains). There has been some interest in extracting these compounds for use in dietary supplements and / or as natural colourants for food.

6.7 Head lettuce

According to reported data, waste in the lettuce industry is relatively low. This is largely because of the significant processing market, which provides an outlet for out of specification product. Although only around 75% of harvested lettuces are suitable for the fresh market, growers with access to a processing plant are able to send much of the remainder for processing. According to some growers surveyed, only 5% or even less of the crop is directly wasted. However, others have stated that losses can be much higher, especially if market prices are poor and product is left unharvested. Similarly, growers without access to processing will discard a larger proportion of their crop.

Some lettuces are grown specifically for processing; these are allowed to develop to a much larger size before harvest. The core and outer leaves result in around 10% waste from lettuce sent to processing (Figure 12).

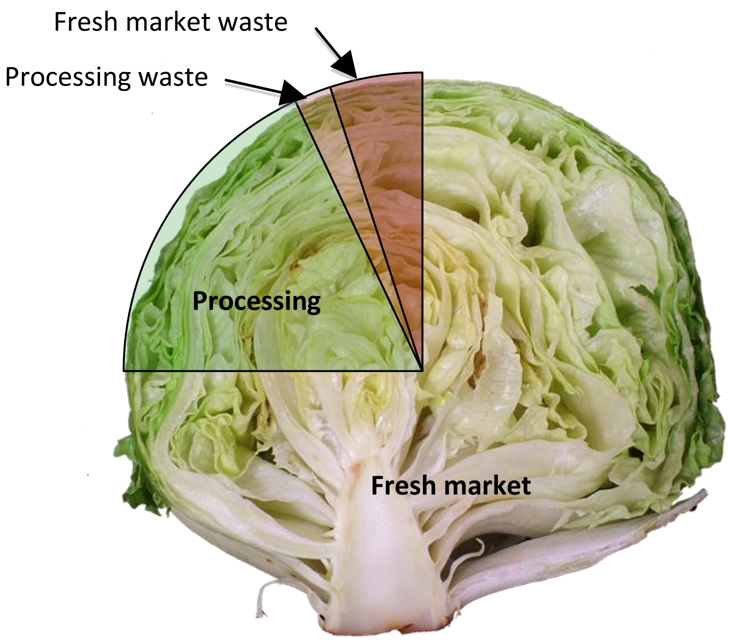

Figure 12. Lettuce uses and waste

6.7.1 *Specifications*

Small - 25-35mm diameter, 150-200mm long

Medium - 35-45mm diameter, 150-200mm long

Jumbo - 45+ diameter, 180-210mm long

6.7.2 *Waste*

Area planted	4,500 ha
Gross yield	Fresh = 27 t / ha – 95% of total crop is grown for the fresh market – 115.4 kt / year – 20% of this crop may be subsequently sent for processing Processing = 38 t / ha – 5% of total crop is grown specifically for processing – 8.6 kt / year
Total production	**124 kt / year**
Waste	Fresh = 5 – 25% – up to 25% left in the field according to supply and demand – 5 – 25% culled postharvest due to 'out of specification' Processing = 10% – core tissue and outer leaves discarded – approx 25% of total production goes to processing (31 kt / year)
Total waste	**17.0 kt / year** – 15% average waste for fresh market lettuce – 10% waste for processed lettuce

There are no real uses for lettuce waste due to its high water content and low nutritional value.

6.8 Baby leaf and fancy lettuce

Loose-leaf lettuce varieties can be sold whole as well as used for processing into salad mixes as baby leaf products. They include a range of different textures and can be highly coloured. Approximately 2/3 of production occurs during summer when demand is highest, the remainder spread throughout the cooler part of the year.

6.8.1 *Specifications*

Premium grade loose leaf lettuce is intact, undamaged and with good colour development. In summer, there is enough colour in the central part of the leaves to allow two portions to be cut from each leaf for processing purposes. However, low light levels during the cooler months inhibit colour development, which is concentrated only at the leaf tips. Under these conditions only the outer halves of the leaves can be used in salad mix (Figure 13).

Other reasons for rejection include the presence of disease and physical damage to the leaves.

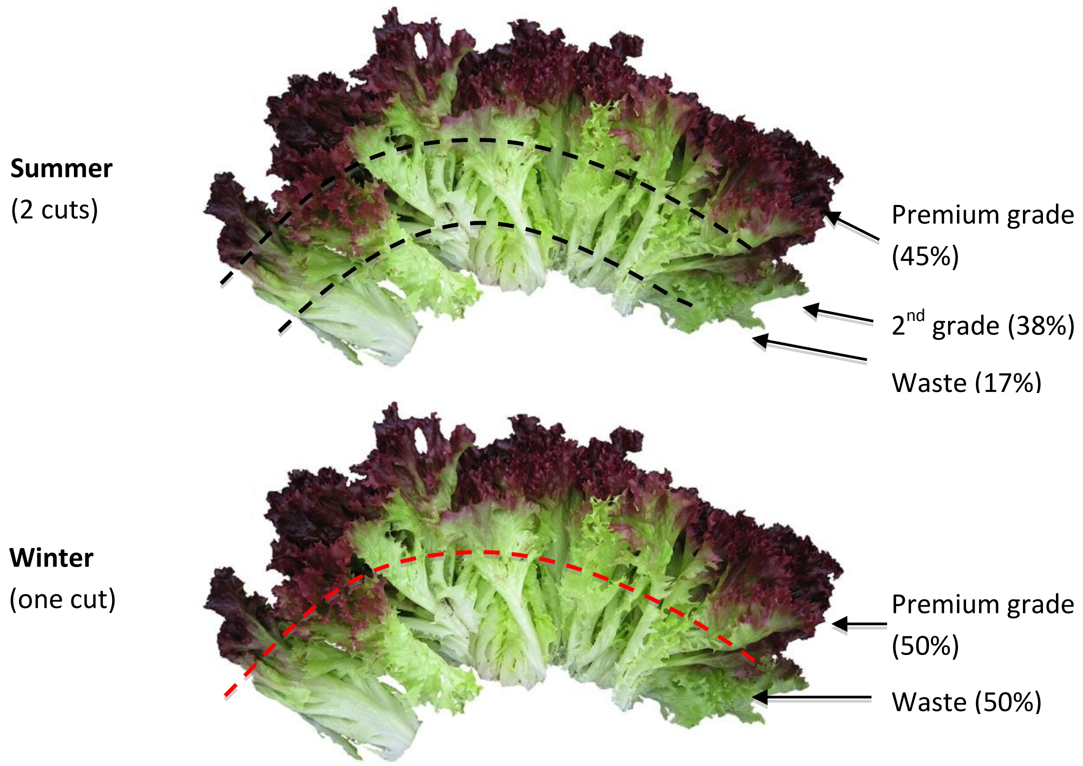

Figure 13. Cutting patterns and waste estimates for baby leaf lettuce.

6.8.2 *Waste estimates*

Area planted	4,500 ha.
Gross yield	35 t / ha
Total production	**157.5 kt / year**
Waste	Summer production = 17% – 45% of leaf 1st grade cut – middle 38% of leaf 2nd grade (less coloured) cut – basal 17% of leaf discarded due to lack of colour Winter production = 50% – basal 50% of leaf discarded due to lack of colour
Total waste	**19.4 kt / year** – 2/3 of production in summer (105 kt) with 10% waste – 1/3 of production in winter (52.5 kt) with 17% waste

The only current use of waste is as green manure or animal feed.

6.9 Baby leaf vegetables

Direct seeded baby leaf vegetables encompass a range of species grown at high densities (7-8 million plants / ha) and harvested while young for inclusion in salad mixes. Vegetables grown this way include spinach, rocket, mizuna, mibuna, mustard, kale, chards and beetroot.

As with baby leaf lettuce, approximately 2/3 of production occurs during summer when demand is highest, the remainder spread throughout the cooler part of the year. Waste is higher during winter (15%) than summer (10%) due to longer development times in the colder months of the year.

Figure 14. Baby leaf rocket, mizuna and lettuce.

6.9.1 *Specifications*

Less than 10% of leaves must be affected by russetting, physical damage or pest damage to meet premium grade specifications. In the case of baby spinach, leaves must be cut with a short petiole, not exceeding 30% of the total leaf length.

6.9.2 *Waste estimates*

Of the marketable yield, approximately 70% is marketed as premium grade, 25% is "wash me eat me" (2^{nd} grade) while up to 5% of over mature leaf is marketed as a cooking vegetable.

Area planted	3,500 ha.
Gross yield	8.5 t / ha
Total production	**29.8 kt / year**

Waste	Winter = 15% – 5% field loss – 10% discarded postharvest Summer = 10% – 3% field loss – 7% discarded postharvest
Total waste	**3.5 kt / year** – 2/3 of production in summer (20 kt) with 10% waste – 1/3 of production in winter (9.8 kt) with 15% waste

Previously, some rejected product was used to produce vegetable juices, particularly spinach juice, for export markets. This no longer occurs and waste is now used as green manure or animal food.

6.10 Capsicums

Capsicums are a significant vegetable crop in Australia, grown both on the open field and under protected cropping. About 46% of the fruit are suitable for 1st grade fresh market, 29% go for processing and the remainder (~25%) are waste. This represents a significant financial loss for the industry, capsicums being a relatively high-value product.

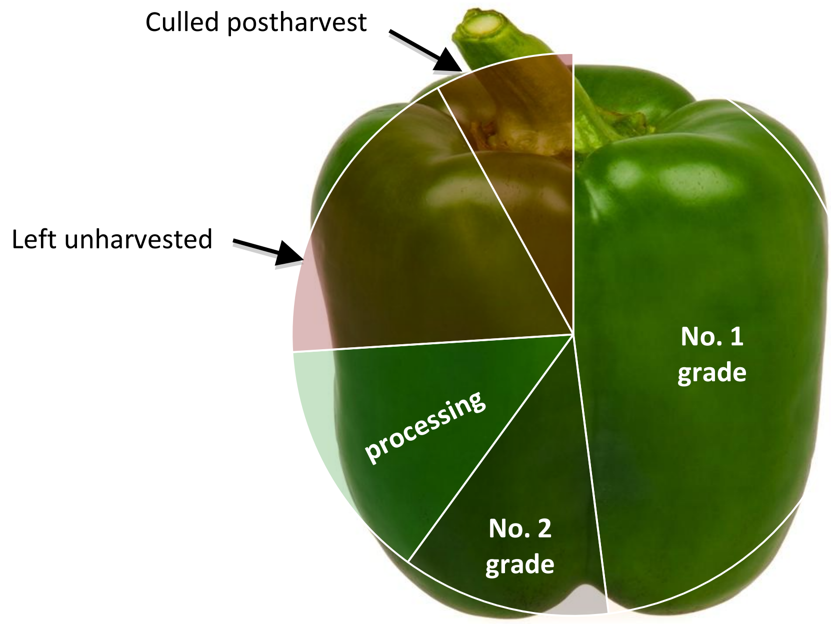

Figure 15. Capsicum uses and waste.

6.10.1 ***Specifications***

There are multiple specifications for capsicums as the fruit vary widely in colour and shape. Prepacked capsicums may be smaller, with some varieties marketed as mini or baby capsicums. A 10% overlap between sizes is allowed within packs, with general sizes defined as;

Small – 110-130mm long

Medium – 130 – 150mm long

Large – 150-170mm long

Shape is required to be cylindrical to oblong and slightly tapered at the bottom end. Mixed colours are generally not permitted within consignments.

Field grown capsicums can be extremely variable in size and shape, resulting in high levels of wastage. In addition, the process by which green capsicums turn red after harvest is still poorly understood and can occur even at low storage temperatures. Capsicums are susceptible to sunburn and cracking and are susceptible to physical damage.

6.10.2 ***Waste***

Area planted	2,300 ha
Gross yield	52 t / ha
Total production	**119.6 kt / year**

- No. 1 grade fresh market fruit = 48%
- No. 2 grade fresh market fruit = 12%
- Processing = 14%

Total waste	**31.1 kt / year**

- 18% left in the field due to rots, splits, damage etc
- 8% culled postharvest due to poor shape or size, not meeting specifications

6.11 Beans

Bean growing has had a major change over previous years in the move to machine harvesting. While clearly a major labour saver, this increases the amount of product left in the field, can damage harvested beans and results in a mixture of maturities within the bins. No data could be gained for this report on the amount of beans left in the field after mechanical harvesting.

Figure 16. Beans.

6.11.1 *Specifications*

Green beans need to be plump, well formed and straight. They should not have russetting, yellowing or softening such that they can be bent without breaking. Specifications do not permit misshapen beans (curly, twisted etc), beans lacking seed development inside the pods, or beans with excessive seed formation (>50% seed definition).

Pods need to be 140 – 200 mm long and 6 – 12 mm diameter. Broken or damaged tips must affect no more than 5% of any one consignment. Achieving such low levels of damage and tight size specifications is difficult, especially given the economic necessity to machine harvest the crop.

6.11.2 *Waste*

Area planted	6,000 ha.
Gross yield	7 - 10 t / ha
Total production	**51 kt / year** – 65% of production No. 1 grade – 10% trimmed, sold as fresh cut or processed
Total waste	**12.8 kt / year**

- 15% left in the field*
- 10% culled postharvest

Bean waste is relatively high in protein and so makes excellent stock feed. It is also a good source of dietary fibre. Plants are generally mulched back into the soil as green waste.

*NB As no data could be found on the efficiency of mechanical harvesting, this is an estimate based on industry experience.

7 Economic value of pre and postharvest losses of fresh and processed Australian vegetables

7.1 Introduction

The purpose of this section of the report is to;

1. Estimate the value/cost to industry of losses due to wastage for selected fresh and processed vegetable crops including brassicas (cabbage, cauliflower and broccoli), sweet corn, carrots, beetroot, lettuce, baby leaf crops, capsicums and chillies and beans.
2. Estimate values of pre- and post-harvest losses for fresh and processing vegetables.

These estimates have been generated using the following data and information:

1. Measures of pre- and post-harvest losses for the selected vegetable crops for the fresh and processing markets
2. Gross margins for vegetables from the Queensland Department of Agriculture, Fisheries and Forestry (DAFF) and gross margins for selected vegetable crops from the New South Wales Department of Primary Industries.
3. Current farm-gate prices for the selected vegetable crops.

7.2 Method

Estimates are made for pre-harvest and post-harvest losses. The methods used for each segment of the vegetable supply chain are outlined in the following sections.

7.2.1 *Pre-harvest losses*

Vegetable losses due to waste comprise edible produce as well as inedible produce and produce components. Edible produce that is wasted is potentially recoverable and can be valued at the price paid at the point in the supply chain where the product was lost to waste. For example, if a portion of a crop was left in the field it can be valued at the farm gate price received for produce that was harvested and sold, minus the costs of harvesting and packing, which are avoided.

Produce may not be harvested because it is damaged by pests or diseases or it does not achieve the market's minimum quality standards such as size, shape or colour. It may also be left in the field because of over-supply in the market, leading to a fall in price such that it is uneconomic to harvest the crop. An abandoned crop also indicates that harvesting and storing the produce until its price improves is not viable.

The inedible component of each plant that is left after the edible and saleable part is harvested generally is ploughed into the soil for the benefit of subsequent crops. Also, unharvested crops may be grazed by livestock, before the field is cultivated. The value of this organic material may increase where or when new markets emerge such as bio-energy or recovery of chemical constituents. However, it is assumed that there is not a better alternative use than to leave it in the field. In some cases an estimate is made of the value of fertilizer replaced by the green manure crop or the livestock feed, but these estimates could withstand review and refinement.

The value placed on an unharvested product should reflect the reason that it was left in the field. In the case of over-supply, unharvested produce is edible and potentially recoverable, whereas damaged and poor quality produce is inedible and left in the field as animal feed or fertilizer.

When vegetable growers sow their crops they do so with the expectation that they will harvest and sell their entire crop at a fair market price. Their yield and price expectations are subject to risks and uncertainty. Some pre-harvest losses, such as those due to severe weather events, can be insured against to protect a grower’s expected income. However, losses due to market oversupply and price declines are borne by the grower. Losses associated with pests and diseases are borne by the grower as well, although they can be minimised through crop protection measures, the costs of which the grower incurs.

Vegetable producers experience a loss of welfare when there is a reduction in price due to over-supply, or a reduction in the quantity of their produce which is accepted by the market. Producer welfare is the difference between producer revenue and the cost of production. This is referred to as producer surplus in economics. Using partial equilibrium analysis differences in producer surplus under expected or normal supply conditions and conditions of over-supply can be estimated. However, estimation of the producer welfare loss associated with abandoned or unmarketable produce requires demand and supply functions for the product and an estimate of the change in production (the size of the shift in the supply curve). Demand and supply functions are not available for all of the vegetable commodities considered here and so an alternative method is used.

Partial budgeting is a relatively simple budget framework that is designed to estimate expected financial gains and losses due to an incremental change or changes in production or market conditions. It is partial in the sense that it only includes the resources that will be changed – i.e., the variable costs – and leaves out those that are unchanged such as fixed assets. It provides a useful framework for tracking the impacts in terms of changes to costs and returns associated with crop losses due to waste.

The partial budget framework comprises 4 key components:

Positive impacts

Additional income: what added revenues are associated with the change?

Reduced costs: what costs are reduced or removed due to the change?

Negative impacts

Additional costs: what costs will be added as a result of the change?

Reduced income: what income will be reduced or lost due to the change?

The partial budget framework is compatible with gross margins as they both use only variable costs. Components of gross margins for the selected vegetable crops are used in assessments of the financial impact of crop losses due to waste.

The partial budget for fresh market cauliflower is presented to illustrate the method. The annual production of cauliflower in Australia for the fresh market is 75,000 tonnes (2,500 ha @ 30 tonnes/ha). Waste is associated with over-production (30%) and post-harvest culls due to produce not meeting minimum market standards (7%) amounting to 27,750 tonnes per year. Unharvested cauliflower, due to over-production, is left in the ground and turned back into the soil as a green manure crop.

On the positive impacts side, there are reduced or avoided costs including fertilizer replacement associated with ploughing in unharvested crop (assumed to be 20% of existing fertilizer cost) and savings associated with not having to harvest and pack produce that is abandoned. There are also savings associated with avoided packing for produce that has been culled on-farm, postharvest.

The negative impacts side includes the cost of ploughing in the unharvested crop and the loss of fresh market sales. This includes postharvest on-farm culls and the unharvested crop (Table 7).

Table 7 - Economic losses associated with fresh cauliflower production

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
		Plough in crop	$64.76
Total additional income	$0.00	***Total additional costs***	$64.76
Reduced costs		**Reduced income**	
Harvesting & packing	$1,609.09	Fresh market sales	$9,102.00
Packing	82.95		
Fertilizer replacement	$36.00		
Total reduced costs	$1,728.04	***Total reduced income***	$9,102.00
Total positive impacts	$1,728.04	**Total negative impacts**	$9,166.76
Net impact	-$7,438.72		

Source: Queensland DAFF

Yield: 30 tonnes per ha Price: $820/tonne

The net impact is equivalent to a loss of $7,438.72/ha which is equivalent to $670.16/tonne for fresh market sales, based on the yield of 30 tonnes/ha. The total value of the 27,750 tonnes lost or wasted cauliflower to the fresh market is $7.44 million per year. The framework is also applied to estimate processing losses.

7.2.2 *Post-harvest losses*

During packing further culling takes place where produce does not meet quality standards. Produce which is damaged or affected by pests or disease is unlikely to be edible and is diverted to animal feed or fertilizer. Culled produce which is blemished, bruised, over-sized or misshapen could be recovered for human consumption. This produce can be valued at the market price for produce that meets market requirements.

Inedible components such as skin, husks or cores are removed during processing of vegetables into juice or other value-added products or during packaging fresh produce. These removed components may be recycled into products such as biogas, compost or animal feed or they may go to landfill.

Wastes can be valued at prices paid by potential buyers of organic waste where a market exists or at the cost of disposing the waste to landfill. Disposal to landfill includes the cost of collection, transport, landfill gate fees and a landfill levy which is designed to capture the negative externalities associated with the landfill in the cost of landfill disposal[39]. While recycling and landfill disposal are competing options, the services are often conducted concurrently by the same service provider. Collection and transport costs are common to both, although separate collection of recyclable waste may include segregation at the source and more careful handling which may increase the cost of recycling over landfill disposal.

Table 8 presents collection costs for municipal solid waste (MSW) for recyclable material and waste to land fill[40]. The difference between the collection costs is the additional cost to a processor choosing to divert wastes to recycling. Disaggregated data for commercial and industrial (C&I) waste are not available due to commercial sensitivity and because commercial customers typically pay a single price for removal of all wastes (recyclable and non-recyclable) which are sent to landfill or recycling facilities. For vegetable processors that recycle their waste it is assumed that organic materials are segregated from other wastes for separate collection, similar to household waste collection. While there are likely to be scale economies for collection of C&I wastes, it is assumed that the costs are the same as for MSW, as presented in Table 8.

Table 8 - Average cost of municipal solid waste collection, 2010-11 by State and Territory ($/tonne)

Activity	NSW	Vic	Qld	SA	WA	Tas	ACT	NT
Recyclables	123	124	119	116	116	126	119	74
Landfill	100	101	94	98	98	84	106	66
Difference	23	23	25	18	18	42	25	12

Source: Department of Sustainability, Environment, Water, Population and Communities 2012.

If waste is diverted from landfill to recycling it avoids the landfill levy, which is a reduced cost to the processor. Table 9 presents landfill levies for municipal wastes in 2011. The difference in levies between jurisdictions reflects the structure of the local waste collection services market and the political will to intervene in the market (Department of Sustainability, Environment, Water, Population and Communities 2012).

[39] An *externality* is a cost or benefit that is not fully transmitted to the market through a price, which results in market failure where the allocation of goods and services in a market is inefficient, or not socially optimal. The existence of market failure may justify the intervention of government to correct the inefficiency.

[40] Department of Sustainability, Environment, Water, Population and Communities. 2012. The Australian recycling sector. Report prepared by Net Balance. January, Cited at: http://www.environment.gov.au/wastepolicy/publications/pubs/australian-recycling-sector.pdf on 09 May 2013

Table 9 - Landfill levies in 2011 ($/tonne)

	NSW	Vic	Qld	SA	WA	Tas	ACT	NT
Landfill levy	70	30	-	35	28	-	118	-

7.3 Estimated annual values of vegetable wastes

Using the partial budgeting method the values of wastes are estimated for the following vegetable crops:

1. Cabbage
2. Cauliflower
3. Broccoli
4. Sweet corn
5. Carrots
6. Beetroot
7. Lettuce
8. Baby leaf crops
9. Capsicums and chillies
10. Beans

Details for each crop are presented in the following sections.

7.3.1 *Cabbage*

Annual production of cabbages for the fresh market is estimated at 41,250 tonnes. The average annual loss of cabbages to waste in the fresh market is estimated to be 32.5% or 13,406.25 tonnes. Losses are due to over-production which can be up to 50% and postharvest culls of 10%. It is assumed that pre-harvest losses are left in the field to be ploughed back as a green manure. Postharvest culls are also used as green manure. It is assumed that there is a fertilizer cost saving of 20% for nitrogen fertilizer. It is assumed that all losses are potentially recoverable for the fresh market and therefore are valued at the fresh market price of $720/tonne[41]. Table 10 presents the partial budget estimate of the value of losses for the fresh cabbage market.

Annual production of cabbages for the processing market is estimated at 32,000 tonnes. The average annual loss of cabbages grown for processing is 20% comprising discarded core and outer leaves (15%) and rejections because of damage due to insects, disease and other causes (5%). It is assumed that this material is disposed of to landfill. Table 11 presents the partial budget estimate for the value of losses for the processing cabbage market. Table 12

[41] Thompson, T and Zhang, Kyann. 2012. Australian vegetable growing farms. An economic survey 2010-11 and 2011-12. ABARES Research Report 12.11. December. The price is a provisional price for 2011-12. The 2009-10 the price was $533/tonne and in 2010-11 the price was $810.

reveals that the estimated annual total value of losses for cabbages due to waste is $9.75 million.

Table 10 - Estimated annual value of losses for fresh cabbages ($/ha)

Positive Impacts	$/ha	Negative Impacts	S/ha
Additional Income		**Additional costs**	
		Ploughing	$14.02
Total additional income	$0.00	***Total additional costs***	$14.02
Reduced costs		**Reduced income**	
Harvesting & packing	$2,464.48	Fresh market sales	$6,435.00
Fertilizer	$20.00		
Total reduced costs	$2,484.48	***Total reduced income***	$6,435.00
Total positive impacts	$2,484.48	**Total negative impacts**	$6,449.02
Net impact	-$3,964.55		

Sources: NSW DPI Cabbage Gross Margin 2009

Table 11 - Estimated annual value of losses for processing cabbages

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
		Recycling	$1,587.20
Total additional income	$0.00	***Total additional costs***	$1,587.20
Reduced costs		**Reduced income**	
Harvesting & packing		Processing sales	$6,400.00
Landfill levy	$384.00		
Total reduced costs	$384.00	***Total reduced income***	$6,400.00
Total positive impacts	$384.00	**Total negative impacts**	$7,987.20
Net impact	-$7,603.20		

Sources: NSW DPI Cabbage Gross Margin 2009

Table 12 - Total annual value of cabbage losses

	Net loss ($/ha)	Net loss ($/tonne)	Total loss (tonnes)	Total Loss ($)
Fresh cabbages	-$3,964.55	-$443.59	13,406.25	-$5,946,817.50
Processing cabbages	-$7,603.20	-$594.00	6,400.00	-$3,801,600.00
Totals			19,806.25	-$9,748,417.50

7.3.2 *Cauliflower*

Annual production of cauliflower for the fresh market is estimated at 75,000 tonnes. The average annual loss of cauliflower to waste in the fresh market is estimated to be 37.1% or 27,825 tonnes on-farm and 24% between the farm and the final consumer. Farm losses are due to over-production which can be up to 30%, postharvest culls of 10% at harvest and a further cull of 7% at packing.

Causes of losses between the farm and the consumer are many including deterioration or degradation in storage, insect infestation in storage, or damage in transport. It is assumed that pre-harvest losses are left in the field and ploughed in as a green manure. It is assumed that there is a 20% saving on the use of nitrogen fertilizer associated with returning the crop residue as green manure. Table 13 presents the partial budget estimate of the value of on-farm losses for the fresh cauliflower market.

Table 13 - Estimated annual value of on-farm losses for fresh cauliflower ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
		Plough in crop	$64.76
Total additional income	$0.00	***Total additional costs***	$64.76
Reduced costs		**Reduced income**	
Harvesting & packing	$1,609.09	Fresh market sales	$9,102.00
Packing	82.95		
Fertilizer replacement	$36.00		
Total reduced costs	$1,728.04	***Total reduced income***	$9,102.00
Total positive impacts	$1,728.04	**Total negative impacts**	$9,166.76
Net impact	-$7,438.72		

Source: Queensland DAFF

On-farm postharvest culls are also used as green manure. It is assumed that all farm losses are potentially recoverable for the fresh market and therefore are valued at the fresh market price of $820/tonne[42]. It is assumed that losses occurring between the farm and the consumer are not recoverable, and are recycled for use in compost or biogas rather than disposed off in landfill. Table 14 presents the estimated value of post-farm losses for fresh cauliflower.

[42] Thompson, T and Zhang, Kyann. 2012. Australian vegetable growing farms. An economic survey 2010-11 and 2011-12. ABARES Research Report 12.11. December. The price is a provisional price for 2011-12. The 2009-10 the price was $533/tonne and in 2010-11 the price was $810.

Table 14 - Estimate annual value of post-farm losses of fresh cauliflower ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
		Recycling collection	$558.00
Total additional income	$0.00	***Total additional costs***	$558.00
Reduced costs		**Reduced income**	
Landfill levy	$135.00		
Total reduced costs	$135.00	***Total reduced income***	$0.00
Total positive impacts	$135.00	**Total negative impacts**	$558.00
Net impact	-$423.00		

Source: DSEWPC 2012

The total value of cauliflowers wasted each year (Table 15) is estimated at $19.65 million, based on estimated losses of 27,750 tonnes per year on farm and 11,250 tonnes per year between the farm and the consumer.

Table 15 - Total annual value of cauliflower losses

	Net loss ($/ha)	Net loss ($/tonne)	Total loss (tonnes)	Total Loss ($)
On farm losses	-$7,438.72	-$670.16	27,750.00	-$18,596,802.50
Post-farm losses	-$423.00	-$94.00	11,250.00	-$1,057,500.00
Totals			39,000.00	-$19,654,302.50

7.3.3 *Broccoli*

Annual production of broccoli is estimated at 49,000 tonnes, of which approximately 90% is for the fresh market. The average annual loss of broccoli to waste in the fresh market is estimated to be 28% or 12,460.5 tonnes. Losses are due to produce failing to meet the premium grade and limited markets for second grade produce. It is assumed that growers leave 9% of their crop in the field due to uneconomic prices and that 19% of the harvested crop is rejected for failing to meet minimum quality standards.

Postharvest culls are returned to the field as green manure. It is assumed that there is a fertilizer cost saving of 20%. On-farm losses are assumed to be potentially recoverable for the fresh market and therefore are valued at the fresh market price of $2200/tonne. Table 16 presents the partial budget estimate of the value of losses for the fresh broccoli market pre-harvest while Table 17 presents the estimated value of on-farm losses, post-harvest.

Annual production of broccoli for the processing market is estimated at 4,500 tonnes. The average annual loss of broccoli grown for processing is 10% comprising discarded base and stem material. It is assumed that this material is recycled rather than disposed in landfill. Table 18 presents the partial budget estimate for the value of losses for the processing broccoli market. Table 19 reveals that the estimated annual total value of losses for broccoli due to waste is $16.66 million.

Table 16 - Estimated annual value of losses for fresh broccoli, pre-harvest ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
		Plough in crop	$64.76
Total additional income	$0.00	***Total additional costs***	$64.76
Reduced costs		**Reduced income**	
Harvesting and packing	$601.98	Fresh market sales	$1,386.00
Fertilizer replacement	$24.00		
Total reduced costs	$625.98	***Total reduced income***	$1,386.00
Total positive impacts	$625.98	**Total negative impacts**	$1,450.76
Net impact	-$824.78		

Source: Queensland DAFF

Table 17 - Estimated annual value of losses for fresh broccoli, post-harvest ($/ha)

Positive Impacts	$/ha	gative Impa	$/ha
Additional Income		**Additional costs**	
Total additional income	$0.00	***Total additic***	$0.00
Reduced costs		**Reduced income**	
Fertlilizer replacement	$24.00	Fresh market	$2,926.00
Packing	$863.98		
Total reduced costs	$887.98	***Total reduce***	$2,926.00
Total positive impacts	$887.98	**Total negat**	$2,926.00
Net impact	-$2,038.02		

Source: Queensland DAFF

Table 18 - Estimated annual value of losses for processing broccoli ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
		Recycling collection	$564.20
Total additional income	$0.00	***Total additional costs***	$564.20
Reduced costs		**Reduced income**	
Landfill levy	$0.00		
Packing	$2,955.73		
Total reduced costs	$2,955.73	***Total reduced income***	$0.00
Total positive impacts	$2,955.73	**Total negative impacts**	$564.20
Net impact	$2,391.53		

Source: DSEWPC 2012

Table 19 - Estimated total annual value of broccoli losses

	Net loss ($/ha)	Net loss ($/tonne)	Total loss (tonnes)	Total Loss ($)
On farm losses pre-harvest	-$824.78	-$1,309.18	4,005.00	-$5,243,265.26
On farm losses postharvest	-$2,038.02	-$1,532.34	8,455.00	-$12,955,963.94
Post-farm losses	$2,391.53	$525.61	2,925.00	$1,537,413.43
Totals			15,385.00	-$16,661,815.78

7.3.4 *Sweet corn*

Annual production of sweet corn for the fresh market is estimated at 64,500 tonnes. The average annual loss of sweet corn to waste in the fresh market is estimated to be 28% or 10,952 tonnes. Losses include postharvest culls from whole cobs and trimmings from packaged cobs. It is assumed that trimmings are packaged and sold for $8/tonne. Other waste material (husks) is not valued. On-farm losses are assumed to be potentially recoverable for the fresh market and therefore are valued at the fresh market price of $200/tonne.

Table 20 presents the partial budget estimate of the value of losses for the fresh sweet corn market.

Table 20 - Estimate annual value of losses for fresh sweet corn ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
Sale of trimmings	$13.08		
Total additional income	$13.08	***Total additional costs***	$0.00
Reduced costs		**Reduced income**	
		Fresh market sales	$1,925.37
Total reduced costs	$0.00	***Total reduced income***	$1,925.37
Total positive impacts	$13.08	**Total negative impacts**	$1,925.37
Net impact	-$1,912.30		

Source: Queensland DAFF

Annual production of sweet corn for the processing market is 36,000 tonnes. The average annual loss of sweet corn grown for processing is 44.2% comprising discarded cobs and kernels. It is assumed that this material is recycled rather than disposed in landfill. Table 21 presents the partial budget estimate for the value of losses for the processing sweet corn market.

Table 22 reveals that the estimated annual total value of losses for sweet corn due to waste is $14.31 million.

Table 21 - Estimated annual value of losses for processing sweet corn ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
		Recycling collection	$294.62
Total additional income	$0.00	***Total additional costs***	$294.62
Reduced costs		**Reduced income**	
Landfill levy	$71.28		
Total reduced costs	$71.28	***Total reduced income***	$0.00
Total positive impacts	$71.28	**Total negative impacts**	$294.62
Net impact	-$223.34		

Source: DSEWPC 2012

Table 22 - Estimated total annual value of sweet corn losses

	Net loss ($/ha)	Net loss ($/tonne)	Total loss (tonnes)	Total Loss ($)
On farm losses post-harvest	-$1,912.30	-$1,169.86	10,952.10	-$12,812,383.20
Processing losses	-$223.34	-$94.00	15,919.20	-$1,496,404.80
Totals			26,871.30	-$14,308,788.00

7.3.5 *Carrots*

Annual production of carrots is estimated at 300,000 tonnes, with 279,000 for the fresh market and 21,000 for the processed carrot market. The average annual loss of carrots to waste in the fresh market is estimated to be 33% or 92,074 tonnes. Losses include postharvest culls due to damage and not meeting minimum quality standards. It is assumed that culled carrots are fed to livestock at $30/tonne. On-farm losses are assumed to be potentially recoverable for the fresh market and therefore are valued at the fresh market price of $310/tonne. Table 23 presents the partial budget estimate of the value of losses for the fresh carrot market.

Table 23 - Estimated annual value of losses for fresh carrots ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
Animal feed	$600.48		
Total additional income	$600.48	***Total additional costs***	$0.00
Reduced costs		**Reduced income**	
Packing	486.1465	Fresh market sales	$6,204.97
Total reduced costs	$486.15	***Total reduced income***	$6,204.97
Total positive impacts	$1,086.63	**Total negative impacts**	$6,204.97
Net impact	-$5,118.34		

Source: Queensland DAFF

Annual production of carrots for the processing market is 21,000 tonnes. The average annual loss of carrots grown for processing is 5%. It is assumed that this material is collected and fed to livestock, rather than being disposed to landfill.

Table 24 presents the partial budget estimate for the value of losses for the processing carrot market. Table 25 reveals that the estimated annual total value of losses for carrots due to waste is $23.97 million.

Table 24 - Estimated annual value of losses of processing carrots ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
		Recycling collection	$28.31
Total additional income	$0.00	***Total additional costs***	$28.31
Reduced costs		**Reduced income**	
Landfill levy	$6.85	Processed market sales	$70.76
Total reduced costs	$6.85	***Total reduced income***	$70.76
Total positive impacts	$6.85	**Total negative impacts**	$99.07
Net impact	-$92.22		

Source: DSEWPC 2012

Table 25 - Estimate total annual value of carrot losses

	Net loss ($/ha)	Net loss ($/tonne)	Total loss (tonnes)	Total Loss ($)
On farm losses post-harvest	-$5,118.34	-$255.71	92,073.68	-$23,544,357.28
Processing losses	-$92.22	-$404.00	1,050.04	-$424,216.97
Totals			93,123.72	-$23,968,574.25

7.3.6 *Beetroot*

Annual production of beetroot is estimated at 36,000 tonnes, with 20,000 for the fresh market and 16,000 for the processed beetroot market. The average annual loss of beetroot to waste in the fresh market is estimated to be 14,000 tonnes for early season (20% of crop) and 19,500 for the mid- season crop (15% of crop). Losses include postharvest culls due to damage and produce not meeting minimum quality standards. It is assumed that culled beetroot is composted and used as fertilizer. On-farm losses are assumed to be potentially recoverable for the fresh market and therefore are valued at the fresh market price of $180/tonne.

Table 20 presents the partial budget estimate of the value of losses for the fresh beetroot market.

Table 26 - Estimated annual value of losses for fresh beetroot ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
Total additional income	$0.00	***Total additional costs***	$0.00
Reduced costs		**Reduced income**	
Fertilizer replacement	$72.00	Fresh market sales	$1,206.00
Packing	$14.81		
Total reduced costs	$86.81	***Total reduced income***	$1,206.00
Total positive impacts	$86.81	**Total negative impacts**	$1,206.00
Net impact	-$1,119.19		

Source: Queensland DAFF

Annual production of beetroot for the processing market is 16,000 tonnes. The average annual loss of beetroot grown for processing is 43%. It is assumed that this material is collected and composted, rather than being disposed to landfill. Table 27 presents the partial budget estimate for the value of losses for the processing beetroot market.
Table 28 reveals that the estimated annual total value of losses for beetroot due to waste is $1.19 million.

Table 27 - Estimated annual value of losses for processing beetroot ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
Packing	$37.29	Recycling collection	$2,132.80
Total additional income	$37.29	***Total additional costs***	$2,132.80
Reduced costs		**Reduced income**	
Landfill levy	$516.00		
Total reduced costs	$516.00	***Total reduced income***	$0.00
Total positive impacts	$553.29	**Total negative impacts**	$2,132.80
Net impact	-$1,579.51		

Source: DSEWPC 2012

Table 28 - Estimated total annual value of beetroot losses

	Net loss ($/ha)	Net loss ($/tonne)	Total loss (tonnes)	Total Loss ($)
On farm losses post-harvest	-$1,119.19	-$167.04	3,350.00	-$559,595.93
Processing losses	-$1,579.51	-$91.83	6,880.00	-$631,802.16
Totals			10,230.00	-$1,191,398.09

7.3.7 *Lettuce*

Annual production of lettuce is estimated at 124,000 tonnes, with 115,400 for the fresh market and 8,600 for the processed market. Due to over-production 10% of the crop is left unharvested and ploughed into the soil. Postharvest on-farm culls of 5% are due to produce not meeting minimum quality standards. On-farm losses are assumed to be potentially recoverable for the fresh market and therefore are valued at the fresh market price of $730/tonne.
Table 29 presents the partial budget estimate of the value of losses for the fresh lettuce market.

Table 29 - Estimated annual value of losses of fresh lettuce ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
		Plough in	$64.76
Total additional income	$0.00	***Total additional costs***	$64.76
Reduced costs		**Reduced income**	
Harvesting and packing	$925.50	Fresh market sales	$2,956.50
Packing (post harvest culls)	$374.25		
Total reduced costs	$1,299.75	***Total reduced income***	$2,956.50
Total positive impacts	$1,299.75	**Total negative impacts**	$3,021.26
Net impact	-$1,721.51		

Source: Queensland DAFF

Annual production of lettuce for the processing market is 8,550 tonnes. The average annual loss of lettuces grown for processing is 5%. It is assumed that this material is collected and composted, rather than being disposed to landfill.

Table 30 presents the partial budget estimate for the value of losses for the processing beetroot market. Table 31 reveals that the estimated annual total value of losses for lettuces due to waste is $7.4 million.

Table 30 - Estimated total annual value of losses of processing lettuce ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
		Recycling collection	$235.60
Total additional income	$0.00	***Total additional costs***	$235.60
Reduced costs		**Reduced income**	
Landfill levy	$57.00		
Total reduced costs	$57.00	***Total reduced income***	$0.00
Total positive impacts	$57.00	**Total negative impacts**	$235.60
Net impact	-$178.60		

Source: DSEWPC 2012

Table 31 - Estimated total annual value of lettuce losses

	Net loss ($/ha)	Net loss ($/tonne)	Total loss (tonnes)	Total Loss ($)
On farm losses post-harvest	-$1,721.51	-$425.06	17,313.75	-$7,359,455.25
Processing losses	-$178.60	-$94.00	427.50	-$40,185.00
Totals			17,741.25	-$7,399,640.25

7.3.8 *Baby leaf – transplanted*

Annual production of baby leaf is estimated at 157,500 tonnes for the fresh market, with 52, 500 tonnes produced in winter and 105,000 tonnes produced in summer. The average annual loss of baby leaf to waste in summer is estimated to be 10,500 tonnes (10% of crop) and 8,925 for the winter crop (17% of crop). Culled material is used as green manure or animal feed – the value of this is not included in the estimates[43]. All losses are assumed to be potentially recoverable for the fresh market and therefore are valued at the fresh market price of $2000/tonne (price to be confirmed). Table 32 presents the partial budget estimate

[43] Gross margin data are unavailable for this crop

of the value of losses for the fresh lettuce market. Table 33 reveals that the estimated annual total value of losses for baby leaf due to waste is $38.85 million.

Table 32 - Estimated annual value of losses for fresh baby leaf-transplanted ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
Total additional income	$0.00	***Total additional costs***	$0.00
Reduced costs		**Reduced income**	
		Fresh market sales	$8,633.33
Total reduced costs	$0.00	***Total reduced income***	$8,633.33
Total positive impacts	$0.00	**Total negative impacts**	$8,633.33
Net impact	-$8,633.33		

Table 33 - Estimate total annual value of baby leaf-transplanted losses

	Net loss ($/ha)	Net loss ($/tonne)	Total loss (tonnes)	Total Loss ($)
On farm losses post-harvest	-$8,633.33	-$2,000.00	19,425.00	-$38,850,000.00
Post-farm losses	$0.00	$0.00	0.00	$0.00
Totals			19,425.00	-$38,850,000.00

7.3.9 *Baby leaf – direct seeded*

Annual production of baby leaf direct seeded is estimated at 29,800 tonnes for the fresh market, with 9,800 tonnes produced in winter and 20,000 tonnes produced in summer. The average annual loss of baby leaf to waste in summer is estimated to be 2,000 tonnes (10% of crop) and 1470 for the winter crop (15% of crop). Culled material is used as green manure or animal feed – the value of this is not included in the estimates[44].

All losses are assumed to be potentially recoverable for the fresh market and therefore are valued at the fresh market price of $2,000/tonne (price to be confirmed). Table 34 presents

[44] Gross margin data are unavailable for this crop

the partial budget estimate of the value of losses for the fresh direct seeded baby leaf vegetable market.

Table 35Table 35 reveals that the estimated annual total value of losses for baby leaf due to waste is $6.94 million.

Table 34 - Estimated annual value of losses for fresh baby leaf-direct seeded ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
Total additional income	$0.00	***Total additional costs***	$0.00
Reduced costs		**Reduced income**	
		Fresh market sales	$1,982.86
Total reduced costs	$0.00	***Total reduced income***	$1,982.86
Total positive impacts	$0.00	**Total negative impacts**	$1,982.86
Net impact	-$1,982.86		

Table 35 - Estimate total annual value of baby leaf-direct seeded losses

	Net loss ($/ha)	Net loss ($/tonne)	Total loss (tonnes)	Total Loss ($)
On farm losses post-harvest	-$1,982.86	-$2,000.00	3,470.00	-$6,940,000.00
Post-farm losses	$0.00	$0.00	0.00	$0.00
Totals			3,470.00	-$6,940,000.00

7.3.10 *Capsicums*

The total annual production of capsicums is estimated at 119,600 tonnes of which 88,500 tonnes is sold in fresh and processing markets and 31,100 tonnes are lost to waste. The average annual loss of capsicums to waste in the fresh market is estimated to be 18% or 21,528 tonnes on-farm and 8% for processing capsicums. Farm losses are due to rotting, splitting and other damage.

Causes of losses in processing are due to fruit failing to meet minimum standards, especially regarding size and shape. It is assumed that pre-harvest losses are left in the field and ploughed in as a green manure. It is assumed that there is a 20% saving on the use of nitrogen fertilizer associated with returning the crop residue as green manure.

Table 36 presents the partial budget estimate of the value of on-farm losses for the fresh capsicum market.

Annual production of capsicums for the processing market is 9,568 tonnes. The average annual loss of capsicums grown for processing is 8%. It is assumed that this material is collected and recycled, rather than being disposed to landfill. These postharvest culls avoid the cost of packing.

Table 37 presents the partial budget estimate for the value of losses for the processing capsicum market. Table 38 reveals that the estimated total annual value of losses for capsicums due to waste is $13.79 million.

Table 36 - Estimated annual value of losses for fresh capsicums ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
		Plough in	$64.76
Total additional income	$0.00	***Total additional costs***	$64.76
Reduced costs		**Reduced income**	
Fertilizer replacement	$72.00	Fresh market sales	$20,475.00
Harvest cost	$9,973.71		
Total reduced costs	$10,045.71	***Total reduced income***	$20,475.00
Total positive impacts	$10,045.71	**Total negative impacts**	$20,539.76
Net impact	-$10,494.05		

Source: Queensland DAFF

Table 37 - Estimated annual value of losses for processing capsicums ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
		Recycling collection	$3,684.57
Total additional income	$0.00	***Total additional costs***	$3,684.57
Reduced costs		**Reduced income**	
Landfill levy	$891.43		
Packing	$4,951.48		
Total reduced costs	$5,842.91	***Total reduced income***	$0.00
Total positive impacts	$5,842.91	**Total negative impacts**	$3,684.57
Net impact	$2,158.34		

Source: DSEWPC 2012

Table 38 - Estimate total annual value of capsicum losses

	Net loss ($/ha)	Net loss ($/tonne)	Total loss (tonnes)	Total Loss ($)
On farm losses	-$10,494.05	-$672.70	21,528.00	-$14,481,789.00
Processing losses	$2,158.34	$72.64	9,568.00	$694,984.56
Totals			31,096.00	-$13,786,804.44

7.3.11 *Beans*

The total annual production of beans is estimated at 51,000 tonnes. The average annual loss of beans to waste in the fresh market is estimated to be 25% or 12,800 tonnes. It is estimated that 15% of production is left in fields where machine harvesting is used and 10% are culled post-harvest. The material left in the field is mulched back into the soil as green manure. It is assumed that there is a 20% saving on the use of nitrogen fertilizer associated with returning the crop residue as green manure.

Table 39 presents the partial budget estimate of the value of on-farm losses for the fresh bean market. Table 40 reveals that the estimated total annual value of losses for beans due to waste is $2.17 million.

Table 39 - Estimated annual value of losses of fresh beans ($/ha)

Positive Impacts	$/ha	Negative Impacts	$/ha
Additional Income		**Additional costs**	
		Plough in	$64.76
Total additional income	$0.00	***Total additional costs***	$64.76
Reduced costs		**Reduced income**	
Fertilizer replacement	$135.00	Fresh market sales	$935.00
Harvest & packing cost	$503.15		
Packing	202.5		
Total reduced costs	$638.15	***Total reduced income***	$935.00
Total positive impacts	$638.15	**Total negative impacts**	$999.76
Net impact	-$361.61		

Source: Queensland DAFF

Table 40 - Estimated total annual value of bean losses

	Net loss ($/ha)	Net loss ($/tonne)	Total loss (tonnes)	Total Loss ($)
On farm losses	-$361.61	-$170.17	12,750.00	-$2,169,681.00
Processing losses	$0.00	$0.00		$0.00
Totals			12,750.00	-$2,169,681.00

7.4 Summary and Conclusions

The estimated waste values for vegetables are summarised in Table 41. These values can be compared to the gross value of production for each crop to provide an indication of the share of loss due to waste in value terms.

Table 41 - Summary of estimated $ values of vegetable losses due to waste

Crop	Value of fresh waste	Value of processing waste	Total value of waste
Cabbage	-5,946,817.50	-3,801,600.00	-9,748,417.50
Cauliflower	-18,596,802.50	-1,057,500.00	-19,654,302.50
Broccoli	-18,199,229.21	1,537,413.43	-16,661,815.78
Sweet corn	-12,812,383.20	-1,496,404.80	-14,308,788.00
Carrots	-23,544,357.28	-424,216.97	-23,968,574.25
Beetroot	-559,595.93	-631,802.16	-1,191,398.09
Lettuce	-7,359,455.25	-40,185.00	-7,399,640.25
Baby leaf - transplanted	-38,850,000.00		-38,850,000.00
Baby leaf - direct seeded	-6,940,000.00		-6,940,000.00
Capsicums	-14,481,789.00	694,984.56	-13,786,804.44
Beans	-2,169,681.00		-2,169,681.00
Total	-149,460,110.87	-5,219,310.94	-154,679,421.81

The waste values estimated in this report are preliminary in many respects. They are a short-term measure. A number of assumptions are made about waste streams and associated costs and cost savings, all of which could withstand closer scrutiny. For example, the impact on fertilizer application and costs of ploughing an unharvested crop into the soil as a green manure crop should be explored in more detail. Similarly, where an abandoned crop is grazed, estimates of the value of the feed provided are needed for those vegetables where it is an option.

For processors it is assumed that they separate wastes at source and divert organic wastes to recycling rather than to land fill. However, the waste management practices of vegetable processors could be explored more fully to identify the nature of the wastes (solid or liquid) and whether or not processors divert wastes to recycling, or what share of wastes are recycled.

More refinement could also be made on prices received by growers for produce supplied to the processing market. For most crops analysed the unit price applied is the same for produce supplied to the processing market as it is for that supplied to the fresh market. However, in many cases prices are likely to be somewhat lower, although perhaps both price and quantities required are more stable over time.

8 Alternative uses for vegetable crop waste in Australia

8.1 Introduction

Part one of this review found that 25% of vegetable crops grown in Australia are not sold. This includes crops which are grown to maturity and not harvested, harvested crops which do not meet specification and are left on farm and crops consigned to wholesale markets or DCs and either rejected or not sold. This waste represents a major cost to vegetable producers.

The review was funded from the Australian vegetable levy and so does not include some major crops that do not pay the vegetable levy. The main ones are tomatoes (fresh market and processing), potatoes, melons, onions and various others. This means that the quantities and values presented in this report are an underestimate of the total waste, including the non-levy paying crops.

Many vegetable growers produce both levy-paying and non levy-paying crops and so we have included a brief summary of potential uses for some of these crops. Tomatoes and potatoes have been relatively well studied and there are some excellent reviews available.

Recoveries of waste by vegetable processors and waste by consumers have also been relatively well documented. These areas will be touched on, but not examined in great detail. Relevant studies covering these areas will be referred to in the review.

The main focus has been on searching for innovative techniques and markets, which can potentially utilise and produce income from harvested and non-harvested vegetable crops at the farm level.

8.2 The hierarchy of uses for waste

There are many uses for by-products, out of specification vegetables and crop residues. They range from high value fresh cut products, such as salad mixes or preserved products, to low value bulk organic materials needed for compost or biofuel production. It can be useful to think about ways of using these products on a hierarchy; those with the highest value (such as fresh cut foods) are likely to use small volumes of best quality vegetables. At the bottom of the scale, large volumes of low value organic matter can be bulked and used as bio-fuel source or soil amendment (Figure 17).

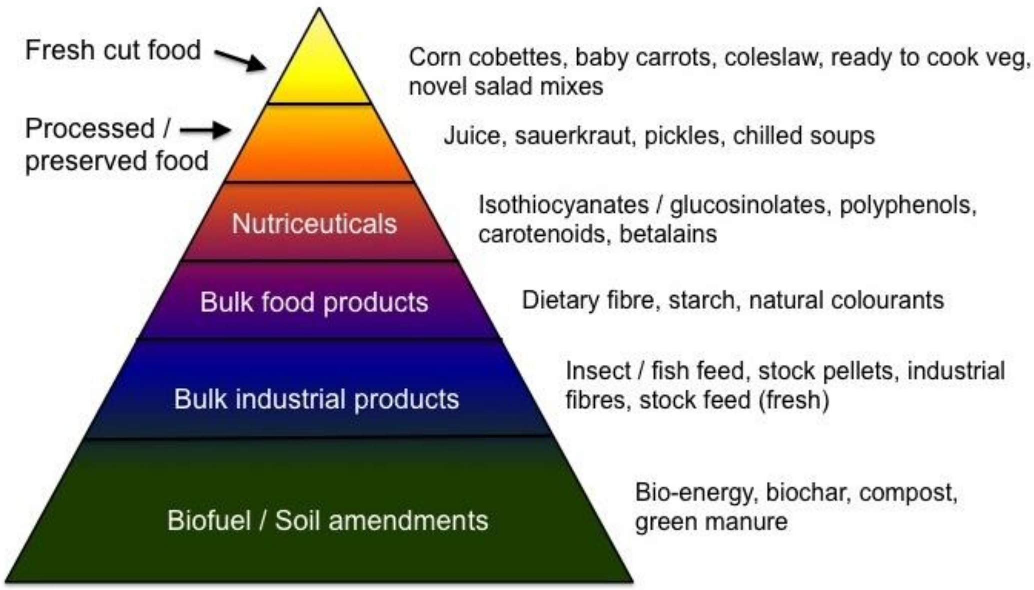

Figure 17 - Hierarchy of alternative uses for waste. Products at the top are the highest value, but utilize smaller quantities and higher qualities of raw materials compared to those at the base.

The viability of many of these options will rest on a number of factors including;

- The quantity and quality of raw material available.
- Regularity of supply of the raw material (seasonal, climate affected, market reliant).
- Costs of consolidating materials, especially if they are sourced from a range of different locations.
- Competitiveness of products in the marketplace.
- Incentives / disincentives for different options (eg carbon credits, tip fees).

While processing may initially seem to be an appealing option for "out of specification" products, in reality this is often not a viable option. Processing usually requires a continual supply of known quality products; it is not well adapted to utilizing occasional amounts of excess or variable product. Australia has already seen a dramatic downturn in fruit and vegetable processing capacity, with most food manufacturers cutting back their purchases of locally grown produce. For example, SPC Ardmona has reduced its intake of fruit for canning from 110 kt annually to only 11 kt over the last 10 years and recently announced that more than half its regular suppliers would not be required next year. Much of the remaining vegetable processing as well as fresh cut salad manufacturing uses materials grown specifically for that purpose.

8.3 Increasing consumption of vegetables

There is one clear main cause of vegetable waste affecting all of the products which have been considered in this review; **oversupply**.

The evidence suggests that the largest cause of vegetables being either discarded in the field or culled postharvest is that **there is no market for imperfect product**. At certain times, market prices are so low that crops are simply abandoned, no matter how good their quality.

Grade standards and crop specification requirements are applied most stringently when the supply of vegetable crops is highest. Paradoxically this often coincides with the middle of production season and ideal weather conditions for a particular crop. Under these conditions, supply is usually plentiful, quality is good but prices are low.

For the supply chain to work effectively the vegetable quality needs to be good, supply must be adequate to meet demand and retail prices must be reasonable; farm gate and wholesale prices must be high enough for production and supply to be economically viable.

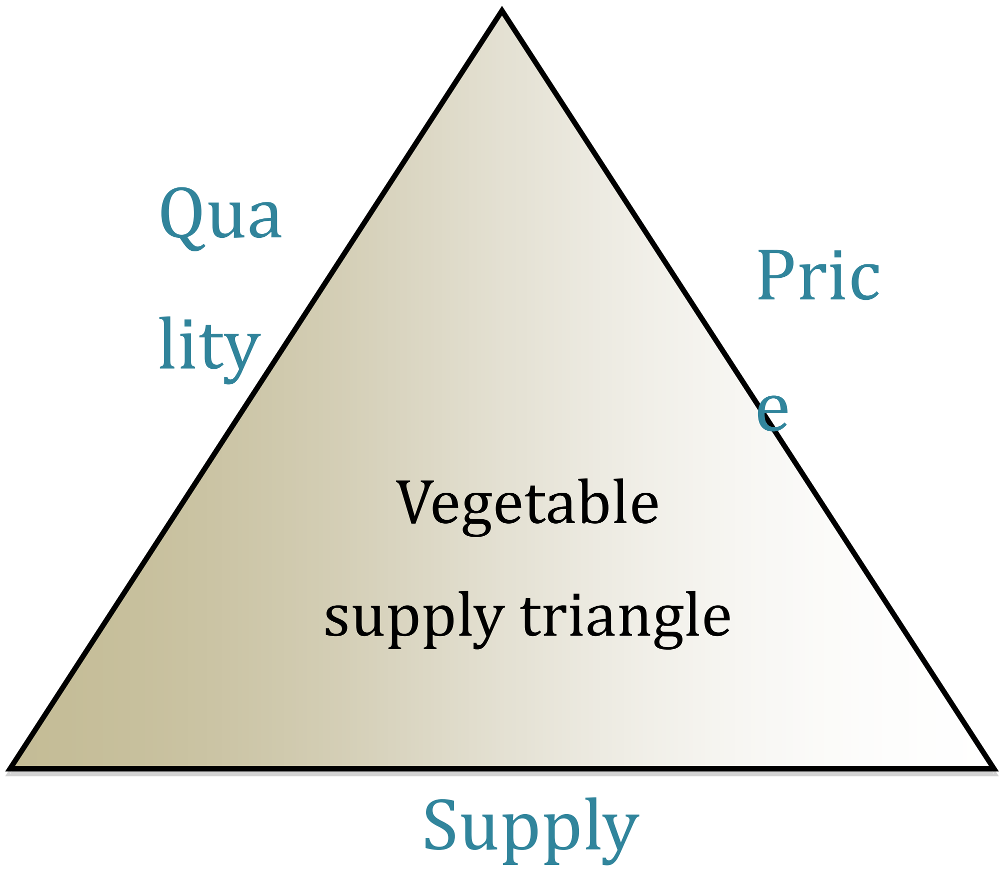

Figure 18 Vegetable supply triangle

Vegtables for better health

Consider the following example of when two parts of the supply triangle are right but the third is not.

8.3.1 *Lettuce: Lockyer Valley mid winter*

The Lockyer Valley, Qld is a major lettuce-growing region. The traditional production time is the winter-spring period. The highest yields and the best quality both occur in July-September (Figure 19).

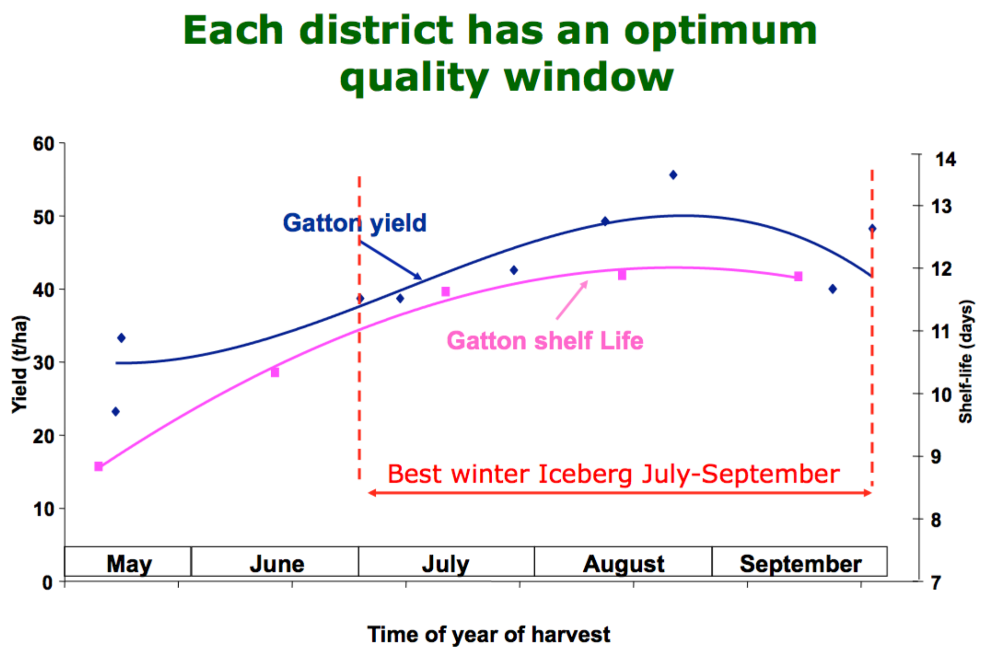

Figure 19 Lettuce yield and quality, Lockyer Valley Qld[45]

This July-September period is where growers should be focussing to produce lettuce. Production efficiencies are good, yields are high, the cut out rate from the field (% harvested) should be high and risks from adverse weather are low. This is also good for consumers; they are getting the best quality for a reasonable price. In a perfect world this is what would occur. However, all too often in our small Australian domestic market the market collapses.

High supply puts downward pressure on prices. The supply triangle is incomplete and the result is either good quality lettuce is left in the field because it is not worth harvesting,

[45] Source: Rogers et al. (2006) Post harvest improvement in iceberg and cos lettuce To extend shelf life for fresh cut salads. Project VX03092.

consignments are rejected at the DC or lettuce is sold by wholesalers at prices below the cost of production.

No one wins out of this situation. Growers are ploughing in perfectly good lettuce, wholesalers are missing out on volume and consumers are missing out on good quality lettuce at a reasonable price – which would have been good for their health.

As a result growers are under pressure to extend their production into early and late shoulder periods. This spreads the risk of low wholesale prices over a longer period, and increases the chance that a crop failure elsewhere will force up prices.

This is an inefficient solution to the problem. It further entrenches the problem of vegetable waste because crops grown outside the optimum production window are more likely to be affected by pests or diseases, be undersize, or suffer other quality problems.

The best solution for the vegetable industry and consumers is clear - Increase demand.

8.3.2 *Vegetables for better health*

Australians do not eat enough vegetables. The National Health and Medical Research Council recommends that adults eat a minimum of 2 serves of fruit and 5 serves of vegetables a day to ensure good nutrition and health. However, the 2011-2012 Australian health survey found that, although 48.3% of Australians ate the recommended number of serves of fruit, only 8.3% met the guidelines for vegetable consumption (Figure 20).

There is no doubt that diets rich in fruit and vegetables contribute greatly to improved human health. Increased consumption of vegetables, in particular, has been associated with reduced rates of cardiovascular disease, cancer, diabetes, obesity, stroke, and many other diseases and disorders too numerous to mention here[46]. Despite this, more than 50% of the population does not even consume 3 servings of vegetables a day.

Increasing consumption of vegetables would not only have major benefits for vegetable growers, but would greatly improve the health of the population.

[46] Causes of Death, Australia, 2011 (ABS).

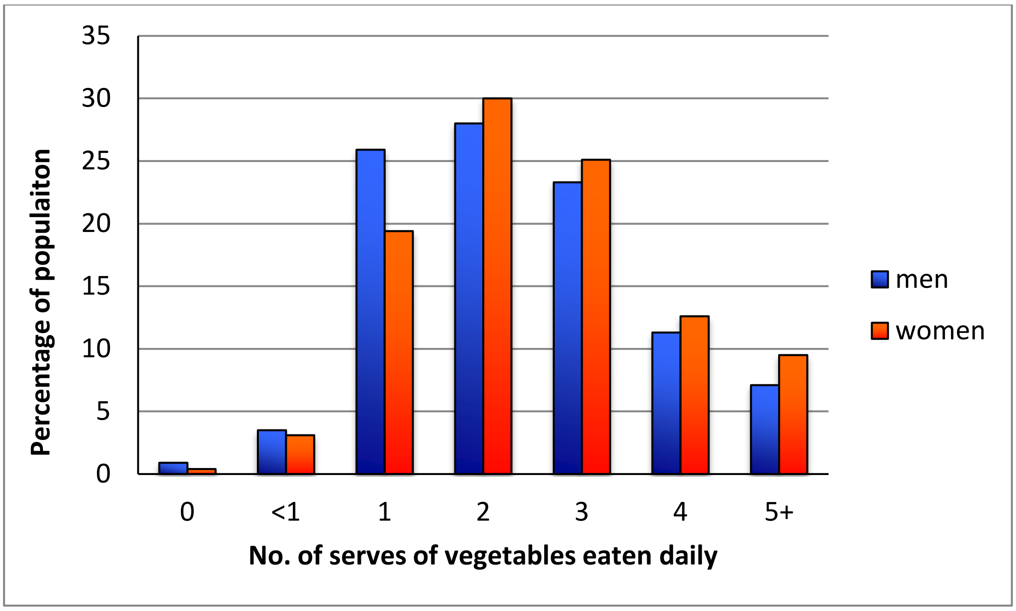

Figure 20 - Vegetable consumption by adult Australians; results from the 2011-2012 Australian health survey.

8.3.3 *Strategies for increasing demand*

The Australian vegetable industry does not have a marketing levy, but that does not mean there is nothing the industry can do about better marketing of Australian vegetables. At least one strategy that could be funded more broadly on the basis of reducing public health spending would involve promoting the health aspects of vegetables. This could be an on-going national campaign justified in a similar way to anti smoking labelling and promotion.

There is an opportunity for the industry to leverage public health funds earmarked for promoting healthy lifestyles into also promoting vegetable consumption, especially if linked with current interest in food and cooking.

The VitalVegetables® research programme aimed to develop a number of high antioxidant vegetables to capitalize on growing public interest in health and nutraceuticals. The project was funded by Horticulture New Zealand, Plant & Food Research and the Department of Primary Industries Victoria, with Horticulture Australia Limited matched funds from the Australian Government and support from the New Zealand vegetable sector. Products included glucosinolate enhanced broccoli and high carotenoid capsicums. At the same time other researchers have developed products such as high zeaxanthin sweet corn, Vitamin D enriched mushrooms and selenium increased potatoes.

They have an excellent website at www.vitalvegetables.co.nz but could do a lot more with a regular advertising campaign. This is excellent background information, but clearly is not changing consumer behaviour sufficiently.

Moreover, even standard varieties of vegetables can more than meet the Food Standard Australia New Zealand (FSANZ) guidelines for label health claims. For example, both rocket and spinach have been demonstrated to be "Good Sources" of Vitamin C (Figure 21).

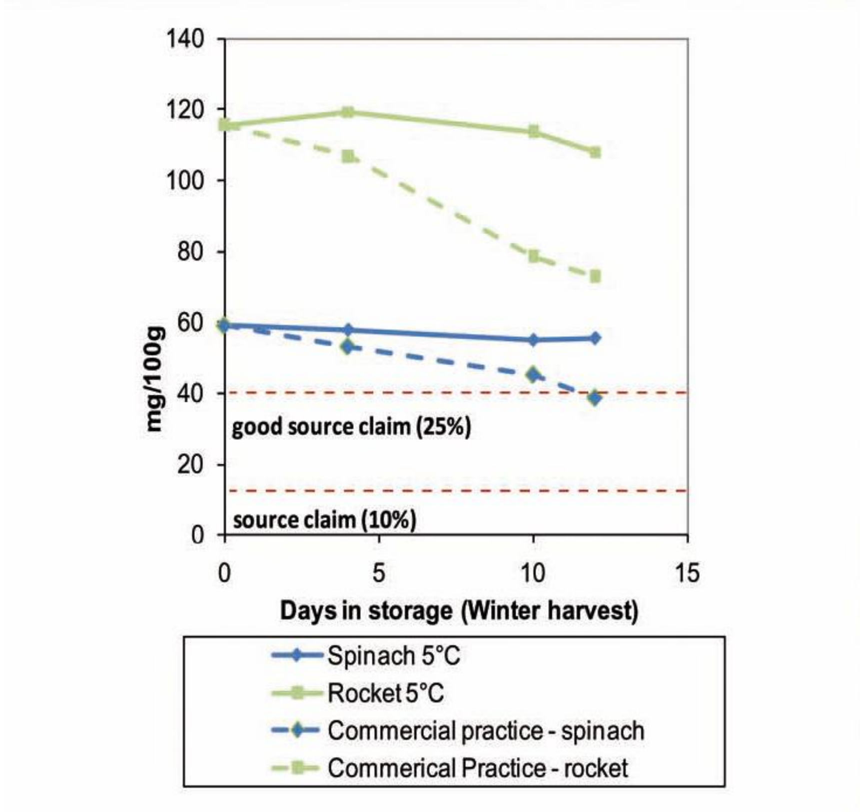

Figure 21 - Vitamin C content in spinach and rocket stored at different temperatures[47]

According to the FSANZ Food Standards Code, any product with >4g dietary fibre per serving can be considered a "Good Source" of fibre. While reported fibre contents of vegetables can vary widely, half a cup of cooked leafy greens such as spinach and kale, green beans, peas, carrots and sweet corn can all contain >4g fibre. This suggests they would be eligible to make this claim. Other claims relevant to vegetables include "Low Cholesterol" (<20mg/100g) "Fat Free", and "A Good Source of Vitamin __" (serving supplies at least 25% of RDI of that vitamin). It is also allowable to state; "A high intake of fruit and vegetables reduces the risk of coronary heart disease"

8.3.4 *Communicating with consumers*

Communicating the benefits of eating more vegetables has the potential to increase awareness, improve knowledge, and create long-term changes in behaviour. Previous campaigns have demonstrated that integrated approaches are better at changing

[47] Bokshsi, A., Jobling, J. and Rogers, G. et. al. (2010) Heath claim labeling of baby leaf spinach and rocket relative to vitamin C and Folate. . Horticultural Congress, Lisbon.

behaviours than single messages. That is, information has to address knowledge, skills and social behaviours as well as environmental factors such as quality, availability and convenience. In the case of vegetables, this could mean;

- Promoting the health benefits of eating vegetables
- Making it 'cool' to eat vegetables and, conversely, 'uncool' or 'socially irresponsible' not to eat vegetables at each meal
- Educating people about purchase and storage of vegetables
- Demonstrating easy and tasty ways to prepare vegetables
- Ensuring that vegetable options are available and affordable wherever people shop and eat

In 2002 the Western Australian Health Department launched a state-wide campaign as part of the Go for 2&5 campaign to promote fruit and vegetables. They then conducted a major survey of consumers about what constituted a serving of fruit and of vegetables, their usual daily fruit and vegetables intake, and their recall of the campaign. The campaign resulted in a moderate increase in consumption of 0.8 servings daily[48].

It was also found that although 42% of respondents were confident that a serving of fruit was one piece, only 14.5% understood that a serving of vegetables was ½ a cup. This misunderstanding meant that some participants thought they were eating ample vegetables when their intake was actually well below guidelines. The study suggested that there was a strong positive association between understanding what constituted a serving and consuming more vegetables. It was concluded that campaigns that differentiated and encouraged greater consumption of vegetables could have a real effect on awareness and consumption[49].

Similarly, an evaluation of the National Go for 2&5 campaign showed that the campaign increased understanding of the recommended serves of vegetables and made people more aware of the benefits of eating vegetables on their health. The campaign had the most effect on people with very low vegetable consumption (<2 serves a day). This group figured prominently in the 28% of respondents who attempted to increase their vegetable consumption as a result of the campaign[50]. While this figure may seem low, if 28% of the population increased their consumption by 1 serve of vegetables per day this would equate to approximately 176 kt additional vegetables consumed per year (one serve = 75g).

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[48] Pollard, C.M., Miller, M.R., Daly, A.M., Crouchley, K.E., O'Donoghue, K.J., Lang, A.J., & Binns, C.W. (2007). Increasing fruit and vegetable consumption: success of the Western Australian Go for 2&5® campaign. *Public Health Nutrition, 11,* 314-320.

[49] Pollard, C.M., Daly, A.M., Binns, C.W. 2007. Consumer perceptions of fruit and vegetables serving sizes. Public Health and Nutrition.

[50] Elliot, D., Walker, D. 2007. Evaluation of the National Go for 2&5 campaign. Woolcott Research report for the Australian Government Department of Health and Ageing

8.3.5 *The role of Government*

According to Benjamin Franklin, "an ounce of prevention is worth a pound of cure". There is a clear role for government in campaigns that encourage public health and social responsibility. Successful past campaigns have included the Life Be In It campaigns of the 1980's (Figure 22), anti-smoking, sun awareness and anti-drink driving campaigns. These have shown that campaigns can change negative behaviours and improve public health. For example, the Sun Smart campaign is estimated to have prevented more than 100,000 skin cancers between 1988 and 2003 in Victoria alone, representing a return of $3.60 for every dollar invested[51].

Figure 22 Example of material from the "Life. Be in it" campaign

The federal government committed to spending over $850M in preventative health including anti smoking advertising campaigns several years ago. It spends large amounts on anti smoking advertising, e.g. $61M in 2011[52], with a new campaign just announced and running until June 2013 (undisclosed cost)[53].

In the case of vegetable consumption, there is now clear and recognized evidence that increased consumption of vegetables improves health outcomes. Eating more vegetables could save billions of dollars per year in sick leave, hospital bills and lost work, quite apart from reducing the impacts of ill health on the quality of life.

At the same time, there is a strong push to reduce children's exposure to advertising for junk food. This is thought by some commentators to represent the cheapest and most effective way to reduce obesity[51]. A recent report by US Insurance company MetLife describes a potential health crisis amongst those over 40 in the near future, mainly due to lack of exercise, obesity and poor diet. In the USA, obesity is estimated to increase the cost

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[51] Moodie, R. 2013. Focus on prevention to control the growing health budget. Published online 2 May 2013, theconversation.com.
[52] Adelaide Advertiser, January 30, 2011
[53] Federal health minister press release April 14 2013.

of Medicare by $1,723 per person annually. The report states that this could be mitigated by increases in education and health literacy, particularly in workplaces[54].

There is no marketing levy for vegetables and, even if there were, the industry could never match the advertising clout of large corporations such as Nestle, Heinz, McDonalds and PepsiCo. Nonetheless, it seems clear that increasing consumption of vegetables can improve health as well as reducing waste, and that this should remain a high priority for the vegetable industry.

The challenge for the vegetable industry is to convince government that increasing vegetable consumption through promotion is preventative health care, and will reduce the demand on health services in the future.

The health message has worked for both the mushroom industry and the avocado industries. It will also work for vegetables.

[54] Weiss, L.J., Malone, M. 2013. On the critical list? A Metlife report on the health status of the 40+ population. Report for the Metlife Institute. Accessed online 3/5/2013 www.metlife.com

8.4 On farm electricity generation from vegetable waste

8.4.1 *What is the product?*

Anaerobic digestion of wastes is a process similar to that which occurs in the human gut. Organic materials are broken down, resulting in the production of solid wastes, liquid wastes, and gas. In this case the solid and liquid wastes are useful fertilisers, while the gas can be used in energy generation.

To generate biogas, organic materials are macerated so that pieces are <5mm size, seeded with specific bacteria and warmed under anaerobic conditions in a large digester. Anaerobic bacteria do not need oxygen to survive, they source their energy from the organic materials. Suitable materials include carbohydrates, oils, sugars and natural fibre. This is referred to as the “volatile solid” (VS) component of the feedstock.

Digestion produces a range of breakdown products, including alcohols, organic acids and carbon dioxide. Specialized methanogen bacteria then break down these compounds further, producing methane gas. Biogas generally contains around 50 – 70% methane, most of the remainder being CO_2. The biogas can be readily turned into electrical power using a generator. Heat produced by combusting biogas in a Combined Heat and Power (CHP) generator can be used to continue heating the digester (Figure 23).

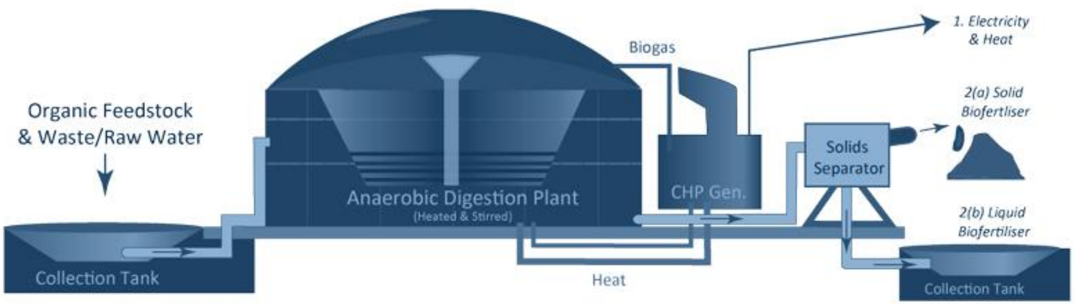

Figure 23 - Biogas generation plant

Biogas production technology originally grew from the need to dispose of municipal wastes, manure and sewage, so much of the published literature relates to these sources of organic material. However, as the technique not only stops organic wastes entering landfill but also generates electricity, it is increasingly used in agriculture. For example, there are already over 6,500 biogas plants in Germany alone, the majority of which are medium sized, farm based systems which average 300kW of installed electrical generation capacity (ie 300kW per hour at full operation). One reason for this is the high gas production possible when a range of different organic materials are added to the digester, including high nitrogen sources, preventing the mix becoming too acid[55]

8.4.2 ***Potential benefits to vegetable growers***

Vegetable wastes are particularly suitable for anaerobic digestion as they have a high moisture contents (75-90%), and are extremely biodegradable[56]. Production of biogas is high (Table 42), being up to 7x more than produced by pig or cow manure alone. Many studies have demonstrated that the technology is feasible. For example, a study of fruit and vegetable wastes from the Mexico City Central Market showed that 0.42m^3 biogas could be produced for each kg volatile solids (VS) (8-18% total weight) of vegetable waste supplemented with buffering salts and nitrogen[57]. Another study reported 0.58m^3 biogas production per kg VS from a mixture of carrots, beans and eggplant[58].

Table 42 - Biogas potential of different crops[59]

Crop	Biogas (m^3/kgVS)	Methane content (%)
Sugar beet	0.75	53
Fodder beet	0.78	53
Corn	0.61	52
Corn cobs and husks	0.67	53
Wheat	0.68	54
Grass	0.56	54

As well as gas, the process generates a mixture of solid and liquid waste referred to as digestate. This can be diluted, supplemented with phosphorus, iron and other balancing nutrients, and used as part of a hydroponic solution[60]. It can also be used as a mulch, soil conditioner or applied through fertigation. For example, application of digestate with humic acid increased productivity of capsicums, tomatoes and cucumbers by 12%, 47% and 20%

[55] Agdag Agdag, O.N., Sponza, D.T., 2005. Co-digestion of industrial sludge with municipal solid wastes in anaerobic simulated landfilling reactors. Process Biochem. 40:1871–1879.

[56] Bouallagui, H., Touhami, Y., Ben Cheikh, R., Hamdia, M. 2005. Bioreactor performance in anaerobic digestion of fruit and vegetable wastes: review. Process Biochemistry. 40:989–995.

[57] Garcia-Pena, E.IU., Parameswaran, P., Kang, D.W., Canul-Chan, M., Krajmalnik-Brown, R. 2011. Anaerobic digestion and co-digestion processes of vegetable and fruit residues: process and microbial ecology. Bioresource Technology. 102:9447-9455.

[58] Sridevi, V.D., Srinivasan, S.V., Kayalvizhi, R., Bhuvaneswari, R. 2012. Studies on conversion of carbohydrate content in the mixture of vegetable wastes into biogas in a single stage anaerobic reactor. Research Journal Chemical Sciences. 2:66-71.

[59] Weiland, P. 2010. Biogas production: current state and perspectives. Applied Microbiology and Technology. 85:849-860.

[60] WenKe, L., QiChang, Y., LianFeng, D., RuiFeng, C., WanLai, Z. 2011. Nutrient supplementation increased growth and nitrate concentration of lettuce cultivated hydroponically with biogas slurry. Acta Agriculturae Scandinavica. 61:391-394.

respectively[61] . As nutrients such as N, P and K are preserved during anaerobic digestion, the composition of solid and liquid outputs from the system will strongly reflect the feedstock materials.

Biogas generation was not previously considered viable in Australia due to the high price of the equipment required and the low cost of power. However, as electricity costs have risen so the price of anaerobic digestion equipment has decreased, now being around one fifth of the cost of some years previously.

8.4.3 ***Materials and equipment required***

Anaerobic digestion systems vary in complexity; there are both single and multiple stage digesters and static and continuous processing systems. They can also vary widely in scale; simple anaerobic digesters are widely promoted for use in the third world to provide light and heat for cooking, while others are multimillion dollar systems designed to process huge volumes of Municipal waste. The main part of an anaerobic digestion system is basically a tank and pipes, with the more complex part involving how the gas is used. Organic material needs to be finely chopped and made into a semi-liquid slurry (by adding water) before adding to the main, continually agitated, digester tank. Evolved methane and CO2 can be piped to where the biogas is needed and accumulated digestate and liquid waste is removed from the bottom of the tank (Figure 24).

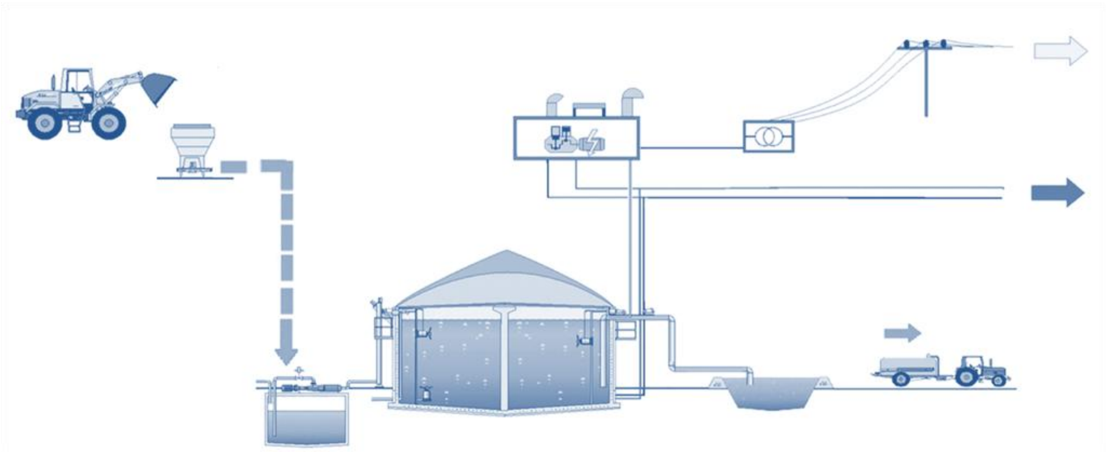

Figure 24 - Continuously stirred reactor biogas plant

The system also requires continual inputs of organic materials to function well. It is likely that the minimum size system would require at least 10t / day of raw materials, although it could be more if materials have a low VS content (lettuce, for example). Intake can also vary so as to increase during peak periods. While it is possible to shut down the system

[61] TongGuo, G., Nan, C., WeiQun, L., BaoZhen, L., HongLi, Y. 2011. Agricultural Science and Technology. 12:567-570.

entirely (over winter, for example) it would then take some weeks lead time to restore operation (Dr J. Keskar, pers. com.).

Any aerobic digestion system needs to be designed to deal effectively with the quantity and type of feedstock that will be used. It should also be matched with the farms' energy demands. One useful characteristic of biogas is that it can be accumulated in storage and used when needed. For example, if electricity use is highest during the day due to packhouse / refrigeration requirements, then gas can be accumulated overnight and used to generate electricity to meet that demand. Moreover, it is possible to link the biogas generator with the refrigerant system used for coolstores so as to directly heat refrigerant materials and power compressors. Alternatively, biogas could be accumulated during the day and used to heat greenhouses overnight.

8.4.4 ***Economic viability***

Electricity costs are generally presented as the "levelised cost of energy" (LCOE). The LCOE takes into account includes the initial capital required as well as the costs of continuous operation, fuel, and maintenance over the lifetime of the equipment.

The current average retail electricity prices at the farm gate are typically in the range $200-300 / MWhr, with off-peak and peak rates usually around $150-350 / MWhr.

A reasonable average retail price for electricity is about $230 / MWh. Electricity produced by Biogas generally costs $80 - $160 / MWh, with farm wastes at the lower end due to their suitability for this process.

The LCOE for electricity production from biogas therefore compares favourably with the average retail cost of electricity ($230 / MWh), being only slightly more than natural gas generation ($61 - $87 / MWh) and potentially similar to wind power ($77 - $112 / MWh).

Despite the apparent competitiveness of biogas energy compared to conventional coal fired power stations, electricity returned to the grid only earns $50 - $70 / MWh, below the cost of production. For this reason biogas is only likely to be economically viable if all or most of the energy produced is used on-site, rather than returned to the main grid. However, this could change. Biogas is clearly a renewable energy source, similar to solar and wind power, both of which sources are paid relatively high rates for the electricity produced.

The minimum digester size would need between 10-20 t of vegetable waste per day to run. The exact amount depends on the nature of the organic waste, and would need to be assessed.

The Company Utilitas, which designs and operates anaerobic digesters suitable for the vegetable industry, has produced an economic analysis of a 500 kW system, which could process around 40t vegetable waste per day. The capital costs would be $3.2 million to plan, design and construct, and would produce electricity at an LCOE of $84 per MWh

This investment would be recovered in approximately 4 years, or even less if the digestate produced has economic value (Table 43). This is consistent with results reported by Cascone *et al*.[62], who also suggested that the costs of establishing an anaerobic digester would be returned within 4 years. In that study, wastes from a 20Ha cherry tomato operation were used to generate 1,480 MWh per year, including both electrical and thermal energy.

Table 43 - Indicative economics for a continuous anaerobic digestion system suitable for a vegetable grower / processor (supplied by Utilitas)

Indicative economics for a 500 kW anaerobic digestion system	
Total project cost	$3,173,618
Vegetable waste treated	15,148 t/pa
Commodities produced annually	
Biogas	34,572 GJs
Electricity generated by biogas	4,055 MWh
Large generation certificates	4,055
Digestate (fertilizer or soil conditioner)	29,735 t
Costs and Revenues	
Annual operating cost (incl. 60,000 h engine overhaul)	$97,829
Annual savings on electricity costs (est. average cost of 21c/kWh)	$829,282
Potential value of digestate	$376,693
Internal Rate of Return	
No value on digestate	26%
Value on digestate	38%
Greenhouse gas emissions avoided	14,243 t
Cost of electricity (LCOE)	
Electricity produced by biomass generator	$84/MWh

It is estimated that a large vegetable farm would produce 30t / day waste during peak season, reducing to closer to 10t / day during winter. In addition, it may be possible for

[62] Cascone, G. ; D'Emilio, A. ; Buccellato, E. ; Beccali, M. ; Trupia, S. 2008. Biogas and electrical power cogeneration through anaerobic digestion of vegetable residual from tomato greenhouse cultivation. Agricultural and biosystems engineering for a sustainable world. International Conference on Agricultural Engineering, Hersonissos, Crete, Greece, 23-25 June, 2008

farms to link with other operations so as to add manures, abattoir wastes or other organic materials into the feedstock. Such additions have the potential to further improve the efficiency of the process and increase biogas production[57]. This suggests that an anaerobic digestion facility could be a viable option for many farms.

8.5 Bio-Active compound extraction from vegetables

8.5.1 *What is the product?*

With adequate sanitation and good levels of health care, few people in the richer parts of the world die from infectious diseases. Instead, the leading causes of death are cardiovascular disease, stroke, cancer, respiratory diseases and complications from diabetes. In addition, osteoporosis, cataract, Alzheimers disease, macular degeneration and many other diseases reduce the quality of lives.

Hundreds of studies have shown that those who eat the most vegetables tend to suffer the lowest incidences of many of these disorders. It now seems that many of the special benefits that come from eating vegetables are due to the various chemical compounds they contain. These include sulfur compounds, phenolics, betalains and carotenoids. Despite growing evidence of their benefits, only 10% of Australian women and 7% of men eat the recommended serves per day of vegetables[63] .

However, there is clear evidence that many Australians are concerned about their health. The 1996 Australian National Nutrition Survey reported that 26% of women and 15% of men regularly took a nutritional supplement. There would appear to be opportunities for either developing new supplements / nutraceuticals based on bio-active compounds extracted from vegetables or replacing compounds in existing products.

While the sulfur compounds found in *Brassicas* such as broccoli are not suitable for extraction and use in supplements[64], many phenolics and carotenoids remain stable during processing and consumption and maintain their activity in the body. This additionally raises the possibility of "dual purpose" crops – vegetables that are high in certain compounds and can be used as sources of bio-active compounds, but which are also suitable for consumption as fresh products.

8.5.2 *Polyphenols*

Polyphenols are one of the largest of all groups of compounds found in plant foods. They are an important part of the diet and are believed to have many possible health benefits, thanks largely to their anti-oxidant and anti-inflammatory properties. They include catechins (found in tea), flavonoids, flavanols and anthocyanins[65]. Ranging from simple

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[63] National Health Survey, 2007-2008. Australian Bureau of Statistics abs.gov.au, accessed 24/4/2012.

[64] Clarke, J.D., Hsu, A., Riedl, K., Bella, D., Schwartz, S.J., Stevens, J.F., Ho, E. 2011. Bioavailability and inter-conversion of sulforaphane and erucin in human subjects consuming broccoli sprouts or broccoli supplement in a cross-over study design. Pharmacological Research 64:456-463.

[65] Scalbert, A., Williamson, G. 2000. Dietary intake and bioavailability of polyphenols. Journal of Nutrition. 130:20735-20855.

phenolic compounds to large and complex molecules, they are both common and variable, being found in most fresh produce.

Plant polyphenols are involved in many plant processes. They contribute to the colours of fruit and vegetables, help plants resist pathogens and predators, and are involved in seed germination[66]. In recent years there has been increased interest in their role in the human diet, as evidence has accumulated on the role of polyphenols in reducing the risk of cardiovascular diseases, certain cancers, inflammatory states (eg rheumatoid arthritis), cataracts, Parkinsons disease, Alzheimers and other disorders associated with ageing[67]. Polyphenols can remove reactive oxygen species from cells, helping to maintain normal metabolic functions.

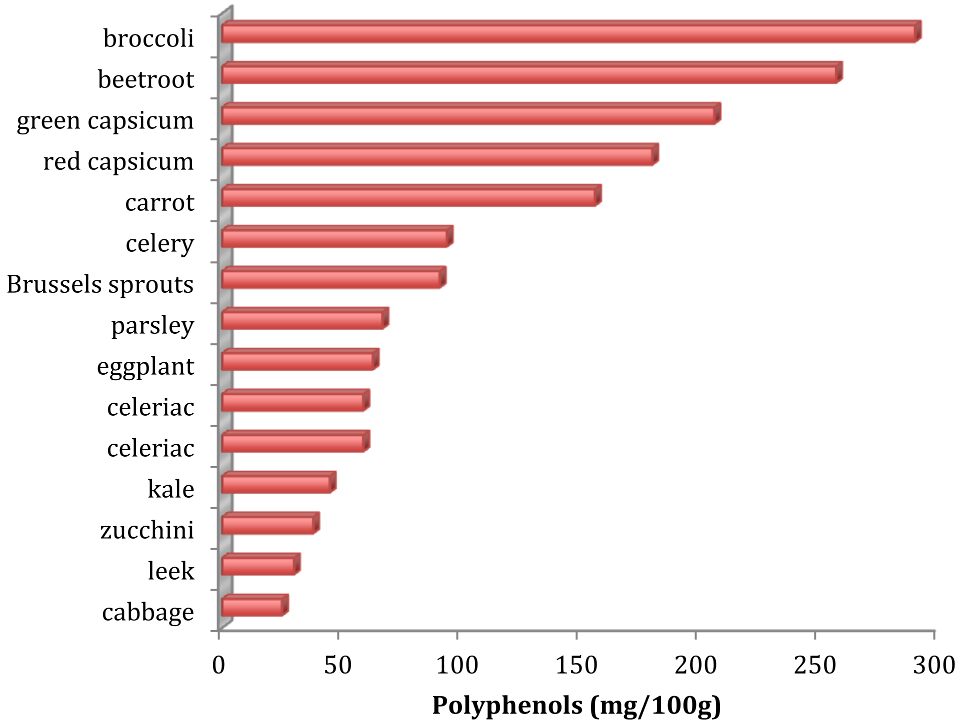

Figure 25 Average total polyphenols in selected vegetables

It has been estimated that a typical French diet contains around 1g of polyphenols per day[65], while others have suggested that no less than 1-2g of polyphenols (including flavonoids) should be consumed daily[67]. Many vegetables and fruit are rich in a wide range of polyphenols (**Figure 25**). Such compounds are often concentrated in peels and stems, the very parts most often discarded after harvest. For example, broccoli stems have been

[66] Bravo, L. 1998. Polyphenols: chemistry, dietary sources, metabolism and nutritional significance. Nutrition Reviews. 56:317-333.

[67] Cieślik, E., Gręda, A., Adamus, W. 2006. Contents of polyphenols in fruit and vegetables. Food Chemistry. 94:135-142.

shown to be high in polyphenols[68,69], while total phenolics in eggplant are highest in the peel, which contains nearly 10x the concentration found in the flesh[70] .

8.5.3 *Stressing crops to increase the yield of bioactive phenolic compounds*

Plants subjected to abiotic stresses synthesize secondary metabolites with potential application in the functional foods, dietary supplements, pharmaceutical, cosmetics and agrochemical markets. This approach can be extended to horticultural crops (Figure 26).

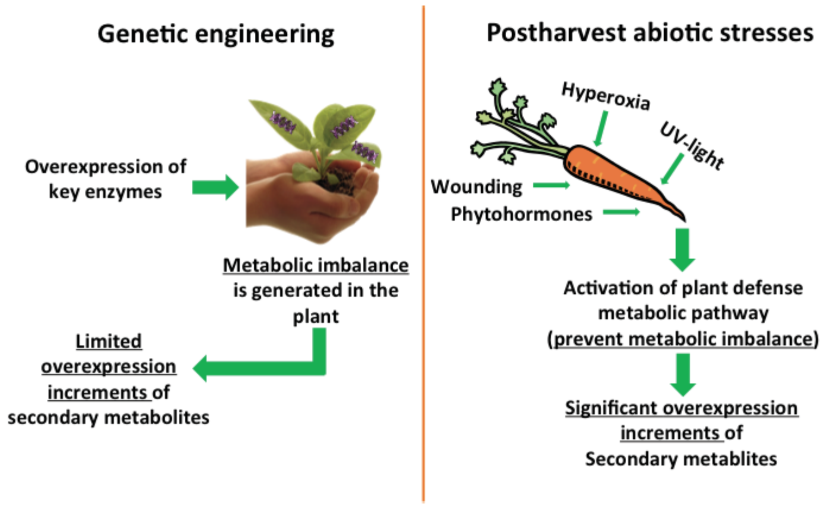

Figure 26 Comparison between genetic engineering and postharvest abiotic stresses as secondary metabolites overexpression strategies.

A review by Jacobo-Velazquez and Cisneros-Zevallos[71] describes previous reports regarding the effect of different postharvest abiotic stresses on the accumulation of phenolic compounds. Likewise, the physiological basis for the biosynthesis of phenolic compounds as an abiotic stress response is described. Stresses could be water stress, flooding, wounding, UV-light (post harvest). The mushroom industry have embraced a technology where exposing harvested mushrooms briefly to xenon light induces the synthesis of Vitamin D,

[68] Wijngaard, H.H., Rößle, C., Brunton, N. 2009. A survey of Irish fruit and vegetable waste and by-products as a source of polyphenolic antioxidants. Food Chemistry 116:202-207.
[69] Peschel, W., Sánchez-Rabanedab, F., Diekmann, W., Plescher, A., Gartzia, Jiménez, D., Lamuela-Raventós, R., Buxaderas, S, Codina, C. 2006. An industrial approach in the search of natural antioxidants from vegetable and fruit wastes. Food Chemistry. 97:137-150.
[70] Jung, E-J., Bae, M-S, Jo, E-K., Jo, Y-H., Lee, S-C. 2011. Antioxidant activity of different parts of eggplant. Journal of Medicinal Plants Research. 5:4610-4615.
[71] Jacobo-Velazquez, D. A. ; Cisneros-Zevallos, L. (2012) An alternative use of horticultural crops: stressed plants as biofactories of bioactive phenolic compounds. Agriculture: 2(3) 259-271

which is then bioavailable to people eating those mushrooms[72]. A similar method has been shown to increase resveratrol (an antioxidant) concentration in grapes.

The information presented in the review would be useful for growers and the fresh produce market which are interested in finding alternative uses for their crops, especially for those not meeting quality standards and thus are considered as waste.

The researchers conclude that up-regulation of the primary and secondary metabolism induced by wounding stress in plants suggests that primary and secondary metabolites of interest, such as shikimic acid and antioxidant phenolics, are being synthesized in the tissue . This demonstrates the potential use of abiotic stresses as a tool for the production of high commercial value plant bioactives. There is more research to be done on the precise effects of various stresses on different categories of bioactive compounds (e.g., carotenoids, vitamin C, others), the response to stresses of different crops, the possible microbial growth during stress applications, and other factors. The full text of the article is available free of charge online[73].

8.5.4 ***Carotenoids***

Carotenoids are responsible for the colour of vegetables such as capsicums, sweet corn, carrots and sweet potato. Some leafy vegetables, such as spinach, are also high in carotenoids (Figure 27). All carotenoid compounds are potent antioxidants and have been associated with a wide range of health benefits.

[72] Kristensen, H. L.; Rosenqvist, E.; Jakobsen, J. (2012) Increase of vitamin D 2 by UV-B exposure during the growth phase of white button mushroom (Agaricus bisporus). Food & Nutrition Research 56: 7114
[73] http://www.mdpi.com/2077-0472/2/3/259

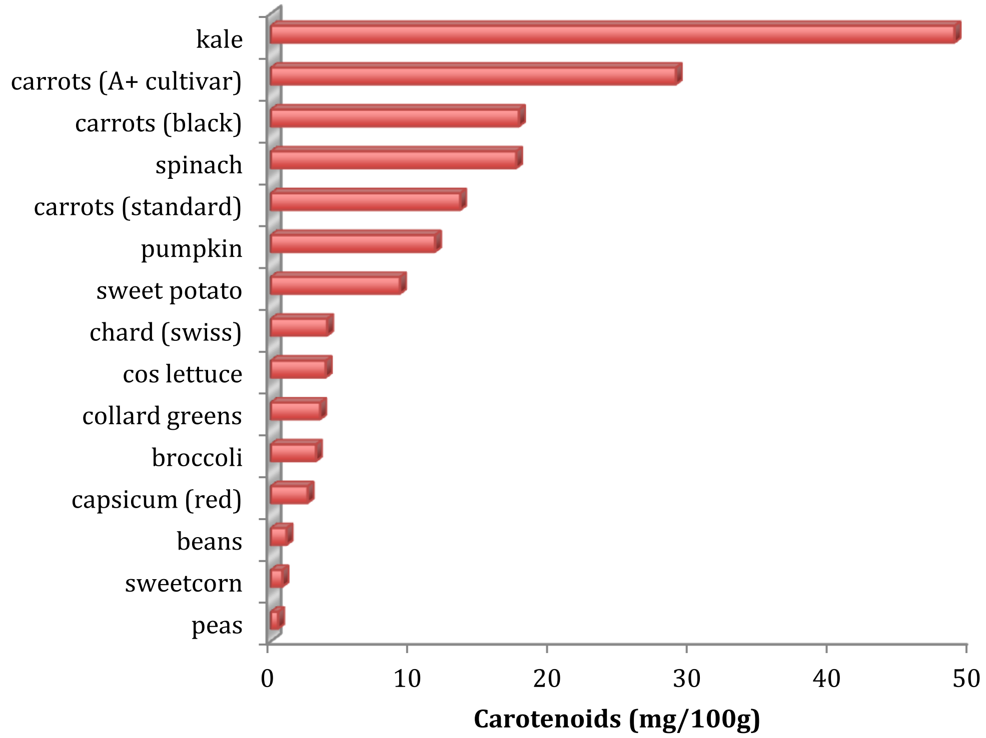

Figure 27 Average total carotenoids in selected vegetables [74]

There was previously intense interest in supplements of β-carotene, which acts as a precursor to vitamin A. Vitamin A deficiency can result in blindness. This remains a major issue in many parts of the Developing World and wherever people are severely deprived of fresh fruit and vegetables. Initial trials suggested that β-carotene also had promising anti-carcinogenic properties. However, clinical trials were abandoned when smokers given β-carotene supplements suffered increased rates of lung disease[75]. Despite this, β-carotene supplements are still widely used for everything from cancer to high blood pressure and sunburn sensitivity to weight loss.

The carotenoid zeaxanthin, primarily found in sweet corn[76], and lutein, common in green vegetables, have been demonstrated to reduce the risk of macular degeneration and cataracts[77]. It is thought that this is because they concentrate in the macula of the eye, where they absorb blue light at the high end of the visible spectrum.

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[74] Holden, J.M., Eldridge, A.L., Beecher, G.R., Buzzard, I.M., Bhagwat, S., Davis, C.S., Douglass, L.W., Gebhardt, S., Haytowitz, D., Schakel, S. 1999. Carotenoid content of US foods: An update of the database. Journal of Food Composition and Analysis. 12:169-196.

[75] Paolini, M., Abdel-Rahman, S.Z, Sapone, A., Pedulli, G.F., Perocco, P., Cantelli-Forte, M.S. 2003. β-carotene: a cancer preventative agent or a co-carcinogen? Reviews in Mutation research. 543:195-200.

[76] Fanning, K.J., Martin, I., Wong, L., Keating, V., Pun, S., O'Hare, T. 2009. Screening sweetcorn for enhanced zeaxanthin concentration. Journal of the science of Food and Agriculture. 90:91-96.

[77] Moeller, S.M., Jacques, P.F., Blumberg, J.B. 2000. The potential role of dietary xanthophylls in cataract and age-related macular degeneration. Journal of the American college of Nutrition. 19:522s-527s.

Anthocyanins are the red and purple pigments found in purple carrots, purple cabbage, eggplant skin and 'jacaranda' cauliflower. Studies have suggested that anthocyanins may be useful in obesity control, diabetes control, cardiovascular disease prevention, and improvement of visual and brain functions.

Table 44 - Types of carotenoids in selected vegetables

Vegetable	Major carotenoids
Peas, capsicum (red), collard greens, chard (swiss), sweet potato, pumpkin, carrots (standard), carrots (A+ cultivar)	β-carotene
Sweetcorn	zeaxanthin
Beans, broccoli, cos lettuce, spinach, kale	lutein
Carrots (black)	anthocyanin

8.5.5 *Betalains*

Betalains are coloured pigments almost exclusively found in plants from the Caryophyllales. They are responsible for the yellow and red colours of beetroot, swiss chard and prickly pear fruit. Betalains are potent antioxidants, with some evidence that they have anticarcinogenic properties. Like anthocyanins, they are water soluble, stable during processing, and concentrated in the most strongly coloured parts of the vegetable such as the skin and stem.

8.5.6 *Potential benefits to vegetable growers*

Processing vegetables to extract compounds potentially beneficial to human health would appear to have a number of particular advantages;

- Some compounds of interest are found most abundantly in peel, stems and leaves, parts of the vegetable that are discarded during trimming and processing. For example carrot peel can contain 20mg/100g β-carotene, nearly twice that of the core[78].
- New varieties of vegetables have been developed in the last few years which have enhanced concentrations of polyphenols, anthocyanins, zeaxanthin and betalains While these have been primarily developed for the fresh market, many would also be suitable for processing.
- Extraction of bio-active compounds would require a regular supply of raw materials; while this would reduce the potential for ad-hoc supply of excess / rejected materials, this could provide a steady income stream for suitable products.
- Bio-active extraction could be combined with other processing. For example, beetroot and carrot pomace left over from juice production are still high in

[78] Chantaro, P., Devahastin, S., Chiewchan, N. 2008. Production of antioxidant high dietary fibre powder from carrot peels. LWT Food Science and Technology 41: 1987-1994.

antioxidants. Carrot pomace was found to contain 4.0mg/100g carotenoids, and could readily be turned into processed carotenoid powder. Beetroot pomace contained 14.4mg/100g betalains[79]

8.5.7 ***Economic viability***

At this time, it seems unlikely that it is economically viable to extract bio-active compounds from vegetables. Supply of bio-active compounds takes place in an International marketplace. Many are sourced from countries such as China or India, where they may be manufactured by industrial means or extracted from non-food sources. For example;

- Zeaxanthin (potentially sourced from improved varieties of sweet corn) is extracted from marigold petals grown in India.
- β-carotene (rich in carrots) is extracted from seaweed.
- Resveratrol is now more commonly extracted from Japanese knotweed (a 'weed' species) than grape skins
- Vitamins generally are commonly manufactured in laboratories, not extracted from natural sources

Prices for whole vegetable powders and concentrates range from $15 - $25 kg depending on quality. For examples, current quoted prices for products sourced from China include;

- Carrot extract powder - $15/kg
- Celery extract powder - $19/kg
- Broccoli extract powder - $17.50/kg

Given that most vegetables are 85 - 95% water, this suggests a gross return of $1.50 - $2.50 / kg. For this to be viable there would have to be access to inexpensive power and facilities for macerating, drying then grinding the vegetables.

Sources of bioactive compounds such as seaweed and knotweed can also have the advantage that moisture contents are generally lower than vegetables, so less bulk of material needs to be processed. In addition, the technology to manufacture these products has been developed in Europe for more than 30 years, so Australia is both technologically behind and potentially more expensive.

However, there is a growing market for whole plant extracts for use in different foods. These are based on the idea that it is the combination of different bio-active compounds found in many plants which give them their important properties for enhancing human health. Vegetable powders are already used in the manufacture of such products. For example, celery powder is already used in a range of different products, while capsicum

[79] Shyamala, B.N., Jamuna, P. 2010. Nutritional content and antioxidant properties of pulp waste from Daucus carota and Beta vulgaris. Malaysian Journal of Nutrition. 16:397-408.

powder is an ingredient in “Melt”, a weight loss product by Blooms Health Products. Although China already manufacturers a range of vegetable powders, in this case, Australia’s reputation as a “clean, green” supplier with control over the content of bio-active compounds can be used to advantage. This would essentially creating a point of difference with product sourced from other countries[80] .

In summary, this is an area which is continuing to develop. While opportunities may be currently limited, they are likely to develop over time. Moreover, plant extracts developed for other purposes – such as dietary fibre – which also contain bio-active compounds, are likely to find ready use in manufactured ‘nutraceutical’ products.

[80] G. Pereira, Blackmores Ltd., pers. com

8.6 Extraction of volatile compounds and food flavours

8.6.1 *What is the product?*

Aromatic compounds can be used as natural flavourings in the food processing industry. Products that are commonly processed include herbs, fruit peels and coffee. However, vegetable wastes and whole vegetables that are high in aromatic compounds are also excellent candidates for this process.

Natural flavours and essences can be extracted from fruit and vegetables using a new technique known as spinning cone column (SCC) technology. The SCC uses mechanical forces to increase contact between different material phases. This allows efficient and rapid separation of volatile compounds from their host material. The method can be used to process clear liquids, viscous products or slurries containing high levels of suspended solids.

Applications in the food and beverage industry include:

- Essential oil extraction from botanicals, herbs and spices.
- Aroma recovery during production of fruit and vegetable purees and juices.
- De-oiling of NFC (not from concentrate) citrus juice.
- Aroma recovery during soluble coffee production.
- Simultaneous flavour and soluble solids extraction from coffee and tea slurries.
- Dealcoholisation and alcohol management in wine, beer and other alcoholic beverages.
- De-odourising of cream and flavour management of other dairy products.

A spinning cone column

Products potentially developed from vegetables would need to be assessed in terms of their potential use as flavours and functional food components. This includes the potential to use enzymatic treatments to improve quality in terms of the release of aroma/flavour from glycosidic precursors.

8.6.2 *Potential benefits to vegetable growers*

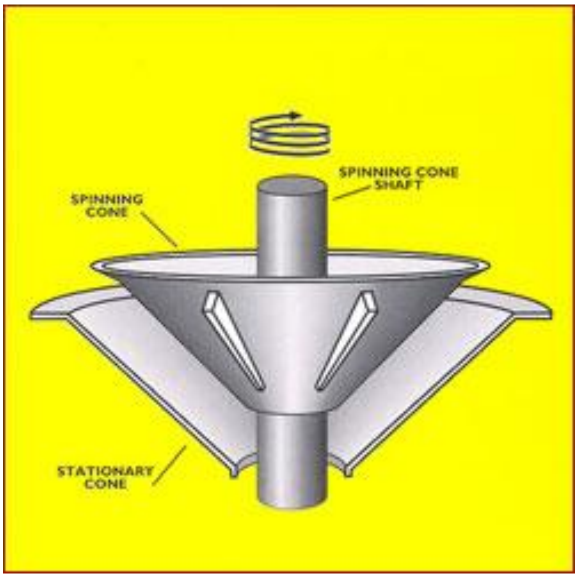
Spinning cone column technology has been used successfully in HAL project (RB10004 New Products from Tasmanian Blackcurrant and Raspberry Fruit) for the extraction of volatile flavour components from raspberry and blackcurrant fruit juice to produce commercially attractive, value added aroma products.

There is potential to extract volatiles from vegetables naturally high in these compounds. Vegetables with significant promise include:

- Celery
- Parsley and other herbs
- Capsicums
- Chillies
- Shallots
- Leeks
- Onion and garlic

8.6.3 *Materials and equipment required*

A spinning cone column (SCC) continuously recovers volatile compounds from a liquid stream using a carrier gas. It consists of several static and rotary cones, one placed over the other inside a column. The static cones are fixed to the column wall and the spinning cones are fixed to a rotary shaft. Liquid falls under gravity to form a thin film over the static cones. It then drops onto the base of a spinning cone and rises up its surface due to centrifugal force to fall again over the next static cone. This process repeats as the liquid descends, until it reaches the base of the SCC[81]. A cut-away diagram of a single cone set is shown in Figure 28.



[81] M.F. Graber et al. (2012) Spinning cone column isolation of rosemary essential oil. Food Control 21: 615–619

Figure 28 A cut-away diagram of a single cone set [82]

The feed material, from which the volatile compounds are to be removed, is fed into the top of the column. This material, either liquid or slurry, flows as a thin film down the upper surface of the first stationary cone. It then drains through the outlet of the stationary cone on to the base of the spinning cone immediately below. Centrifugal force, generated by the rotation of the cone, causes the liquid to flow upwards and outwards across the upper surface of the spinning cone, again as a thin film.

This film breaks up as it is thrown from the lip of the spinning cone; the liquid is then deflected downwards on to the next stationary cone, and the cycle is repeated. In this manner, the liquid works its way, cone by cone, from top to bottom of the column.

At the same time as liquid is flowing down the column, stripping steam is introduced into the base of the column. The vapour flows upwards, across the surfaces of the volatile-rich liquid films, separating and removing the volatile compounds from the liquid. Fins on the undersides of the rotating cones promote turbulence in the vapour stream, increasing mass transfer efficiencies. Figure 29 illustrates the flow of liquid and vapour through the column.

The vapour flows out of the top of the column and passes through a condensing system which captures the volatiles in a concentrated form. The remaining liquid or slurry is pumped out of the bottom of the column.

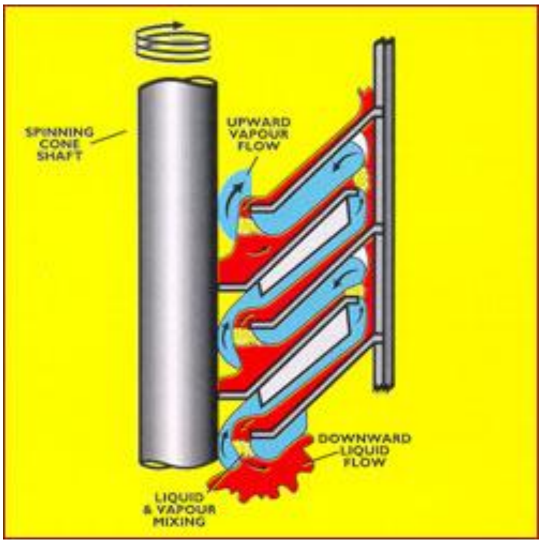


Figure 29 Flow of liquid and vapour through the column[83]

[82] Flavourtech Pty Ltd
[83] Flavourtech Pty Ltd

8.6.4 *Economic viability*

The economic viability of using SCC technology or perhaps even other process extraction methods would need to be assessed. There is expertise available in Australia; the company Flavourtech located in Griffith NSW specialises in providing innovative processing solutions to the Food & Beverage and Pharmaceutical industries.

The concentrates produced are high-value products that are in demand by the food processing industry.

8.7 Dietary fibre from vegetables

8.7.1 *What is the product?*

Dietary fibre (DF) is defined as "the remnants of plant cells resistant to hydrolysis (digestion) by the alimentary enzymes of man"[84]. DF is classified as either soluble or insoluble according to how readily it can be extracted from the plant cells. While both forms of DF resist digestion, once they enter the large intestine they may be partially broken down by gut bacteria.

The beneficial effects of fibre to human health have been known as far back as Hippocrates in 400BC. Diets rich in DF have been associated with reduced rates of cancer (especially colon cancer), cardiovascular disease, constipation, irritable colon and diabetes. DF promotes satiety, so is a useful part of weight loss programs. While part of their effects come from bulking faeces and moving food faster through the digestive system, they have also been shown to absorb carcinogens and may increase the effects of anti-oxidants. Soluble fibre can also decrease cholesterol and reduce glucose absorption[85].

In addition to its effects on human health, DF is a useful ingredient in many processed foods. Among other purposes, it is used as a calorie free-bulking agent, to increase moisture content, to add structure to foods or improve stability, as a fat replacer and as a gelling agent.

Many modern diets are often deficient in dietary fibre. The average recommended intakes of DF are 25g/day for women and 30g/day for men, approximately 25% of which should be soluble fibre[86]. However, Britons consume only 10-12g while most Americans also ingest only half the recommended amount. Many young people may consume as little as 20% of the recommended intake[87] As a result, there is great interest in fortifying foods with additional DF. The Australian Food Standards Code allows the following claims with regard to dietary fibre;

"*A good source of dietary fibre*"	Contains at least 4g DF per serving
"*An excellent source of dietary fibre*"	Contains at least 7g DF per serving
"*Contains increased dietary fibre*"	Contains at least 25% more DF than a reference food, which itself contains at least 2g DF per serving

[84] Trowell, H.C. 1974. Definitions of fibre. Lancet 1:503
[85] Rodriguez, R., Jimenez, A., Fernandez-Bolanos, J., Guillen, R., Heredia, A. 2006. Dietary fibre from vegetable products as a source of functional ingredients. Trends in Food Science and Technology. 17:3-15.
[86] Elleuch, M., Bedigan, D., Roiseux, O., Basbes, S., Blecker, C., Attia, H. 2011. Dietary fibre and fibre-rich by-products of food processing; Characterization, technological functionality and commercial applications: a review. Food Chemistry 124:411-421.
[87] Suter, P.M. 2005. Carbohydrates and dietary fiber. Handbook of Experimental Pharmacology 170: 231–261.

In 2011 the global demand for DF reached 96,400 t with a total value of $1,440 million. This is expected to increase to 216,000 t by 2017, a corrected annual growth approaching 14%. The market is dominated by North America, which accounts for 36% of this demand, followed by Europe (31%) and the Asia Pacific (17%). China and India are emerging as increasingly important markets for DF products. While the overall demand for DF is growing, the supplement market is increasingly seeking soluble (rather than insoluble) fibres, particularly those from alternate sources[88]. Depending on their characteristics and suitability for processing applications, soluble fibre can be worth 2 – 3 times more than insoluble fibre. The soluble fibre market, driven by Asian based pharmaceutical companies, is expected to exceed that for insoluble fibre within the near future[88].

There is good evidence that the market for natural DF remains strong. An Australian Company “Kfibre” recently opened a plant in Ayr, Queensland producing insoluble DF from sugar cane. A key point of difference for this product is that it is totally natural, whereas wheat fibre is chemically modified to enable extraction. The company currently sells the product for $4.50/kg wholesale and claims a 39% return on investment[89].

8.7.2 ***Potential benefits to vegetable growers***

As public understanding of the health benefits of DF has increased, so has demand for natural sources with healthy properties. Many vegetables are high in DF, containing levels similar to those found in pulses such as lentils and kidney beans and even that in cereals[90](Table 45).

[88] Dietary Fiber Market by Product Type (Conventional/ Novel & Soluble/ Insoluble) and Application (Food & Pharmaceuticals) – Global Trends & Forecasts up to 2017. Marketsandmarkets.com, published October 2012. Report FB1318.
[89] www.burdekin.qld.gov.au. Industry update – KFSU presentation. Accessed 27/4/2012.
[90] Anderson, J.W., Bridges, S.R. 1988. Dietary fiber content of selected foods. American Journal of Clinical Nutrition 47:440-447.

Table 45 - Total dietary fibre in vegetables compared to that in selected pulses and cereals

	Total DF (g/100g dry weight)
Vegetables	
Beans	34
Beetroot	24
Broccoli	30
Brussels sprouts	27
Cabbage	23
Carrots	24
Cauliflower	27
Sweetcorn	9
Kale	33
Lettuce	21
Peas	21
Sweet potato	7
Spinach	29
Squash	20
Pulses	
Kidney beans (canned)	21
Lentils (dried, cooked)	16
White beans (dried, cooked)	18
Cereals	
All-Bran (Kellogg Co.)	32
Rolled oats	10
Whole wheat bread	9

Crop residues and product trimmings can also be high in DF. For example, corn cores contain around 15-20% dietary fibre. Fibre extracted from some vegetable waste sources can have additional advantages due to their content of other bio-active compounds;

- The discarded outer leaves of cabbage normally left in the field are not only extremely high in DF but also contain sulforafane, a sulfur compound which may have many potential benefits in the body. Sulforafane is retained when blanched leaves were dried and processed into DF powder[91]. Adding this DF powder to prepared foods such as cookies can increase not only their fibre content, but also their overall nutritional profile, without negatively affecting flavor or texture[92]
- Carrot pomace left after juicing is naturally high in carotenoids including β-carotene, lycopene (red carrots) and anthocyanins (purple carrots). Fibre extracted from this

[91] Tanongkankit, Y., Chiewchan, N., Devahastin, S. 2011. Evolution of anticarcinogenic substance in dietary fibre powder from cabbage outer leaves during drying. Food Chemistry 127: 67-73
[92] Naik, P., Narayana, C.K. 2012. Preparation of nutrient rich fortified biscuit by incorporation of residual cabbage leaf powder. Plant Archives. 12:795-799.

source is ideal for many food-processing applications due its textural and structural qualities[93].

- Cauliflower stems and leaf bases are higher in DF than the florets, containing around 3% DF by fresh weight. They also contain a range of flavanols, glucosinolates and other anti-oxidants. Combined with cauliflowers' pale colour and mild flavor, its high nutritional content appears to make it ideal as a functional food ingredient. Cauliflower flour can be added to snack foods to increase nutritional value without affecting taste[94]

Most of the fibre products currently on the market are derived from cereal crops such as oats, wheat and maize. Not only are bulk quantities of these products available cheaply, but the DF is extracted from what is effectively waste. However, most DF extracted from these sources is celluloses and hemicelluloses - insoluble fibre – mainly useful for increasing the rate at which food passes through the digestive system.

Fruit and vegetables, in contrast, contain more soluble fibres such as pectins. These lower blood glucose and affect metabolism of fats[95], making them the most valuable type of DF for food fortification. Carrot pomace contains 63% DF, or which 13.5% is soluble fibre[96]. Other good sources of soluble fibre include beetroot, beans and bitter melon, which contain 2.4g, 2.1g and 3.1g soluble fibre per 100g portion (fresh weight) respectively. In the case of beetroot, this means that 31% of its DF content is soluble[97]. In comparison, many grains and cereals contain almost no soluble DF.

8.7.3 *Materials and equipment required*

In general, the process to extract dietary fibre from plant materials is relatively simple and inexpensive. However, more complex methods may be required if it is important to preserve particular phytochemicals or to extract both soluble and insoluble DF. Adding specific enzyme preparations under controlled pH and temperature can maximize recovery of soluble fibre. For example, recovery of soluble fibre from apple pomace was maximized

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[93] O'Shea, N., Arendt, E. K., Gallagher, E. 2012. Dietary fibre and phytochemical characteristics of fruit and vegetable by-products and their recent applications as novel ingredients in food products. Innovative Food Science & Emerging Technologies 16:1-10.

[94] Stojceska, V., Ainsworth, P., Plunkett, A., Ibanoglu, E., Ibanoglu, S. 2008. Cauliflower by-products as a new source of dietary fibre, antioxidants and proteins in cereal based ready-to-eat expanded snacks Journal of Food Engineering, 87:554–563

[95] Gorecka, D., Pacholek, B., Dziedzic, K., Gorecka, M. 2010. Rasberry pomace as a potential fiber source for cookies enrichment. Acta Scientaria Polonarium. 9:451-462.

[96] Chau, C.F., Chen, C.H., Lee, M.H. 2004. Comparison of the characteristics, functional properties, and in vitro hypoglycemic effects of various carrot insoluble fiber-rich fractions. LWT- Food Science and Technology, 37:155–160

[97] www.dietaryfiberfood.com, accessed 27/4/2013

using Celluclast enzymes at 45^{o}C with pH 4[98]. Insoluble fibre is essentially the cell wall materials left after other processes, so is primarily the material left after other processes.

An example of possible process flow is shown below.

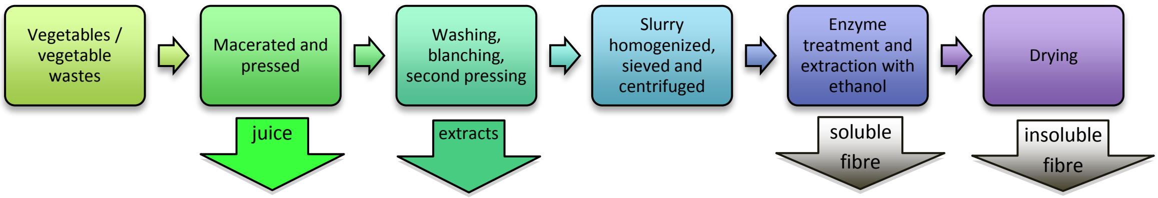

Figure 30 - Example of process used to extract DF from vegetables or vegetable waste products.

8.7.4 ***Economic viability***

Simplot recently conducted a study on the feasibility of extracting DF from corn cores. In this case, they only aimed to recover insoluble DF so the process was relatively simple. Corn cores contain around 23% solid materials, most of which (15% by fresh weight) is DF. Total corn core waste was 9,000 t, but this is produced over only 4 months. Assuming a recovery rate of 12%, 9,000 t of corn cores should yield 1,080 t of fibre material. Based on capital costs and sale prices for DF at the time, it was conservatively estimated that the project would be cash positive after 3 – 4 years operation (Table 46).

Clearly the economics would be different for each crop. If beetroot wastes were used as feedstock, their total DF content of 7.7g/100g fresh weight would be split between soluble and insoluble fibre production. Although costs of recovering the soluble fraction are likely to be higher, they are worth significantly more on the International market. Moreover, they would likely contain betalains, a potent (soluble) antioxidant. This could further enhance their market value as an additive to functional foods.

[98] Bibbins-Martinez, M.D., Enciso-Chavez, B., Galicia, S.B.N., Hernandez, D.C. 2011. Soluble dietary fiber generation from apple pomace. International Congress on Engineering and Food. May 22-26 2011 Athens, Greece.

Table 46 - Indicative economics for processing corn core waste to produce DF. Data from Simplot study[99]

Indicative economics for processing corn core waste		
Capital costs		
Total equipment budget		$1,800,000
Installation, engineering and electrical costs		$810,000
Contingency budget		$360,000
	total	***$2,970,000***
Operating costs		
Labour		$220,000
Drying and power		$210,000
Overheads, maintenance and lab analysis		$56,000
Packaging and sales		$100,000
	total	***$586,000***
Income		
Total corn fibre produced		1,080 t
Total value (@$1.85/kg)		$1,998,000
Gross return assuming ~ 80% of product sold		$1,598,400
Annual profit		$1,012,400
	Break even point	***Approx. 3-4 years***

There would appear to be opportunities to use a range of different vegetable wastes to produce soluble and insoluble DF. Production would be most likely to be economically viable if materials can be accessed year round and processed using a single set of equipment. Materials such as cauliflower and broccoli stems, cabbage leaves, beetroot trimmings, carrots, spinach and kale would all be suitable for this process if sufficient quantities of raw materials can be combined at one location.

[99] Heap, M. 2008. Innovative approaches to adding value to vegetable waste – Phase II. HAL final Report MT06053.

8.8 Other specialist vegetable opportunities

In general, the vegetables with the least waste are those for which there are multiple different uses, and where these different uses have been anticipated and planned for. Lettuce provides an example where careful crop scheduling, predicting market demand, and vertical integration with fresh cut product manufacturing have reduced wastage to as little as 5% for some grower / processors.

Achieving such low levels of waste assumes a positive growing environment, high level of understanding of both the crop and its markets, and a range of strategies to deal with different outcomes; not just a Plan B, but a Plan C and even Plan D!

In a comprehensive review of transforming vegetable waste into value-added products, Laufenberg, and Kunz Nystroem[100] concluded that there were three types of practical value-adding opportunities with a high likelihood of economic and practical success:

1. Upgrading of vegetable residues for the production of novel types of products: multifunctional food ingredients in fruit juice and bakery goods.
2. Bioconversion via solid-state fermentation: vegetable residues as an exclusive substrate for the generation of fruity food flavours.
3. Conversion of vegetable residues into operating supplies: bio adsorbents for waste water treatment.

In this part of the report we present a number of case studies, actual and theoretical, of vegetables where the whole crop can be utilized, in some way, to generate income.

8.8.1 *Carrots for additives to fruit juice and bakery*

There are a number of interesting alternative uses for carrots. Pomace is the term given to the pulpy residue which remains after a product has been crushed for juicing or the extraction of some other material. There are several interesting uses for carrots and carrot pomace.

- Additive to bread for increasing fibre and nutritional value[101]
- Addition to beverages to improve stability[102]

[100] G. Laufenberg et al. (2002) Transformation of vegetable waste into value added products: (A) the upgrading concept; (B) practical implementations. Bioresource Technology 87 (2003) 167–198.
[101] Filipini, M., Hogg, T., 1997. Upgrading of vegetable wastes and applications in the food industry. In: 11 Forum for Applied Biotechnology. Gent (Belgium). 25–26 September 1997. Mededelingen-Faculteit-Landbouwkundige-en-Toegepaste-Biologische- Wetenschappen-Universiteit-Gent (Belgium). 62(4a) pp. 1329–1331.
[102] Henn, T., Kunz, B., 1996. Zum Wegwerfen zu schade. ZFL 47 (1/2), 21–23.

- Activity as a biocontrol agent for the control of the soil-borne disease *Fusarium oxysporum* in melons, especially in conjunction with citrus pomace[103]
- Carrot reside added to hens diet to enhance egg size and production[104]

8.8.2 ***Industrial uses of corn cobs***

8.8.2.1 Activated charcoal from corn cobs[105]

A series of activated carbons were prepared by burning corn cobs in the absence of oxygen (pyrolysis) in conjunction with chemical activation by zinc chloride ($ZnCl_2$). The effect of process variables such as temperature, soaking time and $ZnCl_2$/corn cob ratio (impregnation ratio) of the production of adsorbent were examined.

The most important parameter in the chemical activation of corn cob with $ZnCl_2$ was found to be the impregnation ratio. The percentage of micropores decreased at higher impregnation ratios. The pyrolysis (or activation) temperature is another important variable, which had a significant effect on the pore surface area evolution. Under the experimental conditions, 500^{o}C was the optimal temperature for producing high surface area carbons with $ZnCl_2$ activation. The study showed that the $ZnCl_2$ activation of corn cob was suitable for the preparation of microporous activated carbons.

8.8.2.2 Bio adsorbents for wastewater treatment from corn cobs and onions skins[106], [107], [108]

These studies converted corncobs to metal ion adsorbents for wastewater treatment. Ground corncobs were modified with either 0.6 M citric acid (CA) or 1.0 M phosphoric acid (PA) to help improve their natural adsorption capacity.

The effect of a combination of wash and modification treatment was tested for corncob adsorption efficiency with five different metal ions (cadmium, copper, lead, nickel, zinc) individually or in a mixed solution containing each metal at a 20 mM concentration. Results were compared to those of commercial resins Amberlite IRC-718, Amberlite 200, Duolite GT-73 and carboxymethylcellulose (CMC). Modified corncobs showed the same adsorption

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[103] Mukherjee, K., Sen, B., 1998. Biological control of Fusarium wilt of muskmelon by formulations of Aspergillus niger. Israel Journal of Plant Sciences 46 (1), 67–72.
[104] Zia-ur-Rehman, Ali, S., Khan, A.D., Shah, F.H., 1994. Utilisation of fruit and vegetable wastes in layers diet. Journal of Science in Food Agriculture 65 (4), 381–383.
[105] Tsai, W.T., Chang, C.Y., Lee, S.L., 1998. A low cost adsorbent from agricultural waste corn cob by zinc chloride activation. Bioresource Technology 64, 211–217.
[106] Hawthorne Costa, E.T. et al., 1995. Removal of cupric ions from aqueous solutions by contact with corncobs. Separation Science and Technology 30 (12), 2593–2602
[107] Odozi, T., Emelike, R., 1985. The sorption of heavy metals with corncob hydroxylate-red onion skin resins. Journal of Applied Polymer Science 30, 2715–2719.
[108] Vaughan T, Seo CW, Marshall WE. (2001) Removal of selected metal ions from aqueous solution using modified corncobs. Bioresour Technol. 78(2):133-9.

efficiency as Duolite GT-73 for cadmium, copper, nickel and zinc ions and had greater adsorption than CMC for nickel and zinc ions.

For mixed metals, the modified corncobs exhibited the same adsorption efficiency as Duolite GT-73 for cadmium and copper ions and the same or higher adsorption than Amberlite IRC-718 for lead ions. Adsorption capacities of modified samples were compared to those of Amberlite IRC-718, Amberlite 200 and Duolite GT-73. Commercial resins generally had higher adsorption capacities than modified corncobs. However, the adsorption capacity of modified corncobs for copper and lead ions was equivalent to Duolite GT-73, but was lower than for Amberlite IRC-718 or Amberlite 200. Depending on the specific metal ion and the presence or absence of other metal ions, chemically modified corncobs were at least equivalent in adsorption properties to all of the commercial cation exchange resins examined in this study.

8.8.3 *Onions and Garlic for onion oil flavour*[109]

The technology allows for the recovery of will be used to recover valuable organic solutes, such as flavour and fragrance chemicals, from aqueous waste streams. Onion flavour was recovered from an aqueous waste stream generated during the production of onion oil. The technical and economic feasibility of the process was demonstrated and it relies on selective partitioning of flavour components from the aqueous waste into a food-grade oil. The researchers also demonstrated that onion-flavour can be recovered at high concentrations in the product oil and that the overall production costs are very low, about 1% of the oil's selling price. Refer to the spinning cone technology which may also be suitable for extracting these volatile oils from alliums such as leeks, shallots and green onions (8.6).

8.8.4 *Alternative uses of black carrots*

At an estimated 93 kt annually, more carrots are wasted than any of the other vegetables studied. However, carrots have many qualities that make them ideally suited to other uses. Fresh carrots can be processed into a range of products including shred, pickled, ‘baby’, fresh cut and ‘microwave ready’. They can be turned into a highly nutritious and healthy juice. Different varieties are rich in natural anti-oxidants such as β-carotene, lycopene and anthocyanins. Carrots contain high levels of dietary fibre, including high value soluble dietary fibre. They are extremely suitable for processing into animal food. Alternatively, carrots are a suitable food source for insects, which can in turn be used as a high quality, high protein food for cattle, poultry or fish.

[109] Brose, D.J., 1993. Novel process technology for utilisation of fruit and vegetable waste. SBIR Phase I project USDA ICSRS, Washington, DC.

A recent Horticulture Australia project (VG06145) defined the production methods necessary for growing purple carrots. These varieties are rich in anthocyanins, a potent anti-oxidant associated with a wide range of benefits for human health. Substituting black carrots for standard orange carrots could both produce the range of different products noted above, while also adding significant additional value to these products (Figure 31).

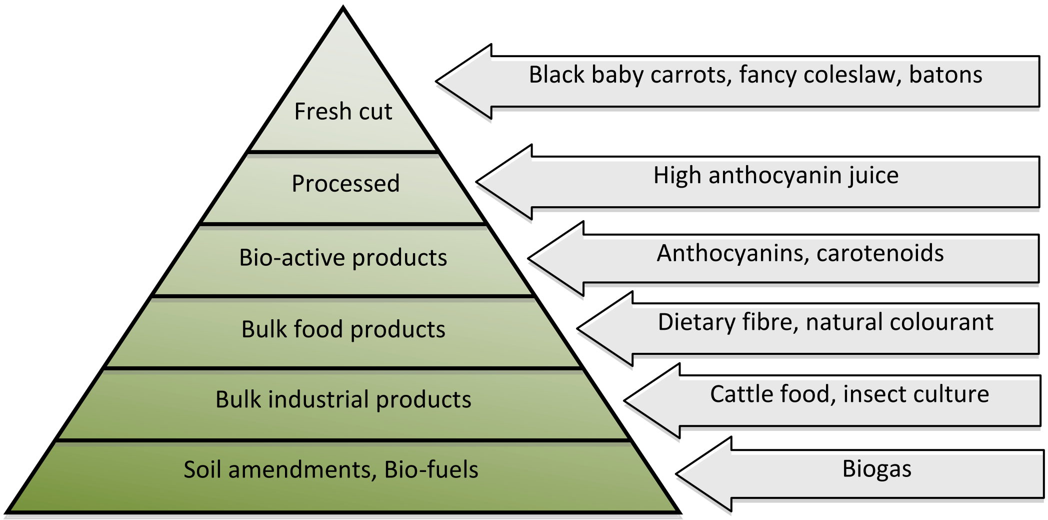

Figure 31 - The hierarchy of uses for waste, as applied to purple carrots.

Black carrot juice is a product with great market potential. The juice can be extracted, concentrated and can be sold in bulk domestically or to export markets in the same way as high β-carotene varieties. However, there is strong evidence for additional nutritional benefits from black carrot juice specifically due its potential anti-carcinogenic effects[110]

There is wide interest in incorporating natural anthocyanins, such as those found in black carrots, in a range of different food and drink products. However, there are a number of issues with these pigments. One is that they reversibly change their molecular structure as the pH of solutions changes from acidic to basic. This change in structure results in a colour shift from red to purple to blue as the pH changes from acidic to basic. Another issue is that the high concentrations of other phenolics found in grape skin – the major source of natural anthocyanins – can cause hazing and precipitation when added to other fruit juices.

Anthocyanins from black carrots are more stable over a wider pH range than anthocyanins from other sources. They can provide an excellent bright strawberry red shade at acidic pH values, making them an ideal choice for colouring fruit juices, soft drinks, conserves, jellies,

[110] Netzel, M, Netzel, G., Kammerer, D.R., Schieber, A., Carle, R., Simons, L., Bitsch, I., Bitsch, R., Konczak, I. 2006. Cancer cell antiproliferation activity and metabolism of black carrot anthocyanins. Innovative Food Science and Emerging Technologies. 8:365-372.

confectionery and low pH foods such as yoghurt and dairy products[111]. They also contain only low levels of the phenolics that can cause issues with juice clarity and, as a natural colourant, do not to be declared with an E-number on the food label.

Dietary fibre derived from black carrots containing both soluble and insoluble fibre and anthocyanins would be a valuable addition to many manufactured products. As fibre could be extracted using the pomace left over fruit juice production, this would provide an additional use for the same crop.

Any remaining carrots could also be used in animal feeds, particularly those developed for the high value companion animal market. The addition of colour as well as fibre, starch and natural sugars would make them an ideal high quality ingredient in feed pellets.

[111] Kirca, A., Ozkan, M., Cemerog, B. 2006. Stability of black carrot anthocyanins in various fruit juices and nectars. Food Chemistry 97:598-605.

8.9 Biochar from crop waste

8.9.1 *What is the product?*

Biochar is a type of charcoal produced by heating organic materials (feedstock) in an oxygen-limited environment. Once the process has been initiated, biochar production generates energy, which can be used directly as heat or turned into electricity (Figure 32). It can also produce bio-oil, which can be used directly in suitable boilers or furnaces, or processed further to make bio-diesel.

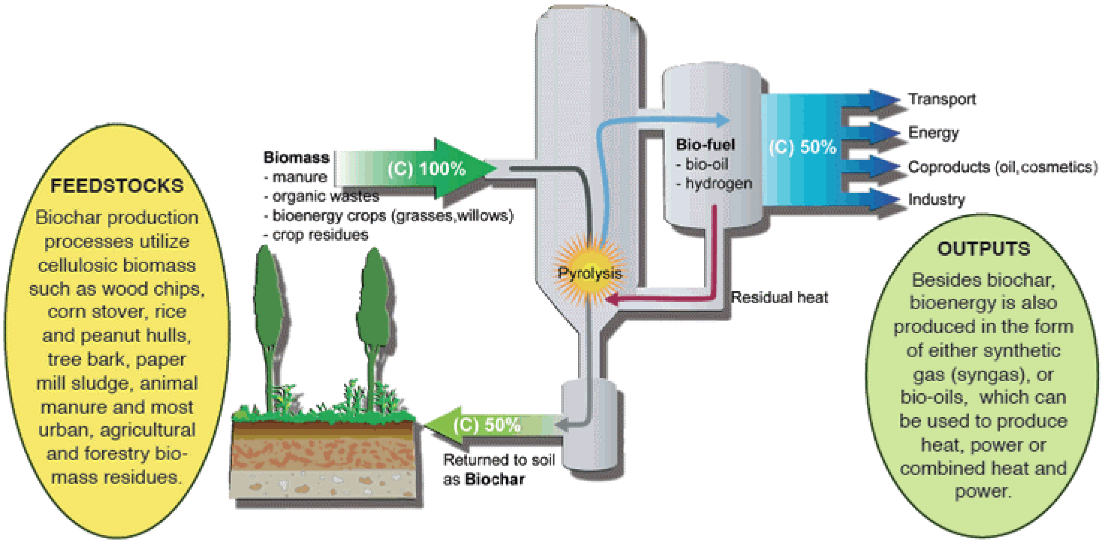

Figure 32- A conceptual model of biochar production [112]

The characteristics of biochar vary according to the feedstock used. However, it is generally biologically and chemically stable. Farmers who permanently store carbon on their land (minimum 100 years) can earn saleable carbon credits under the government initiated Carbon Farming Initiative (CFI). Although application of biochar to soils is on the CFI positive list, suggesting it is an eligible way to earn carbon credits, there is no approved method for assessing carbon sequestration through this method. As a result it is not yet eligible under the scheme, but may become so in the future.

8.9.2 *Potential benefits to vegetable growers*

The immediate return from biochar production is the generation of electricity and / or bio-oil. The power generated could be used on-site or returned to the grid as “green energy”. These benefits of can be summarized as;

[112] International Biochar Initiative 2012. www.biochar-international.org. Accessed 11/4/2013

- Waste management; mass and volume of organics, and therefore haulage costs, are reduced
- Energy security; energy needs met using local materials
- Minimising / avoiding environmental 'rents'; potential carbon credit offsets, reduced fertilizer run-off and leaching,
- Corporate 'green image'; reduced environmental footprint, sustainability

For vegetable growers, some of the major benefits from biochar may be long term. Application of biochar to soil can have a range of benefits, including

- Increased response to applied fertilisers
- Improved soil moisture retention
- Increased crop yields
- Reduced greenhouse gas (methane, nitrous oxide) emissions
- Improved soil structure and biodiversity

The potential costs and benefits of application of biochar are reviewed in "Biochar in Horticulture: Prospects for the use of biochar in Australian horticulture"[113] (Cox *et al*., 2012). In general, comparatively little has been published in the peer-reviewed literature on the use of biochar on commercial vegetable crops. However, some results include;

- Application of up to 50t/ha biochar increased production of kang kong, wombok, buk choy and gai choy by 39, 100, 300 and 350% respectively. It also increased protein content and decreased crude fibre in the vegetables [114]
- Amending soils used for vegetable production in Bundaberg with 25t/ha green waste biochar reduced subsequent nutrient leaching, increased soil water holding capacity and improved soil carbon. Seedling weights were 31-32% higher in 25t/ha biochar treated soil[115].
- Biochar produced from pine forest waste increased romaine lettuce weight when applied as 2% but reduced growth applied at 4% vol:vol in pots. The biochar also reduced microbial activity, possibly due to toxic compounds in the pine forest waste biochar[116].

[113] Cox, J., Downie, A., Jenkins, A., Hickey, M., Lines-Kelly, R., McClintock, A., Powell, J., Pal Singh, B., van Zwieten, L. 2012. Biochar in horticulture: Prospects for the use of biochar in Australian horticulture. HAL Final Report AH11006, available online at www.dpi.nsw.gov.au

[114] Ty, C., Sina, V., Borin, K., Preston, T.R. 2013. Effect of different levels of biochar on the yield and nutritive value of celery cabbage (*Brassica chinensis* var), Chinese cabbage (*Brassica pekinensis*), mustard green (*Brassica juncea*) and water spinach (*Ipomoea aquatica*). Livestock Research for Rural Development. 25:1 8p.

[115] Pudasaini, K., Ashwath, N., Walsh, K., Bhattarai, T. 2012. Biochar improves plant growth and reduces nutrient leaching in red clay loam and sandy loam. Hydro Nepal: Journal of Water, Energy and Environment 2012 special issue:86-90.

[116] Artiola, J.F., Rasmussen, C., Freitas, R. 2012. Effects of a biochar amended alkaline soil on the growth of romaine lettuce and bermudagrass. Soil Science. 177:561-570.

- Production of choy sum (*Brassica rapa* var. *Chinensis*) and en choy (*Amaranthus mangostanus*) was increased by up to 48% by incorporating biochar produced from corn waste at 20-40t/ha. In the presence of fertilisers, biochar increased productivity while reducing N_2O and CH_4 emissions[117].
- Lettuces grown in chromium polluted soil were significantly less contaminated when soil was amended with up to 10t/ha biochar produced from corn waste[118]
- Low mineral ash biochar applied at 0-11% vol:vol in pots increased biomass of radishes grown with low levels of nitrogen. It is suggested that it could be possible to reduce fertilizer applications by up to 90% in the presence of biochar and achieve similar crop productivity[119].

8.9.3 *Materials and equipment required*

Biochar has been successfully produced from a range of organic materials, including corn wastes (stalks from maize) and olive pomace. However, materials need to be chipped into small pieces before pyrolysis (approx. $1cm^3$), and need to be pre-dried to <25% moisture content for maximum effectiveness. As vegetables and plant materials are generally 70-95% moisture they would need to be dried and chipped before processing, which would significantly increase costs.

Production of biochar through pyrolysis is a relatively complex process, with heating rates, temperatures and gas fluxes all affecting the results. Dangerous gases can be released under some conditions, so production has to be tightly controlled. Small scale, mobile units are commercially available, although expensive. For example, Agri-Therm (part of the University of Western Ontario) has a laboratory scale pyrolysis system available which can process up to 18kg/hour of dry materials into bio-oil and biochar. The cost of the unit is approximately $250,000. They have also developed a new technology called the Mechanically fluidized reactor which can process up to 3t/day of dry biomass into bio-oil and biochar, or biochar only, for around $1 million.

Pacific Pyrolysis has a demonstration plant located at Somersby (north of Sydney) which can process 300kg/hour dry waste in order to power a 200kW electrical generator (Figure 33). The company is now developing a large plant for Ballina Shire Council which will generate 6,000 MWh energy from 29,000 tonnes of organic waste.

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[117] JunZiang, J. Bo, L., ZhaoZhi, C., ZuBin, X., ZhengQin, X. 2012. Effects of biochar application on vegetable production and emissions of N_2O and CH_4. Soil Science and Plant Nutrition. 58:503-509.
[118] Nigussie, A., Kissi, E., Misganaw, M., Ambaw, G. 2012. Effect of biochar application on soil properties and nutrient uptake of lettuces (Latuca sativa) grown in chromium polluted soils. American-Eurasian Journal of Agricultural & Environmental Sciences. 12:369-376.
[119] Van Zwieten, L., Kimber, S., Downie, A., Morris, S., Petty, S., Rust, J. Chan, K.Y. 2010. A glasshouse study on the interaction of low mineral ash biochar with nitrogen in a sandy soil. Soil Research. 48:569-576.

Figure 33 - Pacific Pyrolysis pilot plant at Somersby

8.9.4 *Economic viability*

A study by NSW DPI[113] analysed the potential economic benefits of biochar application to sweet corn and tomatoes. It was found that although fertilizer requirements were reduced, this cost was a relatively minor component of the total. In addition, the current carbon price was considered too low to provide a strong motivation for farmers to use biochar should it become eligible under the CFI. While the initial cost of biochar was also considered a significant deterrent to its use, this would not be the case if it was produced from crop wastes on the farm itself.

Biochar is most likely to be economically viable if it becomes eligible for carbon credits under the CFI, and the price of carbon increases. Viability would also be increased if sources of carbon such as timber wastes could be combined with vegetable wastes to produce the char.

8.10 Fish food from vegetable waste

8.10.1 ***What is the product?***

Consumption of fish and seafood in Australia has doubled in the last 10 years and currently stands at around 13kg per person year. This has been predicted to increase to 17kg by 2020 and 25kg per year by 2050, giving a total domestic requirement of 1.15kt annually. Given falling wild catches, aquaculture needs to double by 2020 and double again by 2050 to meet this demand [120].

In the period 1970–2008, the production of fish from aquaculture increased at an average annual rate of 8.3 percent. This is in comparison with poultry and livestock meat production at an average rate 2.7% per year (FAO 2010). Currently, about one third of aquaculture production consists of highly carnivourous fish e.g. salmon, sea breams, barramundi. If the aquaculture sector is to sustain its current growth rate, then the supply of production inputs will also have to grow at similar rate to meet demand.

One of the major factors restricting increased use of aquaculture is that most production systems rely on feeding high value aquaculture species on relatively low value wild caught fish. This is not sustainable in the long term, and has led to a search for alternative sources of high protein, high fat food sources. These have included cottonseed meal, legume crops such as lupins and soy, meat and bone meal and poultry wastes[121].

Plant-based fish food have problems with poor palatability, presence of anti-nutrients (e.g. phytic acid), intolerance to complex carbohydrates and deficiencies in essential amino acids. Animal-based foods are better but also have problems such as poor consumer acceptance, high levels of saturated fats, absence of omega 3 fatty acids and issues with food safety from rendered animal meal.

Insect-based protein meals offer an alternative to plant and animal-based fish food as ingredients in fish food for aquaculture. The main species that have been studied are:

- Yellow mealworm (*Tenebrio molitor*)
- Black soldier fly (*Hermetia illucens*)
- The super worm (*Zophobas morio*) (Figure 34).

Each of these insects has its own characteristics, but all can be reared wholly or partly on vegetable wastes such as carrots, green leaves, and plant stems[122].

[120] Kearney, B., Foran, B., Poldy, F., Lowe, D. 2003. Modelling Australia's fisheries to 2050: Policy and management implications. Fisheries Research and Development Corporation. Final report.
[121] Nguyen TN, Davis, D.A. 2009. Evaluation of alternative protein sources to replace fish meal in practical diets for juvenile Tilapia *Oreochromis spp*. Journal of the World Aquaculture Society. 40:114-121.
[122] Li, LY, Zhao, Z.R., Liu, H. 2012. Feasibility of feeding yellow mealworm (*Tenebrio molitor* L.) in bioregenerative life support systems as a source of animal protein for humans. Acta Astronautica. In Press.

Figure 34 - yellow mealworm (l), superworm (c) and black soldier fly (r) larvae

Importantly, all three species have a high reproduction rate; *T. molitor* reaches adulthood in 10 weeks and can lay up to 160 eggs, while *Z. morio* takes 15 weeks to mature but can then lay 1,500 eggs[123]. Adult black soldier flies lay around 900 eggs during her short adult life of only 5-8 days. The eggs take around 4-5 days to hatch and 2-3 weeks to mature. At this point they leave the food material to pupate, making them easy to collect.

These insects also have a high food conversion rate; 2.2kg of carrots produced around 1kg of mealworms, which is similar to chickens (1 kg from 2.3kg feed) and much more efficient than animals such as pigs or cattle (1 kg from 4 – 9kg feed)[124]

Mealworms are around 28% high quality protein (59% after drying) and 12.5% fat when harvested as mature larvae weighing around 190mg[125]. Mature soldier fly larvae weighing around 110g each are approximately 44% dry matter, of which up to 42% is protein and 35% fat[126], although this can be affected by the type and quantity of feed with which they are provided[127] After harvest, insect larvae can be dried and milled, producing high protein 'flour' that can be readily made into other products.

8.10.2 ***Potential benefits to vegetable growers***

There has already been considerable interest in using insects in poultry food. Chickens, especially laying hens and meat birds, require protein levels of 15 – 20% to optimize

[123] Friederich, U., Volland, W. 2004. Breeding Food Animals: Live Food for Vivarium Animals; Friederich U, Volland W, editors. Malabar, Florida: Krieger publishing company.
[124] Oonincx, D.G.A.B., de Boer, I.J.M. 2012. Environmental impact of production of mealworms as a protein source for humans - A life cycle assessment. PLoS ONE 7(12)
[125] Ghaly, A.E., Alkoaik, F.N. 2009. The yellow mealworm as a novel source of protein. American Journal of Agricultural and Biological Sciences. 4:319-331.
[126] Sheppard, D.C, Tomberlin, J.K., Joyce, J.A, Kiser, B.C., Sumner, S.M. 2002. Rearing methods for the black soldier fly (Diptera: Stratiomyidae). Journal of Medical Entomology. 39:695-698.
[127] Wuertz, S., Pahl, C., Kloas, W., 2012. Hermetia meal in fish meal substitution – influences of substrates on Hermetia meal quality affecting fish nutrition of Tilapia *Oreochromis hiloticus*. Aqua2012, September 1-5, Prague, Czech Republic.

productivity. The range of amino acids in insect protein is ideal for poultry, and offers a novel way of enhancing feed quality[128]. However, chicken feed is relatively low value, retailing in the order of $200-$400/t as a bulk supply.

In contrast, quality fish food for aquaculture can be $3,000/t. Basic dried fishmeal costs approx. $900-$1,500/t. Different fish species vary widely in how well they will tolerate non-fish based feed. Despite this, some modern fish diets for salmon and barramundi have already reduced the content of fishmeal as low as 10%. In the laboratory, good results have been achieved with 0% fishmeal in some prawn and fish food mixes (B. Glencross, pers. com). Alternative protein sources for such feeds currently include animal wastes from abattoirs and processing, leguminous grains such as lupins and soy, and vegetable oils.

There appears to be general agreement that insects would be a suitable ingredient in fish feeds. Their high dry matter and range of amino acids mean they are suitable for a range of species. For example, one study showed that up to 50% of fishmeal could be replaced with yellow mealworm meal without affecting fish growth[129]. Up to 33% of the protein requirements of turbot could be met using black soldier flies produced commercially from greenhouse wastes, without affecting fish quality[130] while rainbow trout partially fed on enriched black soldier fly larvae had the same growth rates and flavour as those fed purely on fishmeal [131]

8.10.3 *Aquaponics*

Using vegetable wastes to feed insects, which can then be turned into fish feed, raises the possibility of a circular production system. Fish wastes from aquaculture can be used in "aquaponics", hydroponic solutions that can be then be used to grow vegetables.

Aquaponics, which combines aquaculture with hydroponics to produce fish and vegetables in the one structure is an inherently energy-efficient system and could have significant potential to produce vegetables close to urban centres. The design of these systems recycles waste produced by the vegetable crops and uses the fish effluent as a nutrient source for the plants. There is a 0.8 ha commercial pilot system in operation at Camden in NSW

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[128] Khusro, M., Andrew, N.R., Nicholas, A. 2012. Insects as poultry feed: a scoping study for poultry production systems in Australia. World's Poultry Science Journal. 68:435-446.

[129] ShiPing, S., QiChao, Y., Lei, S., LiHui, H., Jun, L., PeiSong, S. 2010. Effect of two kinds of insect protein source as substitute for fish meal on growth, body composition and protease activity of juvenile yellow catfish *Pseudobugrus fulvidraco.* Journal of Fujian Agriculture and Forestry University (Natural Science Edition): 39:608-613

[130] Kroeckel, S., Harjes, A-G.E., Roth, I., Katz, H., Wuertz, S., Susenbeth, A., Schultz, C. 2012. When a turbot catches a fly: Evaluation of a pre-pupae meal of the black soldier fly (*Hermetia illucens*) as fish meal substitute – growth performance and chitin degradation in juvenile turbot (*Psetta maxima*). Aquaculture. 364-365:345-352.

[131] Sealey, W.M., Gaylord, T.G., Barrows, F.T., Tomberlin, J.K., McGuire, M.A., Ross, C., St-Hilaire, S. 2011. Sensory analysis of rainbow trout, Oncorhynchus mykiss*, fed enriched black soldier fly prepupae, Hermetia illucens*. Journal of the World Aquaculture Society. 42:34-45.

operated by Urban Ecological Systems in a joint venture arrangement with the University of Sydney[132]. There is also a combined barramundi / hydroponic lettuce farm at Port Stephens.

The UES system shown in Figure 35 involves:

- Fingerlings-are housed in multiple tanks where they grow to harvestable size.
- The waste from the fish is processed by UES patented bio-converter. This turns an effluent that would otherwise be toxic to the environment into an allowable input for certifiable organic production, which is used to irrigate the plant crops.
- Plant seedlings are grown in an organic compost plug supplemented by the flow of organic nutrients from the bio-converter.
- Clean water, its nutrients having been taken up by the plants, flows back to the fish.

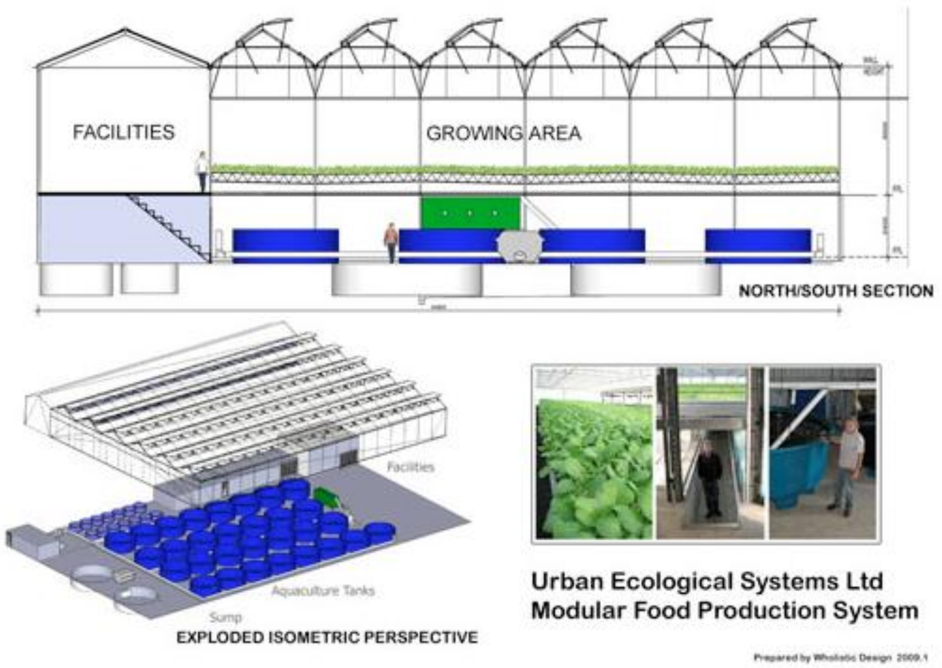

Figure 35 - Pilot aquaponics system developed by the University of Sydney and Urban Ecological Systems at Camden

132 Hogan Gleeson info@ecocityfarm.com.au

8.10.4 *Materials, equipment and research required*

While there is a considerable body of research on turning insects into fish feed, there has been far less consideration of the source of raw materials. While it has been shown that potato is suitable for black sawfly larvae[127] and mealworms can be raised on carrots[124], there is little information on the quantities and quality of materials required, or the effects on insect growth rate, protein content or suitability for meal.

A proper economic analysis is also needed to determine the costs of production, particularly the costs of drying and milling which could be $150-400/t. A number of technical issues would need to be overcome in terms of genetic replenishment, ensuring a high level of mating and egg production by mature insects, as well as maintaining a disease free environment.

The UES facility at Camden plans to develop the use of Black Soldier Fly larvae as a source of fish food made from vegetable waste. This project will involve the University of Sydney Veterinary Science and Agriculture faculties, and could be an excellent opportunity for the vegetable industry to take part in the development and commercialisation of fish feed produced from vegetable waste using Black Soldier Fly larvae.

Another aspect of the UES aquaponics system is that it has a patented process for converting vegetable waste from the plant production facility into an organic plant fertilizer that can be used to supply nutrients back to the hydroponically-grown crops produced in the facility. This nutrient source also appears to be able to suppress plant disease in the hydroponic system, and this is currently being investigated as part of a proposed ARC Linkage research project with the Sydney University faculty of Agriculture and Environment.

This use of vegetable waste to produce an organic fertiliser is a potential commercial use of vegetable waste.

8.10.5 *Economic viability*

The main factor limiting commercial production of insects has been the costs of growing, collecting, drying and milling the insects, and the lack of sufficient raw materials to produce an economically viable volume of insects (G. Allan, pers. com.). For example, soldier flies will only mate and lay eggs under certain conditions, and the cost of drying and milling the larvae is likely to be $150 – $400/t.

This may be changing. There is already a commercial facility in South Africa – AgriProtein - which is mass producing house fly larvae (*Musca domestica*) to turn organic wastes into high quality protein meal sold for fish feed production. The larvae are fed on vegetable wastes combined with slaughterhouse blood, with overall production around 24.5t dry feed per month. Organis Nutrition, Florida has constructed an integrated pilot production facility for black soldier fly, technology that it plans to extend into larger facilities globally [133]. Another US based company, Enviroflight, is also developing mass reared black soldier fly for use in fish feeds[134]. There is also an existing mealworm farm in Europe, although this is currently focused on mealworms as human food (D. Hogan, pers. com.).

Feed sources are generally sold on the basis of their protein content. Dried and milled larvae, with a protein content of close to 60%, would be expected to be worth approx. $700/t, whereas if protein levels were close to 40% they would be worth closer to $400/t. Mealworms and soldier fly larvae 55-60% water, so this return would require 2.2-2.5 t live insects. In the case of mealworms, feed would have to include up to 40% grains, whereas soldier flies can be fed purely on organic wastes.

At this time there are still too many unknowns to determine whether this is an economically viable option for the Australian vegetable industry. However, this certainly appears to be an area worthy of further investigation.

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[133] Papadoyianis, E.D, Cherch, X.T. 2011. Mass production of insects for aquaculture – an innovative solution to the protein bottleneck. World Aquaculture 2011, June 6-10 Natal, Brazil.
[134] Park, P. 2012. Farmed insects could provide feed for livestock. www.scidev.net accessed 20/4/2013.

8.11 Animal feeds

Fruit and vegetable wastes are rich in many bioactive and nutraceutical compounds, such as polyphenolics, carotenoids and dietary fibre and have potential to be used in the production of animal feed products. Potential areas include processing fruit and vegetable waste into high protein stock feeds for cattle and dairy cows, and processing waste into silage.

8.11.1 *Bio-processing of vegetable wastes into stock feeds*

The use of vegetable waste in stock feed formulation has been negligible until recently due to nutritional and technical constraints. These constraints have now been overcome by innovations in solid-state fermentation and new silage techniques, renewing interest in this area. Production of stock feeds or additives from wastes such as vegetable peelings, whole vegetables, fruit and vegetable pomace and seeds has been recently evaluated[135]. While not all of the products reviewed are part of the Australian vegetable industry, similar results may be possible with levy paying industries;

- Plant by-products such as husks, pods, leaves and tender stems of peas and beans can be used as nutritious cattle feed and are also good sources of digestible protein.
- Tomato pomace contains 14% digestible protein and 65% total digestible nutrients. Dried and ground, it can make up to 35% content of animal feed.
- Citrus pulp contains high levels of soluble sugars with a digestibility of 85%, and about 6% protein. It can be used to replace up to one-third of animal feed mixtures without ill effects.
- Pineapple waste together with maize grain, wheat bran, and molasses has successfully been fed to 5,000 feedlot beef cattle in the Philippines. A diet of fresh (and silage) pineapple wastes containing peel, pomace, and leaves resulted in a growth rate of 600–700 gm /day in growing and finishing steers.
- Dried cashew fruit contains about 9.5% protein and 70% soluble sugars and can be used to partially replace grains in livestock rations.
- Mango by-products, such as mango-seed kernels contain 6% protein, 70% total digestible nutrients, and 5–7% tannin, and can be used as an ingredient in livestock rations.
- Chinese cabbage juice, waste brine generated from kimchi production, deproteinized leaf juices and corn silage juice have been used as a nutrient sources for yeast production.

[135] Ajila, C. M. 2012. Bio-processing of agro-byproducts to animal feed. Critical Reviews in Biotechnology 32:382-400.

- Animal feed produced from potato pulp has been assessed for its nutritional quality and effect on growth performance of poultry farming.

8.11.2 *Solid state fermentation*

Recently there has been interest in using the solid-state fermentation (SSF) technique to produce several bulk chemicals and enzymes from fruit and vegetable waste [136]. The enzymes can them be used as additives to stockfeed to improve their digestability and nutritional profile.

Using SSF has a number of practical advantages over other methods. It is a low-tech process, so could potentially be used to process waste on farms. It uses little energy and produces a stable product with multiple potential uses.

Some of the enzymes extracted from plant materials in the past include α-amylases, pectinases, lipases, tannases, xylanases and phytases[135]. Most of the work to date has been done on fruit crops such as apples, pineapple and tomato as well as potato and cereal crop residues. However, vegetable by-products are rich in nutrients and therefore likely to be highly suitable for processing using this technique. Such wastes could also be used to add colour and flavour to animal feeds.

8.11.3 *Suitability of vegetable waste as silage*

The suitability of various types of vegetable waste for silage was evaluated by Ozkul in 2010[137] who investigated the usefulness of vegetable wastes as silage for ruminant animals. Wheat straw, wheat bran and salt were combined with minced vegetable wastes before making into silage. The different mixtures of vegetable waste were found to have a high ensilage capacity and can serve as an alternative roughage source for ruminants. The addition of 9% bran significantly improved the silage in view of both dry matter content and nutritive value.

In a separate study[138], the above ground parts of peas were used for silage after pod harvest, with or without the addition of 5 or 10% maize meal. The higher maize meal rate decreased the crude fibre and ash percentages, and increased the nitrogen-free extract percentage.

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[137] Ozkul, H., Klc, A., Polat, M. 2010. Evaluation of mixtures of certain market wastes as silage. Asian-Australasian Journal of Animal Sciences 24:1243-1248.
[138] Ordevic, N., Koljajic, V., Dujic, D. 1998. Efficiency of ensiling different by-products from vegetable and field crop production. Review of Research Work at the Faculty of Agriculture, Belgrade 43:99-105

Sugar beet tops were tested for making silage alone, or with the addition of 15, 30 or 45% of fifth-cut lucerne. Increasing the lucerne percentage increased the crude fibre and lipid percentages. Wheat cv. Balkan straw (15%) was used as a supplement for binding excess moisture in combination with 85% cabbage leaves or pumpkin stems. In both silages, acetic acid content was approximately twice as high as lactic acid content.

8.11.4 *Using waste to grow fungal cultures*

Cauliflower and cabbage leaves can be used indirectly to increase protein levels in diets of cattle and poultry[139]. Cauliflower and cabbage leaves containing about 8.0% solid material (dry weight basis) were treated with local strains of *Aspergillus niger*, capable of hydrolysing cellulolytic materials and producing up to 2.7% monosaccharides (fresh weight basis). The sugars produced were then used to culture *Torulopsis utilis*, which when dried was used in the preparation of protein-rich feeds. The dried products contained 22.6% protein compared with 14.5% for the control culture.

8.11.5 *Using raw vegetable waste as stock feed*

This is a usage that is already widely practised by vegetable growers in disposing of vegetable waste. A recent study however confirmed that fruit and vegetable waste is generally a suitable stock feed for cattle[140].

This study evaluated the use of fruit and vegetable waste from a marketplace as feedstuff for diets of lactating Holstein cows with an emphasis on milk yield and quality. The study found that fruit and vegetable waste can be used as a dietary ingredient for high-yield lactating cows without detriment in the milk yield and with improvement in the milk quality. Fruit and vegetable waste could be included at proportions of between 6% and 18% in the concentrate, as long as the animal's nutritional requirements are met.

8.11.6 *Economic viability*

It is difficult to assess the economic viability of using vegetable waste as a stockfeed, given the relatively small number of studies, which have investigated this area specifically. New

[139] Majid, A., Haroon, S., Joarder, G.K. 1995. High protein feed from vegetable waste. Bangladesh Journal of Scientific and Industrial Research 30: 1–11.

[140] Angulo, J., Mahecha, L., Yepes, S. A., Yepes, A. M., Bustamante, G., Jaramillo, H., Valencia, E., Villamil, T., Gallo, J. 2012. Nutritional evaluation of fruit and vegetable waste as feedstuff for diets of lactating Holstein cows. Journal of Environmental Management 95:210-S214.

technologies such as solid state fermentation (SSF) to extract enzymes, flavours and colours which could be used as supplements to stock feeds may warrant further investigation.

8.12 Biofertilisers and vermicompost

8.12.1 *What is the product?*

Vegetable waste can be converted into bio fertilisers or vermicompost, which can have disease suppressive and bio insecticidal properties[141], [142]. Vermicomposting involves the use of earthworms to convert biodegradable solid waste into a useful product (vermicompost or vermicast). This method has a unique position in the domain of environmental engineering, as it is the only pollution control that uses a multicellular animal as the main bioagent. It is actually a process of stabilisation of organic material through the joint action of earthworms and micro-organisms. Microbes are responsible for the biochemical degradation of organic matter, while earthworms are the important drivers to condition the substrate and alter the biological activity.

It has been clearly demonstrated that only certain species of earthworm live together with decaying organic matter. During vermicomposting, they are capable of degrading organic matter into fine particulate material or vermicompost that is rich in nutrients and can be used commercially as a plant growth medium and soil amendment. Vermicompost has good buffering characteristics, making it less likely than synthetic fertilisers to result in salinity stress[143].

8.12.2 *Potential benefits to vegetable growers*

There may be some benefits in producing vermicompost as a source of plant nutrients for use on farm. Vermicompost has also been reported to have disease suppressive properties and can improve soil structure. For example, capsicums grown in a potting mixture containing 40% vermicompost produced from food waste yielded 45% greater fruit weight and 17% greater mean number of fruits than those grown in commercial medium alone [144]. Similarly, vermicompost from food waste or paper waste increased the growth and yield of peppers significantly, increasing leaf area, plant shoot biomass and marketable fruit weight as well as decreasing yield of non-marketable fruit[145]. Vermicomposted municipal waste (up

[141] Keshav, S., Shukla, R.C. 2013. Potential utilization of different wastes through vermicomposting in agriculture. Dynamic Soil, Dynamic Plant 6:65¬72.

[142] Gorakh, N., Keshav, S. 2013. Combination of vermiwash and biopesticides against aphid (*Lipaphis erysimi*) infestation and their effect on growth and yield of mustard (*Brassica campestris*). Dynamic Soil, Dynamic Plant 6:96-102.

[143] Yih Shyang Sim, E., Ta Yeong, W. 2010. The potential reuse of biodegradable municipal solid wastes (MSW) as feedstocks in vermicomposting. Journal of the Science of Food and Agriculture. 90:2153–2162.

[144] Arancon, N.Q., Edwards, C.A., Atiyeh, R. Metzger, J.D. 2004. Effects of vermicomposts produced from food waste on the growth and yields of greenhouse peppers. Bioresource Technology 93:139–144.

[145] Arancon, N.Q., Edwards, C.A., Bierman, P., Metzger, J.D. Lucht, C., 2005. Effects of vermicomposts produced from cattle manure, food waste and paper waste on the growth and yield of peppers in the field. Pedobiologia 49:297–306.

to 250 kg ha^{-1}) caused a significant increase in growth parameters, germination of seeds and chlorophyll content of rice[146].

Vermicompost is also a saleable item, as is the "worm juice" or liquid that may be produced as part of the process.

8.12.3 *Earthworm species*

The criteria for selecting suitable earthworm species for use in vermicomposting are ease of culture, high affinity for the substrate to be vermicomposted and high rate of vermicompost output per worm and per unit digester volume. In general, epigeic species (living on the soil surface in leaf litter) are normally used in vermicomposting as opposed to species which are anecic (making permanent vertical burrows in the soil) or endogeic (making horizontal, often deep burrows in the soil).

The commonly used epigeic species are *Eisenia fetida*, *Eudrilus eugeniae* and *Perionyx excavatus*. *Eudrilus eugeniae* and *P. excavatus* are extensively used in vermicomposting throughout the world and both have proven to be efficient and versatile solid waste decomposers. However, E. *fetida* has a wider temperature tolerance than E. *eugeniae* and P. *excavatus*, which allows it to be cultivated at soil temperatures ranging from 5 to 40 °C.

8.12.4 *Vegetable waste substrates*

Vegetables wastes need to be combined with manure in order to maximise the results from vermicomposting. For example, earthworm species *Megascolex mauritii* produced a higher quality vermicompost (with higher contents of nitrogen, phosphorus and potassium) when it was fed a mixture of vegetable wastes and cow dung compared to vegetable waste alone. Similarly, earthworm species *E. fetida* reduced the C/N ratio by 62.7% when fed a 1:1 mixture of cow dung and vegetable wastes, compared to a 49.4% reduction when fed vegetable wastes alone. This ratio of cow dung / vegetable wastes produces the optimum levels of macronutrients in vermicompost after 30 days.

Vermicomposting using E. *fetida* is more suitable than the windrow method to transform pre-composted vegetable waste, dry tree leaves and cow dung into finer and better-quality compost within 20 days. Nitrogen mineralisation rate is usually found to be higher in cow dung and vegetable wastes (2:1 ratio), possibly owing to the greater proportion of easy digestible feedstuff and microbial populations. Earthworms can mineralise cow dung more easily than other organic wastes, because it contains a greater population of decomposing communities such as bacteria, protozoa, nematodes, fungi and actinomycetes. The variety

[146] Mishra, M., Sahu, R.K., Sahu, S.K., Padhy, R.N. 2005. Effect of vermicomposted municipal solid wastes on growth, yield and heavy metal contents of rice (*Oryza sativa*). Fresenius Environmental Bulletin 14:584–590.

of microbes in cow dung may accelerate the mineralisation process through enzyme synthesis.

Besides cow dung, several other wastes such as biogas digestate, leaf litter, wheat straw, pericarp and sawdust and dairy effluent can also used in the vermicomposting of vegetable wastes. Biogas digestate is an efficient bulking agent for rapid decomposition of waste through vermicomposting using E. f*etida*. In fact, the greatest increase in phosphorus content (110.4% more than the initial level) in vermicompost occurred in biogas slurry and vegetable wastes (1:1 ratio) within 15 weeks of vermicomposting. Also, the maximum increase in exchangeable potassium content (52.8% more than the initial level) occurred in biogas slurry and vegetable wastes (2:1 ratio) within 75 days of vermicomposting using *Allolobophora parva*.

Earthworm P. *sansibaricus* showed maximum biomass production, growth rate, mean cocoon numbers and reproduction rate in leaf litter and vegetable waste (1:2 ratio) compared to other substrate materials after 150 days of vermicomposting.

The addition of 40% sawdust enhanced the growth and reproduction of E. *fetida*, but growth and reproduction were adversely affected when 50% sawdust was added. A similar phenomenon occurs with addition of wheat straw to vegetable wastes, which affected their palatability for worms. Both sawdust and wheat straw may contain large fractions of slowly degradable substances such as lignin, cellulose, polyphenolic compounds, hemicelluloses, suberins and others, which directly influence the waste-minimising efficiency of inoculated earthworms.

Dairy effluent can be added to vegetable wastes and the samples allowed to undergo partial decomposition naturally for 15–20 days. When earthworms are introduced into the partially decomposed waste, the results showed that the samples with dairy effluent were high in nutrient content and worm population after only 13 days of vermicomposting.

The economic viability is unknown and would need further investigation.

9 Conclusions

Growing a crop requires major inputs of fertiliser, water, fuel and labour. If the crop is then abandoned in the field, culled after harvest or rejected at market, then the waste represents a significant loss for the farmer, other supply chain members, and the environment as a whle. Despite this, surprisingly little research has previously attempted to quantify the size and scope of this issue, either in Australia or for similar production systems overseas. Even where specific claims are made regarding the impact of a specific pest or disease, these are generally estimates based on experience rather than calculated from known data.

Waste comes in many forms and at different locations within the supply chain. In most cases, it is the interests of the observer that define what is waste. For example, non-harvested, non-edible plant material is counted as organic waste if the focus is potential production of biofuel. However researchers concerned about the environmental cost of food waste rarely consider this issue. Some studies have not deemed product to be waste if it has been subsequently sold for processing or used as animal food[147], whereas others have included all products graded out during packing[148], even if it is subsequently sold to a food processor.

In addition, most studies of waste have focused on losses due to processing or examined food thrown out by consumers, rather than evaluated what is lost at the farm level. The aim of these studies is usually to encourage consumers to purchase less and recycle or compost what they can’t eat. This is not the focus of the current study, which aims to find new products, uses and markets for vegetable waste products.

Waste may therefore be considered as recoverable versus non-recoverable waste. That is, waste which can be physically recovered and profitably recycled versus waste that is difficult or impossible to recover and re-use. As produce moves away from the grower / packer, recovery becomes less viable.

9.1 Quantification of waste in the Australian vegetable industry

The total amount of waste for each of the vegetable crops studied in this review have been presented in the preceding sections and are summarised in Table 47.

Carrots produce the most waste at 93,000 tonnes per year, which represents 31% of total production. In order of the amount of waste produced, the crops are: carrots, capsicums,

[147] McPhee, J. 2002. Increasing the opportunities for use of organic wastes in the Tasmanian vegetable industry. Horticulture Australia Final Report VX99002.

[148] Phillips, D. 1997. Export cauliflower improvement. Horticulture Australia Final Report VG221

cauliflower, sweet corn, cabbage, baby leaf (transplanted), lettuce, broccoli, beans, beetroot, and baby leaf (direct-seeded).

The overall annual production of the vegetables studied was 1,116 kt per year and the total amount of waste produced is 278 kt, which represents and overall level of waste of 25%.

Table 47 - Summary of annual yield and waste.

Crop	Area planted (Ha)	Yield (t/ha)	Production total (kt/year)	Total waste (kt)	Total waste (%)	Value of waste ($ million)
Carrots	4,600	60-70	300	93.0	31	24.0
Capsicums	2,300	52	119.6	31.1	26	13.8
Cauliflower	2,500	30	75	27.8	37	19.6
Sweet corn	6,700	15	100.5	26.9	27	14.3
Cabbage	2,000	25-30 (60-68 proc)	73.2	19.8	27	9.7
Baby leaf lettuce	4,500	35	157.5	19.4	12	38.8
Head lettuce	4,500	27 (38 proc)	124	17.0	14	7.4
Broccoli	7,000	7	49	15.4	31	16.7
Beans	6,000	7-10	51	12.8	25	2.2
Beetroot	900	40	36	10.2	28	1.2
Baby leaf veg	3,500	8.5	29.8	3.5	12	6.9
Totals	**44,500**		**1,115.6**	**276.9**	**25**	**154.7**

9.2 Alternative uses for vegetable crop waste in Australia

Increasing consumption of vegetables: The main cause of waste affecting all of the products considered in this review is oversupply**.** Grade standards and crop specification requirements are applied most stringently when the supply of vegetable crops is highest, even though this is often also when quality is best, further adding to the problem.

The best solution for the vegetable industry and consumers is clear - Increase demand. One clear way to do this is to focus on communicating the importance of vegetables in improving health and wellbeing, and that current intake needs to double to achieve the recommended 5 serves a day.

Increased vegetable consumption can potentially be linked with current interest in food and cooking. This can be combined with ongoing efforts to positively influence and maintain public health rather than focussing on treating what are often preventable illnesses. There therefore appear to be opportunities for the industry to leverage public funds earmarked for illness prevention and use them to promote vegetable consumption.

The challenge for the vegetable industry is to convince government that increasing vegetable consumption through promotion is preventative health care, and will reduce the demand on health services in the future.

On farm electricity generation from vegetable waste: On farm power generation using biogas produced from the anaerobic digestion of vegetable waste is a viable option for larger vegetable growers in Australia. The levelised cost of energy (LCOE) for Biogas is generally \$80 - \$160 / MWh, with farm wastes at the lower end due to their suitability for this process. This compares favourably with the average retail cost of electricity (\$230 / MWh). Only natural gas generation (\$61 - \$87 / MWh) and wind farms (\$77 - \$112 / MWh) can produce electricity more cheaply.

It is estimated that a large vegetable farm would produce 30t / day waste during peak season, reducing to closer to 10t / day during winter. In addition, it may be possible for farms to link with other operations so as to add manures, abattoir wastes or other organic materials into the feedstock. Such additions have the potential to further improve the efficiency of the process and increase biogas production. Unlike wind farms, biogas can be stored so as to generate electricity when demand is highest eg to run cooling during the middle of the day or heating systems at night. This suggests that an anaerobic digestion facility could be a viable option for many farms.

Bio-Active compound extraction from vegetables: Many of the special benefits that come from eating vegetables are due to the various chemical compounds they contain. These include sulfur compounds, phenolics, betalains and carotenoids. While the sulfur compounds found in *Brassicas* such as broccoli are less suitable for extraction and use in supplements, many phenolics and carotenoids remain stable during processing and consumption and maintain their activity in the body.

At this time, it seems unlikely that it is economically viable to extract bio-active compounds from vegetables. Supply of bio-active compounds takes place in an International marketplace. Many are sourced from countries such as China or India, where they may be manufactured by industrial means or extracted from non-food sources. However, there is a growing market for whole plant extracts for use in different foods. These are based on the idea that it is the combination of different bio-active compounds found in many plants which give them their important properties for enhancing human health.

In summary, while opportunities may be currently limited, they are likely to develop over time. Moreover, plant extracts developed for other purposes – such as dietary fibre – which also contain bio-active compounds, are likely to find ready use in manufactured ‘nutraceutical’ products.

Extraction of volatile compounds and food flavours: Aromatic compounds can be extracted from vegetables for use as flavourings in the food processing industry. This is now possible using new extraction techniques such as spinning cone columns (SCC). Appropriate vegetables include celery, parsley, capsicums, chillies and alliums such as leeks, shallots, onion and garlic. The economic viability of using SCC technology or perhaps even other process extraction methods would need to be assessed. There is expertise available in

Australia with the company Flavourtech located in Griffith NSW, which specialises in providing innovative processing solutions to the Food & Beverage and Pharmaceutical industries.

Dietary fibre from vegetables: Dietary fibre (DF) is defined as “the remnants of plant cells resistant to hydrolysis (digestion) by the alimentary enzymes of man”. Diets rich in DF have been associated with reduced rates of cancer (especially colon cancer), cardiovascular disease, constipation, irritable colon and diabetes.

Many vegetables and vegetable waste products are high in both soluble and insoluble dietary fibre. Examples include cabbage leaves, corn cores, carrots and beans. An additional advantage of vegetables is that the extracted DF may also be high in anti-oxidant compounds such as carotenoids. For example, beetroot wastes contain 7.7g/100g fresh weight DF split between soluble and insoluble fibre. Although costs of recovering the soluble fraction are likely to be higher, they are worth significantly more on the International market. Moreover, they would likely contain betalains, a potent (soluble) antioxidant. This could further enhance their market value as an additive to functional foods.

Other specialist vegetable opportunities: In general, the vegetables with the least waste are those for which there are multiple different uses, and where these different uses have been anticipated and planned for. Lettuce provides an example of where careful crop scheduling, predicting market demand, and vertical integration with fresh cut product manufacturing have reduced wastage to as little as 5% for some grower / processors.

Some potential uses in this area include:

- Carrots for additives to fruit juice and bakery
- Corn cobs for biofiltration
- Celery and parsley for oil flavour
- Chillies for sauces, purees and semi-dried products
- Black carrots for natural food colouring

Biochar from crop waste: Biochar is a type of charcoal produced by heating organic materials (feedstock) in an oxygen-limited environment. Once the process has been initiated, biochar production generates energy, which can be used directly as heat or turned into electricity. It can also produce bio-oil, which can be used directly in suitable boilers or furnaces, or processed further to make bio-diesel.

Biochar is most likely to be economically viable if it becomes eligible for carbon credits under the CFI, and the price of carbon increases. Viability would also be increased if sources of carbon such as timber wastes could be combined with vegetable wastes to produce the char.

Fish food from vegetable waste: One of the major factors restricting increased use of aquaculture is that most production systems rely on feeding high value aquaculture species on relatively low value wild caught fish. This is not sustainable in the long term, and has led to a search for alternative sources of high protein, high fat food sources. One alternative is the production of insect based protein meals. to plant and animal-based fish food, is the use of insect-based protein meals for producing fish food for aquaculture, and vegetable wastes could be used to feed the insects.

At this time there are still too many unknowns to determine whether this is an economically viable option for the Australian vegetable industry. However, this certainly appears to be an area worthy of further investigation.

Animal feeds: Fruit and vegetable wastes are rich in many bioactive and nutraceutical compounds, such as polyphenolics, carotenoids and dietary fiber and have potential to be used in the production of animal feed products. Potential areas include processing fruit and vegetable waste into high protein stock feeds for cattle and dairy cows, and processing waste into silage.

Biofertilisers and vermicompost: Vegetable waste can be converted into bio fertilisers or vermicompost, which can have disease suppressive and bio insecticidal properties. Vermicomposting uses earthworms to convert biodegradable solid waste into a useful product. There may be some benefits in producing vermicompost as a source of plant nutrients as well as to take advantage of reported disease suppressive properties of vermicompost. The economic viability is unknown and would need further investigation.

10 Appendices

10.1 Growers interviewed

- Russell Lamattina, Rosebud
- Happy Valley Robinvale, Russell Lamattina
- Pace Farms Bilimari via Cowra
- Camenzuli (Michael & Karen) Bathurst NSW
- Cox Farms
- Bewray Produce PL
- Andrew Dewar (Qld)
- Troy Parchert
- Story Fresh Farms
- Reck Farms
- Mulgowie Farming Company, Rodney Emerick
- Michael Camenzuli
- KALFRESH, Robert Hinrichsen
- Kalfresh, Richard Gorman
- Jeff McSpeddan
- Houston Farms
- Harvest Moon
- Gibb Bros
- Gavin & Fiona Thorne, Gatton
- David Vernon
- Covino Farms
- Frais Farms
- Mulyan Farm, Ed Fagan

10.2 Processors interviewed

- Cut Fresh Salads
- Mulgowie Farming Company
- Story Fresh
- Simplot
- Riviera Salads
- AusChilli, David De Paoli

10.3 Appendix - Processing waste estimates

Product	Processed products	Waste	Waste products
Baby leaf transplants	Fancy lettuce leaves	50%	(Winter) Leaf bases lacking colour
		10%	(Summer) plant base
Baby leaf direct seed	Eg spinach, rocket. Leaves (70%) with short petioles (30%)	15%	(Winter) Damaged / out of spec. leaves
		10%	(Summer)
Beetroot	Cryovac products Baby beetroot Canned / preserved	40%	Mis-sized (large or small) Uneven shaped Peel Trimmings
Broccoli	Florets Fresh cut / pre-packs	65%	Stem and branches Damaged florets
Cabbage	Shredded (coleslaw)	20%	Core Outer leaves
Carrots	Baby Sticks Shredded		Trimmings Peel / pomace
Cauliflower	Florets Fresh cut / pre-packs	60%	Stem and branches Outer leaves Core
Celery	Sticks		Outer petioles Heart / inner leaves
Lettuce	Baby cos Salad mixes	10%	Damaged / out of spec. leaves
Pumpkin	Peeled portions Soup mixes		Seeds Peel Trimmings
Sweet corn	Trimmed cobs	32-45%	Husks Cores Tips (nobettes)
	Kernels (frozen, canned	50-55%	

10.4 Appendix: Grower Survey Form

Name of Grower ____

Crop	Area planted (last 12 months)	Harvested % (or area)	Yield marketed (t/ha)	% of harvested crop wasted	Why was it wasted? (eg low price, out of spec)	What did you do with the waste?

10.5 Appendix: Processor survey form

Name of Processor ____

Crops processed	**Total throughput per year (tonnes)**	**% waste**	**Reason for waste (top 3)**	**What do you do with the waste**

Questions/comments

Do you have any ideas on what could be done to reduce waste?	
Suggestions on alternative uses for waste?	
Other comments or suggestions.	

10.6 Appendix: Growing regions by crop and harvest time of year for the Australian vegetable industry (ABS with modifications)

State	Region	Area (ha)	Crops	Harvest times	
				Start	End
NT	Darwin	300	vegetables general	January	December
	Katherine	800	watermelons rockmelons	April	May
Total NT		**1100**			
Tasmania	Cambridge, Hobart	1000	baby leaf	January	December
			lettuce and brassicas	September	June
	NW Devonport, Smithton	6400	potatoes	November	May
			onions	January	May
			lettuce	October	June
			celery	January	December
			brassicas	January	December
			beans	December	April
			carrots	January	June
	NW Scottsdale	4400	potatoes	January	June
			onions	February	May
			carrots	January	June
	Cressy (Midlands)	500	broccoli	January	May
			onions	February	April
Total Tasmania		**12300**			
WA	Perth metropolitan	3400	lettuce	January	December
			brassicas	January	December
			baby leaf	January	December
			Asian vegetables	January	December
			carrots	January	December
			potatoes	January	December
			tomatoes	December	May
	Manjimup, Pemberton	3400	lettuce	November	June
			baby leaf	November	June

State	Region	Area (ha)	Crops	Harvest times	
				Start	End
			brassicas	January	December
			potatoes	January	December
	Carnarvon	1400	tomatoes	May	December
			cucurbits	May	December
			sweet corn	May	December
			beans	May	December
	Kununurra, Broome	700	rockmelons	May	November
			watermelons	May	November
			pumpkin	May	November
			sweet corn	May	November
			beans	May	November
Total Western Australia		**8900**			
SA	Riverland, Murray Bridge	6900	Onions	January	April
			Potatoes	January	December
			Carrots	January	December
	Virginia, Adelaide Plains	2000	lettuce	January	December
			brassicas	January	December
			carrots	January	December
			tomatoes (glasshouse)	January	December
			onions	February	April
			cucumber (glasshouse)	January	December
	Adelaide Hills	700	leeks	December	April
			lettuce	December	April
			celery	December	April
			brassicas	December	April
	Mt Gambier, Pinnaroo	4300	onions	December	April
			potatoes	November	June
Total South Australia		**13900**			
Victoria	Werribee	5500	lettuce	October	June
			brassicas	October	June
			cauliflower	July	September
	Melbourne sandbelt (Cranbourne, Rosebud, Koo-	6,500	lettuce	January	December

State	Region	Area (ha)	Crops	Harvest times	
				Start	End
	Wee-Rup)				
			celery	January	December
			parsnips	January	December
			baby leaf	January	December
			salad onions	January	December
			potatoes	January	May
			Asparagus	September	November
	Thorpdale, West Gippsland	5000	potatoes	January	May
	East Gippsland (Sale, Maffra, Lindenow)	2600	lettuce	January	December
			baby leaf	January	December
			brassicas	January	December
			sweet corn	January	May
			beans	January	May
			carrots	January	December
	Goulburn Valley, Upper Murray, North central	4500	Tomatoes (Fresh market)	January	May
			Tomatoes (Processing)	February	April
	Mildura, Robinvale, Swan Hill	2000	carrots	January	December
			lettuce	May	December
			baby leaf	May	December
			brassicas	May	December
			rockmelons	December	April
			watermelons	December	April
			potatoes	November	December
			potatoes	April	May
			capsicums (glasshouse)	November	January
Total Victoria		**26100**			
NSW	Sydney basin, Mangrove Mountain	3500	leafy vegetables	January	December
			Asian bunching vegetables	January	December
			lettuce	January	December
			bunching onions	January	December
			Lebanese	January	December

State	Region	Area (ha)	Crops	Harvest times	
				Start	End
			cucumbers (glasshouse) Tomatoes (glasshouse)	January	December
	Central tablelands (Bathurst, Blaney)	1210	brassicas	December	May
			lettuce	December	May
			sweet corn	January	April
	Lachlan valley (Cowra, Canowindra, Condobolin)	2130	brassicas	April	December
			lettuce	April	December
			watermelons	January	April
			sweet corn	January	May
			beetroot	April	November
	MIA, Hillston, Hay	4000	rockmelons	January	April
			watermelons	January	April
			onions	November	January
			tomatoes (processing)	January	March
			sweet corn	December	January
			beetroot (Hillston)	April	November
	Finley, Berrigan	660	potatoes	November	December
			potatoes	April	June
	Murray - NSW side (Barum, Balranald, Dareton, Wentworth)	440	potatoes	November	December
			potatoes	April	June
			onions	November	December
			onions	April	June
	Northern Rivers (North coast)	1123	cucurbits	January	December
			tomatoes	January	December
			sweet potatoes	January	December
Total NSW		**13063**			
Queensland	Bowen, Gumlu, Ayr	6330	tomatoes	May	November

State	Region	Area (ha)	Crops	Harvest times	
				Start	End
			capsicums	May	November
			sweet corn	May	November
			beans	May	November
			rockmelons	May	November
	Bundaberg, Gympie	7100	tomatoes	April	December
			capsicums	April	December
			zucchini	April	December
			squash	April	December
			baby leaf (Gin Gin)	April	December
			watermelon	April	December
			sweet potatoes	April	December
	Lockyer valley	11800	brassicas	May	October
			lettuce	May	October
			baby leaf	May	October
			celery	May	October
			carrots	May	October
			tomatoes	April	May
			tomatoes	October	December
			potatoes	April	May
			potatoes	October	December
			sweet corn	April	May
			sweet corn	October	December
			beans	April	May
			beans	October	December
			onions	September	November
	Fassifern valley (Kalbar)		carrots	June	December
			onions	November	January
	Stanthorpe		lettuce	October	May
			celery	October	May
			baby leaf	October	May
			brassicas	October	May
	Toowoomba, Eastern Darling Downs		lettuce	October	November
			onions	December	February
	Chinchilla	2700	watermelons	January	April
			rockmelons	January	April

State	Region	Area (ha)	Crops	Harvest times	
				Start	End
	Fizroy (Rockhampton)	1000	sweet potatoes	January	December
			potatoes	August	October
	Emerald	500	melons		
	Wet Tropics (Atherton tablelands)	2300	Potatoes	July	November
			lettuce	July	November
	St George	2400	rockmelons	January	April
			watermelons	January	April
			onions	November	February
Total Queensland		**34130**			
Total area		**109,493**			