Scoping horticultural industry waste streams to determine suitability for use in pet food manufacture

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MARS Australia Pty Ltd

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PUBLIC RELEASE VERSION

Note Information of a sensitive or confidential nature has been removed in order to maintain confidentiality with key contributors and the petcare manufacturer providing this report. Any reference to the said manufacturer or contributor is to be removed for publication

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MEDIA SUMMARY

Fruit and vegetable products have been used in companion animal pet foods for some time. They primarily have been used at a low inclusion level to provide visual variety to both animal and owner. The fruit and vegetables used in commercial pet foods today are premium quality ingredients that can also exist in the human food chain. It would be advantageous to both fruit and vegetable processors and the pet food industry to identify by-product streams that complemented existing human quality ingredients without competing for materials destined for human food channels.

The findings of a jointly funded project identified the potential to develop novel raw materials for use in pet food products that offer benefits in terms of product performance or nutrition. Further work needs to be undertaken to provide cost-effective, stable and value-added fruit and vegetable-derived ingredients to the pet food industry.

Further work includes, but is not necessarily limited to:

- Applying appropriate hygiene standards to allow collection in a safe manner
- Intentional segregation of different materials currently collected as waste
- Developing cost effective methods to rapidly stabilise waste product and by-product materials

The project outcomes identified a number of fruit and vegetable by-product streams that, with concentration and conservation of nutrient content, could potentially be used in pet food products to supplement existing raw materials and / or deliver enhanced nutrition to cats and dogs. In order to give the best possible chance of a successful outcome, a co-development agreement between fruit and vegetable processors and a major pet food manufacturer is considered likely to be an efficient way to assess and commercialise opportunities identified.

TECHNICAL SUMMARY

Fruit and vegetable products have been used in companion animal pet foods for some time primarily to add variety to the animal and owner through namer components at a low inclusion level. The fruit and vegetables used in commercial pet foods today are premium quality raw materials that are also in the human food chain. It would be advantageous to both fruit and vegetable processors and the pet food industry to identify by-product streams that complemented existing human quality ingredients without competing for materials destined for human food channels.

The aim of this project was to evaluate existing fruit and vegetable by-product streams and assess their suitability for inclusion into prepared pet foods that would offer benefit in terms of product performance or nutrition.

The key outcomes of this project were:

- Fruit and vegetables do not contain an adequate nutrient concentration to meet dog and cat requirements on an “as is” basis, however, if concentrated they prove to be more viable as an alternative to current materials.
- Some fruit and vegetable materials may contain high levels of antioxidants and could act as partial replacements to current materials, especially if they are concentrated, although financial analysis of an example did not show a cost advantage.
- There is an absence of an intentional segregation and collection systems that could provide stable fruit and vegetable materials to the pet food industry.
- There is interest by several large industries that handle or process fruit and vegetable materials to reduce the amount of waste material they generate.

Fruit and vegetable materials that were deemed to be of interest include bananas, broccoli, corn, potatoes, carrots, strawberries and pears. These materials contained higher levels of nutrients and antioxidants, compared to the other fruit and vegetable by-product streams considered in this project, and following further processing e.g. concentration, they may be able to supplement existing raw materials in supplying the nutrient requirements of cats and dogs.

It is a recommendation of this report that industry groups that produce materials of interest are approached to consider a co-development agreement to develop cost-effective, stable and value-added fruit and vegetable-derived ingredients for the pet food industry.

ACKNOWLEDGEMENTS

The sponsors of this project would like to acknowledge the valuable contributions made to this project by:

- Food and Agribusiness Intelligence and Strategy Specialists - Reetica Rehky and Stephan Wellink.
- Authors of the review “Fruit and Vegetables as a possible source of nutrients for companion animals” held in confidence

INTRODUCTION

The pet food industry is a multibillion-dollar industry in Australia. In general there is a preference not to use safe and stable raw materials not typically consumed in the human food chain. This however, is not always possible as the quality of by-products is variable and often does not meet quality standards. Historically, pet food manufacturers have used products from the grain and meat industries to meet nutritional requirements of prepared pet foods. However, with increased demand to add value to by-products in these industries, the pet food industry is now looking beyond the traditional supplier set to develop high quality, alternative raw materials.

Currently, fruit and vegetable waste products have minimal commercial value and are either disposed of in landfill or sold for stockfeed. It is hypothesised that the use of fruit and vegetable by-products in pet food may reduce disposal costs and thereby increase the commercial value of the material.

The contribution of fruit and vegetable by-products could include:

- Improved aesthetic cues
- Basic nutrient requirements
- Enhanced nutrition such as antioxidants
- Functional ingredients such as pectins

This project aims to evaluate existing processing by-product streams and assess their suitability for inclusion into prepared pet foods, as a means of providing nutrition to cats and dogs.

MATERIALS AND METHODS

A review and evaluation process was undertaken to understand the current situation within the horticultural industry and to identify opportunities to utilise existing or develop new materials. This project was undertaken in five parts:

1. A survey of existing by-product streams within the horticultural industry was undertaken by using an external consultant to directly approach known producers, wholesalers and large retail organisations.
2. Evaluation of the nutritional profile of fruit and vegetable materials to understand the viability of including these materials in companion animal diets.
3. Internal knowledge on palatability performance (as supplied in confidence) of pet food containing fruit or vegetable material.
4. Evaluation of the commercial viability of the fruit and vegetable by-products *via* consideration of the transport logistics from industries of interest and the costs of raw materials of interest.
5. Discussion of results presented in Parts 1 to 4.

RESULTS

Part 1. Survey of existing by-product streams within the horticultural industry

The following section reviews the information provided by the consultants for each of the significant industries or companies that were identified to be of interest in their market survey.

From the information collected by the consultants, it is noted that a number of key FMCG and waste management providers are interested in discussing potential business opportunities that would help them reduce the cost of disposing organic waste materials. These companies handle fruit and vegetable material of interest. The challenge, however, at present is the lack of segregation of fruit and vegetable waste streams.

Fruit processors

The largest industry segment within the horticultural industry is the juicing industry, which represents 50% of the industry. By-products from the processing of fruit can be as high as 50% (range 20 – 50% depending on fruit type), with an estimated 27,000 tonnes of waste produced per annum. The nutritional value of higher volume by-products (oranges, pears and apples), however, was low and as a result these materials were excluded during the Evaluation Process (refer Appendix 2).

Common factors that currently restrict the use of by-products from the fruit juicing industry are: (1) high level of dietary fibre in the wet pomace - approximately 15-20% on a wet basis (Roy and Kattnig) and (2) presence of terpenes (limonene) in citrus peel (EPA, 1994).

The high fibre content of these materials is likely to result in decreased nutrient digestibility, changes in faeces quality and consistency and negative stool odour in dogs and cats, depending on the fibre type. Having said that, the soluble fibre in these materials includes pectin, which has been utilised in the food industry for its gelling properties.

Limonene is a monoterpene found naturally in citrus and other foods. It is a registered pesticide, insecticide and repellent against insects, cats and dogs (EPA, 1994). It has low oral toxicity and skin irritation has been observed in some animals, especially kittens (EPA, 1994).

The consultant identified a number of fruit and fruit juice manufacturers that could provide byproduct streams. The report on companion animal nutrition (Appendix 2) has identified some of these materials as having high levels of antioxidants.

According to the consultant's report the Australian banana industry has recently set a strategic plan that includes an objective to reduce waste from the industry. Bananas that are not of a saleable grade, which includes those with blemishes, are sold for livestock feed.

Vegetable processors

From the 15 horticultural industries (processors and retailers) contacted as part of the survey of existing by-product streams in the horticultural industry, the consultant identified a couple of vegetable processors that produce by-product materials of interest or who are interested in co-development opportunities.

Collection process and supply chain

At present, organic waste from markets and supermarkets is not being segregated and occasionally includes meat, fish and other foods in addition to fruits and vegetables. Typically inorganic materials, such as packaging, are removed. Compost Australia, which is part of Waste Management Association of Australia, identified that nationally over 79,000 tonnes of organic waste was received during 2006/07. New South Wales and Victoria produced 94% of the total organic waste. New South Wales has the largest concentration of fruit and vegetable processors in Australia (31.2%) followed closely by Victoria (27.3%).

Gaining relevant market information on what fruit and vegetable material is discarded is challenging due to the confidentiality statements given to the consultants and the generic nature of some of the information given.

The non-segregation of waste materials presents a major challenge for pet food manufacturers, as it results in variable quality and composition and may include hazardous or undesirable materials. In order for pet food manufacturers to be able to turn waste materials into value-added fruit and vegetable by-product materials, a dedicated segregation and collection pipeline needs to be developed. At the same time, rapid processing of these materials is important to allow the collected product to be stabilised to prevent microbial, chemical or enzymatic spoilage.

Part 2. Fruit and vegetables as a source of nutrients for companion animals

Basic nutrient requirements

As part of the report on companion animal nutritional benefits of fruit and vegetable materials (Appendix 2) an Evaluation Process was used to identify fruits and vegetables that could provide high quality nutrients to pet food. The outcome of this process was that no single whole fruit or vegetable material in either its raw or processed state, was able to provide significant levels of nutrients to the diet to support the basic nutrition requirements of cats or dogs.

Unfortunately, all fruits and vegetables assessed using this process were eliminated due to low nutritional content or significant losses in nutrients after they underwent standard food (thermal) processing.

The opportunity exists to use some of the eliminated fruit and vegetable materials if their nutritional content could by conserved and concentrated. Bananas, broccoli, corn and potatoes were identified (as part of the output of Stage 3 in the Evaluation Process reported in Appendix 2) as having some potential if a process was developed to conserve and concentrate the nutritional value. These materials may contribute to the mineral and vitamin content of the diet, although like all the materials assessed, they are unlikely to contribute to the amino acid requirements of cats and dogs.

Although it was not addressed in this review, it is expected that fruit and vegetable processing by-products could also benefit from the concentration and conservation of nutrients. However, there is insufficient data at this time to comprehensively evaluate the ability of fruit and vegetable by-products to deliver basic nutrition to cats and dogs.

It should be noted that lentils were found to provide reasonable levels of some key nutrients for dog diets, but the inclusion level of this material would be limited by known anti-nutritional factors. lentil will not be considered further in this report as it is outside the scope of the Horticulture Australia project (Sargent, *pers comm.* 2009).

High value micronutrients

A second aspect that the companion animal nutrition report (Appendix 2) identified was that some of the raw materials assessed in the report might be capable of delivering enhanced nutrition to companion animals through the provision of high value micronutrients.

Part 3.

Removed due to confidential nature of information

Part 4. Commercial viability and stability of horticultural by-products

Supply chain overview

Fruit and vegetable by-products are perishable and susceptible to microbial spoilage and oxidation. As a result, damaged product may be affected by (1) mould growth and subsequently mycotoxin formation, (2) detrimental changes to appearance and taste and (3) a reduction in nutrient content. Therefore, it is critical that the supply chain, including handling and storage facilities, are designed to manage materials of this type.

Conventional handling treatments, such as freezing, drying or thermal processing, are frequently employed to maintain the integrity of fruit and vegetable materials. The drawback of this model is that it requires processors to install additional equipment to complete this processing, which in turn adds unwanted cost and complexity into the supply chain for both the processor and the end user.

Alternative supply chain routes were assessed and it was concluded that further is required to assess the viability as quality standards of the raw material needs to be balanced with additional conversion cost of stabilisation.

(Further details held under confidence)

Cost benefit analysis

Carrots were identified as containing high levels of antioxidants and, hence, capable of supplementing existing raw materials in providing enhanced nutrition. A simple cost comparison of cost per unit carotenoid was conducted on carrots and marigold meal. Results indicate a significant oncost of using carrots as a source of carotenoid versus an existing commercialized version of the purified antioxidant.

DISCUSSION

Based on the outcomes of this project, it appears there is some potential to further develop specific fruit and vegetable by-product streams for use in commercially prepared cat and dog foods. Extensive work would be required to develop the collection and supply chain for these materials and to develop processing methods to conserve and concentrate the materials for use in pet food.

At present, fruit and vegetable by-product streams are not intentionally segregated or treated as a food material at the time of processing. In order to be considered for commercial supply as a pet food raw material, the processors will need to start segregating specific components and apply the same hygiene standards that are required for human food materials. This will present not only a technical challenge for processors, but will also require a significant cultural change by processors to treat materials that are currently considered waste into materials that have the same hygiene standards as human foodstuffs.

Additionally, in order to stabilise the raw material to prevent microbial, enzymatic and oxidative spoilage, it will be necessary to develop processing steps to allow the raw materials to be stored prior to conversion in finished pet food products. It is possible that current commercial supply chain routes would make an acceptable model for the supply chain that would need to be established for the collection of horticultural by-product streams.

It appears feasible to develop a partnership with fruit and vegetable processors or companies that handle the by-products to develop materials of interest. The benefits of working with the processors directly would be access to by-products that require limited separation to isolate the materials of most value, however these processors also tend to produce lower volumes of waste material. In contrast, there are some companies that handle larger volumes of waste that would require more extensive separation and may yield lower volumes of materials of high value.

This report has identified that fruit and vegetables do not contain adequate nutrient concentration to meet dog and cat requirements on an “as is” basis. However, fruit and vegetable by-product materials that have been concentrated in a manner to conserve the nutrient content may provide viable alternatives to current raw materials. The inclusion rate of these materials will be limited based upon impact on palatability, digestibility and cost. As these types of materials have been demonstrated to have a negative impact on feeding performance for dogs (dry food formulations), it is advisable to determine the best method to improve the palatability of the fruit and vegetable materials for dogs before commencing work on cat products.

Some fruit and vegetable materials may contain high levels of antioxidants, in particular carotenoids that could be of use in formulations that make use improving the antioxidant status of animals. However, these fruit and vegetable materials, and in this case carrots, contain significantly lower concentrations of carotenoids than other commercial sources which are currently used and the cost per unit carotenoid is substantially higher in carrots whether it was in its whole raw state or dehydrated.

If carrots are considered representative of other sources of high value micronutrients then the cost comparison indicates fruit and vegetable by-product streams are not a cost-effective option for delivering the high value micronutrients assessed in this report. Although carrots and other fruit and vegetable by-product streams could not completely replace current raw materials, they could act as partial replacements and supplement the level of antioxidants in pet food formulations, in addition to delivering aesthetic differentiation between diets.

The quality and food safety of raw materials used is of absolute importance to petfood manufacturers in general. It is essential that any materials developed out of this project undergo the appropriate raw material and vendor risk assessment processes to ensure it is safe to feed to companion animals.

TECHNOLOGY TRANSFER

Unfortunately, no single existing whole fruit or vegetable by-product material was found to meet the requirements as set out at the beginning of this project.

There remain a number of significant challenges to develop fruit and vegetable by-products, both in terms of collection and stabilisation at the time of processing, in addition to the application into commercially prepared pet foods. Therefore, this is a potential activity set that will require a close collaborative effort between the pet food industry and fruit and vegetable processors and is likely to require substantial investment in both capital equipment to process and detailed research to establish efficacy and performance in pet food products.

RECOMMENDATIONS

This project was undertaken to understand the potential use of fruit and vegetable by-product streams in commercial cat and dog food. A review and evaluation process was undertaken to understand the current situation within the horticultural industry and to identify opportunities to utilise existing or develop new materials.

The key outcomes of this project are:

- Fruit and vegetables do not contain adequate nutrient concentration to meet dog and cat requirements on an “as is” basis, however, if concentrated they prove to be more viable as an alternative to current materials.
- Some fruit and vegetable materials may contain high levels of antioxidants and could act as partial replacements to current materials, provided they can be concentrated, although financial analysis of an example did not show a cost advantage.
- There is an absence of segregation and collection systems that could provide stable fruit and vegetable materials to the pet food industry.
- There is interest by several large industries that handle or process fruit and vegetable materials to reduce the amount of waste material they generate.

Based upon these outcomes, the following opportunities were identified:

Confidential

Potential Uses Of Horticultural Waste Products By Value-Addition In The Preparation Of Pet foods

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By

Food & Agribusiness Intelligence And Strategy Specialists

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Withheld.

ABOUT THE CONSULTANTS

Reetica Rekhy holds an MBA from the prestigious Australian Graduate School of Management at the University of New South Wales. She has more than 15 years of professional experience across a broad range of businesses including banking, consulting and manufacturing and has worked for Unilever, Simplot Australia, Australian Business Limited, Rabobank and the National Food Industry Strategy. Reetica is a senior industry analyst and strategy specialist, with extensive experience in project management, opportunity & risk assessment, strategy formulation and commercialisation. She has an in-depth understanding of the Food and Agribusiness industry developed within the banking and private sectors in Australia and overseas.

Stephan J Wellink has more than 20 years of senior management and leadership experience with public and private sector organisations including Auspharm, ICI, CSIRO and the University of Technology, Sydney (UTS). He has been involved in two ASX public listings – Auspharm in 1986 and GroPep in 2000 for which he was awarded the CSIRO Medal for Business Excellence in 2001. He has served on a number of Boards and influential committees including the Prime Minister's Science Engineering & Innovation Council Working Group for Commercialisation of Public Sector Research; the Editorial Board of Rural Research; Director of the foundation Board of AusBiotech Ltd; Chair of the Stored Grain Research Laboratory; Chair of the Food Into Asia initiative and member of the inaugural Advisory Board of the UTS Institute for Biotechnology of Infectious Diseases (IBID) and has lectured regularly in the Doctor of Technology program at UTS.

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DISCLAIMER

Care has been taken to ensure that the information contained in this Report is reliable and that the Findings and Recommendations reflect considerable professional judgement. The project consultants, however, do not guarantee that the Report is without flaw or is wholly appropriate for all purposes and therefore, disclaim all liability for any loss or other consequence which may arise from reliance on any information contained therein.

I. BOUNDARIES AND LIMITATIONS OF THE PROJECT

There is general acknowledgment in the horticulture sector that it is difficult to collect contemporary, robust data due to the complex and fragmented nature of the

sector. This issue, the reluctance to share information by many of the actors in the sector and the limitations placed on the Project Consultants by the Client, in terms of being unable to disclose the name of the Client to the organizations surveyed and in most cases needing to establish contact and trust with organizations through cold calling techniques and over a short timeframe, were the major obstacles faced by the Project Consultants.

The Project Consultants undertook this work understanding that these boundaries and limitations would impact on the access, assembly and synthesis of data and information.

The reader is asked to recognize these constraints and this report is not meant to be a comprehensive paper on the issues germane to the commercialization of horticultural waste stream products.

II. EXECUTIVE SUMMARY

A large petcare manufacturer in Australia is seeking to develop new areas for sourcing materials that provide nutritional and functional benefits in the pet food products it manufactures. The brief for this scoping project was to study existing processing waste streams from the horticulture sector and to evaluate their suitability for use in prepared pet foods, thus potentially adding value for the pet food industry, the fruit and vegetable sector, the consumers who purchase nutritious food for their pets and ultimately, delivering health benefits to companion animals. The petcare manufacturer believed that the horticulture industry, specifically fruit and vegetable processors, may yield a potential opportunity whereby current waste products that are either disposed of in landfill or nominally sold for stockfeed may be value added by utilization in prepared pet foods.

The Project Consultants undertook extensive research conducted via literature review, discussions on phone (selective commercial in confidence) and site visits with relevant personnel from peak industry bodies, waste management collectors and FMCG companies with a view to collate data and develop an understanding of the dynamics of horticultural waste streams, methods of disposal, potential uses and quantities.

The research clearly highlighted that good quality, contemporary and comprehensive data on horticultural waste does not exist in the public domain. Given that there is no national knowledge management database in existence means the publicly-available data is scant, much of it is anecdotal and there is no one place where an industry-wide snapshot can be obtained.

Furthermore, industry is circumspect and often unwilling to share information which is considered commercial-in-confidence. Confidentiality arrangements with respect to waste cartage agreements and rates between waste management companies and their clients in retail, wholesale and processing exist. Therefore, understandably, relevant specific commercial data is not accessible.

Research suggests that peak industry bodies should be best placed to provide metrics on waste but have difficulty in doing so either because the data does not exist, or exists but is not codified or because it is considered confidential by their stakeholders.

Moreover, in data which may exist at a broad level, horticultural waste is not segregated from other organic waste such as meat, fish, garden waste etc.

Within the above bounds and the agreed scope of the project, in-depth research was conducted, which revealed the following key findings:

- In order for horticultural waste to be diverted towards pet food manufacture, such waste will need to be segregated at the point of waste generation (often, waste produce arrives at disposal companies in cartons and polystyrene containers) – the quality of waste and length of time will be important to consider from a quality control perspective;

- Food safety issues need to be considered both for the pets and Environmental Health & Safety issues for the handlers;

- Seasonality and availability of specific horticultural waste needs to be taken into consideration to ensure reliable supply;

- The capacity for the recipient company to accept and process potentially large volumes of green waste will need to be taken into account depending on the seasonality and availability of specific products;

- Supply chain and storage of waste from point of generation to point of processing will need to be clearly mapped out;

- Waste disposal from collection points at wholesale markets and processors comes at a cost to the wholesaler/processor. Organic waste is primarily water and expensive to transport. If it could be processed on site, there could be a cost benefit to the wholesaler/processor. Issues to consider include if it will be feasible to install dryers on the waste generation site or perhaps a fit-for-purpose waste processing facility at the point of generation to convert it into say powdered, flaked, granular or extruded dried product for use in the pet food facility. Given the cost of waste disposal, any proposal for using the waste in a value-added way could make for an attractive commercial arrangement.

Note – specific information related to next steps are removed due to confidential nature. Details are available in full report.

III. PROJECT BACKGROUND & OBJECTIVES

"The pet food industry is a multimillion dollar a year industry. The manufacture of prepared pet foods is generally regarded as a scavenging industry, sourcing raw materials from waste streams not typically considered for use in the human food chain. Historically, pet food manufacturers have used products from the grain and meat industries to provide nutritional content in prepared pet foods. However, with increased efficiencies and utilization by these industries, it is important that the pet food industry seeks to develop new areas from which to source materials to provide nutritional and functional benefits in the products manufactured.

It is believed that the horticulture industry, specifically fruit and vegetable processors, may yield a potential opportunity whereby current waste products that are either disposed of in landfill or nominally sold for stockfeed may be value added for producers by utilization in prepared pet foods. It is anticipated that nutritional and functional benefits in existing waste streams may be of value to the pet food industry and as such may increase the value of existing waste streams"[1].

A large petcare manufacturer invited Food & Agribusiness Intelligence And Strategy Specialists (FAISS) to submit a Proposal for undertaking a scoping project to study existing processing waste streams from the horticulture sector and evaluate their suitability for inclusion into prepared pet foods, thus adding value for both the pet food industry and fruit and vegetable processors.

The major objectives of the project were to research, analyze and present strategic information, knowledge and findings related to the following key elements[2]:

- Who are the main horticulture (fruit and vegetable) processors in Australia;
- Where are they located;
- What materials are they processing;
- What volumes of material are they processing;
- What waste materials are generated by these processors;
- What is the current disposal method for these waste streams;
- What format is this waste material in – wet pommace etc;
- Is this material generated seasonally or is there continuous production.

IV. METHODOLOGY

The Project Consultants used the following methodology:

Desk Research, Interviews, Data Analysis and Reporting

- Based on the project brief agreed with the petcare manufacturer, the scope of the project was limited to cover the following segments within the horticulture industry:
    - The Australian fruit juice sector;

[1]Reference removed
[2] Reference removed

- The three large vegetable processors in Australia – Heinz, Simplot and McCain Foods;
- The two major Australian supermarkets; and
- Key wholesale markets handling fresh produce (fresh fruits and vegetables) – with a focus on their disposal avenues/processes for handling overripe / spoiled / unsold produce.

- The Project Consultants conducted discussions via phone, email (using a structured questionnaire) and site visits with relevant personnel from peak industry bodies, waste management companies, fresh produce packers, wholesale markets, supermarkets and other relevant organizations active in the Australian fruit and vegetable sector, with a view to collate data and develop an understanding of the dynamics of horticultural waste streams, methods of disposal, potential uses and quantities.

- Each of these contacts was achieved through extensive web research and phone calls to identify the potential sources of information and the relevant personnel in the respective organizations. Once identified, organisations were approached by the Project Consultants, using "cold calling" techniques, to seek information and data (where it existed and was not commercial-in-confidence).

- The scope of the project did not require the Project Consultants to undertake discussions/interviews with the key Australian vegetable/fruit processors (companies). The Client had communicated to the Project Consultants that they would undertake such discussions independently when they were ready to do so.

- Extensive and in-depth internet / desk research and literature review was undertaken to identify relevant industry reports, papers and conference proceedings available in the public domain, containing statistics, information and strategic knowledge on fruit and vegetable processing in Australia including key players, products processed, volume of material processed, resultant waste streams, seasonality, end-use etc. IBIS World's Report titled "Fruit and Vegetable Processing in Australia, 29 October, 2008" was purchased and studied to seek initial data to inform further research and analysis.

- The data, information and knowledge was collected and synthesized through a combination of: responses to a questionnaire (refer Annexure 1); vetting industry and annual reports; telephone discussions and site visits.

- The primary and secondary research was analyzed to draw out key findings; conclusions and potential next-steps.

V. HORTICULTURE INDUSTRY WASTE SEGMENTS

1. Fruit And Vegetable Processing in Australia

Fruit and Vegetable processing in Australia includes firms engaged in activities such as packing, canning, bottling, preservation, quick freeze or drying of fruit and vegetable products.

Figures 1, 2 and 3 below detail and highlight that industry parameters such as revenue, industry gross product, number of establishments and domestic demand are exhibiting a declining trend over the last few years.

Figure 1:

Constant Prices

Industry Parameters	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	Unit
Industry Revenue	5,733.0	5,236.6	4,641.1	4,367.4	4,109.8	$Mill
Industry Gross Product	1,393.9	1,305.8	1,133.2	1,109.0	1,085.3	$Mill
Number of Establishments	*289	*315	*318	*312	*311	Units
Number of Enterprises	*259	*282	*284	*279	*277	Units
Employment	*12,784	*13,100	*14,232	*13,893	*13,477	Units
Exports	844.5	939.9	938.9	936.8	944.2	$Mill
Imports	1,319.2	1,319.4	1,450.5	1,503.4	1,558.2	$Mill
Total Wages	681.7	686.0	642.8	604.8	569.2	$Mill
Domestic Demand	6,207.6	5,616.1	5,152.7	4,933.9	4,723.8	$Mill

Source: IBISWorld Industry Report – Fruit and Vegetable Processing in Australia: C2130, 29 Oct 2008

Figure 2:

Real Growth

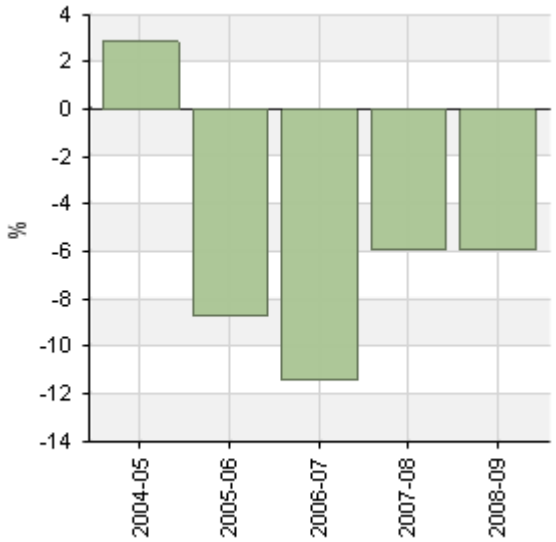
Industry Parameters	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	Unit
Industry Revenue	2.9	-8.7	-11.4	-5.9	-5.9	%
Industry Gross Product	-0.2	-6.3	-13.2	-2.1	-2.1	%
Number of Establishments	*12.5	*9.0	*1.0	*-1.9	*-0.3	%
Number of Enterprises	*4.4	*8.9	*0.7	*-1.8	*-0.7	%
Employment	*0.5	*2.5	*8.6	*-2.4	*-3.0	%
Exports	-6.9	11.3	-0.1	-0.2	0.8	%

Imports	8.3	0.0	9.9	3.6	3.6	%
Total Wages	-7.9	0.6	-6.3	-5.9	-5.9	%
Domestic Demand	NC	-9.5	-8.3	-4.2	-4.3	%

Source: IBISWorld Industry Report – Fruit and Vegetable Processing in Australia: C2130, 29 Oct 2008

Figure 3:

Revenue Growth Rate



Source: IBISWorld Industry Report – Fruit and Vegetable Processing in Australia: C2130, 29 Oct 2008

Research suggests that the industry value can be segmented as follows[3]:

- By Product – 65% Fruit Processing (comprising fruit juice 50%, canned/bottled fruit 10%, preservatives 5%) and 35% Canned and Frozen Vegetables (e.g. tomatoes, corn, tomato paste, frozen peas and beans etc);

- By Market Segment/Distribution Channel –
  - Grocery Wholesalers 34.5%;
  - Supermarket Chains 30.3%;
  - Exports 15.8%;
  - Other Food Manufacturers 11%;
  - Food Service Industry 8.4%.

According to IBISWorld, the fruit and vegetable processing industry in Australia is 'moderately concentrated' with the turnover from fruit and vegetable processing generated by a mix of small, medium and large organisations. Industry estimates suggest that over half of all business entities generate turnover below $ 100,000.

[3] IBISWorld Industry Report – Fruit and Vegetable Processing in Australia: C2130, 29 Oct 2008

However, a large percentage of the industry's total revenue is estimated to be the result of its largest players. Reports also indicate that currently, a relatively static market and the need to achieve economies of scale are pushing the industry towards higher concentration and rationalization.

A large proportion of the fruit and vegetable processing industry is located in New South Wales (31.2% by establishments); Victoria (27.3%); Queensland (17.2%) and South Australia (10.4%), with the balance distributed among the other States.

Country regions such as the Goulburn Valley in Victoria and the Murrumbidgee Irrigation Area in New South Wales hold a significant chunk of the Australian fruit and vegetable processing industry. There are some exceptions where large players are based in metropolitan areas, such as Golden Circle in Brisbane.

Per Capita Consumption

According to IBISWorld estimates, the average Australian consumes over 300 kg of vegetables and fruits each year, where vegetables constitute about 130 kgs.

Major Players

The following organisations are key players in the Australian fruit and vegetable processing industry:

Figure 4:

Industry Player	Market Share in 2009 by value
Simplot Australia (Holdings) Pty Limited	13%
Heinz Wattie's Pty Ltd	13%
Coca-Cola Amatil Limited	8%
Golden Circle Limited	5%
Other	61%

Source: IBISWorld Industry Report – Fruit and Vegetable Processing in Australia: C2130, 29 Oct 2008

2. Fruit Juice Sector

According to a paper[4] presented by Dr Robert Sleigh (Food Science Australia, North Ryde), Dr Rosalie Durham and Dr Jim Hourigan (University of Western Sydney, Hawkesbury), titled "Trash to cash, waste minimization", dated 13 July 2005:

- "The waste from juice processing can be a significant disposal issue (e.g. mango 30-50%, banana 20%, pineapple 40-50%, citrus 30-50%);

[4] Source: http://www.foodscience.csiro.au/aifst2005/Sleigh.pdf

- **Waste produced by Australian fruit juicers is estimated at 27 million kg per annum;**
- These fruit "by-products" contain sugars, organic acids, pectins and a wide range of interesting phenolic components, such as catechins and bioflavonoids, which are strong antioxidants, anticarcinogens and anti-inflammatory agents."

According to Jason Baker of IBISWorld[5], the key statistics of the fruit juice industry are that 52 companies employ 1,750 people, industry revenue in 2006 was ($927 million with revenue growth of 2.7% from 2005 to 2006), exports were $5.7 million and imports were $58.2 million.

Main Players

The key players in the Australian fruit juice industry include:

- National Foods Limited;
- Golden Circle Ltd;
- Coca-Cola Amatil Ltd.

Location of plant / processing facility / point of waste generation;

- National Foods and Berri Ltd (juice business) merged in 2005. The brands include Berri, Daily Juice, Australian Fresh and Just Juice[6]. The company packages approximately 50% of all fruit juice beverages processing operations are located in Lytton (Queensland), Smithfield (NSW), Leeton (NSW), Riverland (South Australia) and Bentley (Western Australia).

- Golden Circle manufactures more than 500 fruit and vegetable products from two sites, the main operation at Northgate, just north of Brisbane, Queensland and at the Original Juice Company, Mill Park, Victoria.

- Coca Cola-Amatil owns SPC Ardmona Ltd / Goulburn Valley and produces apple juice and concentrate and processes pears and peaches at Shepparton, Victoria.

Horticultural materials processed / handled - by Product & Volume;

- National Foods: Processes apples, mangoes, oranges, bananas, apricots and grapes. Volumes of waste for National Foods (apart from National Packaging

[5] Source: Juice toasts a bright future; smart company; Thursday, 13 September, 2007; http://www.smartcompany.com.au/Premium-Articles/Industry-Trends/Juice-toasts-a-bright-future.html?source=RSS

[6] National Foods website – "About Us"; http://www.natfoods.com.au/default.aspx?sectionID=0&section=Home

Covenant Reports[7] which is packaging material specific and outside of the project brief) are not readily-accessible from public domain sources.

- Golden Circle: Approximately 20% of Golden Circle's products are pineapple-based. The company also processes fruits such as apples, mangoes apricots, bananas, citrus, strawberries, peaches, plums and pears, which are used in juices, jams etc. Vegetables, including peas, carrots, beans and beetroot are also processed. The Original Juice Company processes orange, apple, grapefruit, tomato and pineapple juices[8].

- Coca Cola-Amatil: Refer sub-section 3 below on Vegetable Processing Sector for details on SPC Ardmona (now a part of Coca Cola Amatil).

Waste materials generated - by Format; Volume; and Seasonality;

- Golden Circle has stated that approximately 7% of solid waste generated at the Northgate site is sent to landfill with the remaining 93% recycled[9].

Specific information / data on horticulture waste streams generated by the players is not available in the public domain. This information was not sought via primary research (interviews) as it was beyond the scope of this project and the Client had communicated to the Project Consultants (on contract execution) that they wished to contact these Processors directly when they deemed it was necessary.

Current method of disposal of these waste streams - including waste management companies used, price paid per tonne etc.

Specific information / data on horticulture waste streams generated by the above players is not available in the public domain. This information was not sought via primary research (interviews) as it was beyond the scope of this project and the Client had communicated to the Project Consultants (on contract execution) that they wished to contact these Processors directly when they deemed it was necessary.

3. Vegetable Processing Sector

Main Players

The vegetable processing sector in Australia is dominated by a few key players which include:

[7] Source: National Foods Limited, National Packaging Covenant Report F05; 2005; http://www.nationalfoods.com.au/downloads/packaging_covenant_2005.pdf
[8] Source: Golden Circle International; Original Juice co.; http://international.goldencircle.com.au/brands/originalJuice.cfm
[9] Golden Circle Annual Report 2006; http://www.goldencircle.com.au/corporate/documents/GoldenCIrcleAnnualReport2006.pdf

- Simplot Australia (Holdings) Pty Ltd;
- Heinz Wattie's Pty Ltd;
- Coca-Cola Amatil Ltd;
- McCain Foods (Australia) Pty Ltd; and
- Moraitis Group.

Location of plant / processing facility / point of waste generation

- Simplot Australia is headquartered in Melbourne with processing facilities spread around Australia. It has nine processing plants and six sales offices. Its canned food processing facilities are located in Echuca (Victoria) and Bathurst (NSW). Its state-of-the-art potato French fry processing plant is located in Ulverstone in Tasmania. It also has a frozen vegetables processing facility in Devonport (Tasmania).

- Heinz Wattie's has its Australian head office located in Melbourne (Victoria). It has an annual sales turnover of $ 598,164,000. The Company has manufacturing facilities located around Victoria including in Echuca, Dandenong, Girgaree etc. and in other States such as South Australia.

  In December 2008, Heinz finalized the acquisition of Golden Circle which has manufacturing plants at Northgate (Queensland) and Mill Park (Victoria).

- Coca-Cola Amatil is a key operator in the Australian fruit and vegetable processing sector through its subsidiary SPC Ardmona, which it acquired in early 2005.

  SPC Ardmona has its headquarters in Shepparton, Victoria. It has three production facilities in Victoria's Goulburn Valley, namely in Shepparton, Mooroopna and Kyabram.

- McCain Foods (Australia) has its head office in Ballarat Victoria, with production plants located in Ballarat (Victoria), Smithton (Tasmania) and Penola (South Australia).

- Moraitis Group[10] is a leading hard produce, hydroponic tomato and banana supplier with growing, packing, transport, wholesaling, ripening and pre-packing operations. While the business has its head office in Homebush Bay in NSW, it operates in almost every state with sizeable operations located within Sydney, Melbourne and Brisbane Wholesale Markets. Its principal operations include Wholesaling and Fresh Packaging of vegetables and fruits.

[10] http://www.moraitis.com.au/contactus.aspx

Horticultural materials processed / handled - by Product & Volume;

- Simplot Australia processes a large range of vegetables with operations scattered around Australia. In its factory in Devonport alone, more than 55,000 tonnes[11] of locally grown vegetables are processed per annum. Research[12] suggests that the Tasmanian economy is heavily dependant on large processors such as Simplot and in 2007, the State had planned a production of approximately 365,000 tonnes of vegetables, with a gross value of about $ 96 million at the farm gate to be produced on 13,000 hectares of land, for supporting Simplot's production in the State.

  The Company owns several brands in the processed vegetable category which include Edgell (canned vegetables including corn, carrots, peas, beetroot, cabbage and canned bean mixes); Birds Eye (frozen vegetables including potatoes, green beans, vegetable mixes etc); and Leggo's (pasta sauces, tomato paste etc), among several others.

- Heinz Wattie's[13] produces a large range of processed vegetables and fruits which include baked beans, spaghetti, sauces & dressings, soups, baby foods, frozen vegetables, frozen & canned meals, processed fruit, desserts etc. Figures on volume of material processed are not available in the public domain.

- Coca-Cola Amatil via its SPC Ardmona[14] operations processes a range of fruits and vegetables:

  - Shepparton site: The plant covers 21 hectares, and processes peaches, pears, apples, plums, apricots, grapes, beetroot, beans, pasta, rice and vegetables. The Company website states processing capacity figures of 80,000 – 100,000 tonnes of fruit per annum. Products include single strength juice, juice concentrate, single strength fruit purees, and aseptic fruit particulates;
  - Mooroopna site: Is on 18 hectares and processes peaches, pears, apples, plums, apricots, grapes, tomatoes and mangoes. Website provides capacity figures of 50,000 – 80,000 tonnes of fruit per annum and 30,000 – 40,000 tonnes of tomatoes per annum.
  - Kyabram site: On 8 hectares, this plant produces jams, fruit sauces, toppings, bakery fillings, fruit preparations and marinades.

  SPC Ardmona's products are sold under brands which include SPC, Goulburn Valley, Ardmona, IXL and Taylor's.

[11] Source: IBISWorld Industry Report – Fruit and Vegetable Processing in Australia: C2130, 29 Oct 2008
[12] http://www.pc.gov.au/__data/assets/file/0018/30744/subdr082.rtf
[13] http://www.heinz.com.au/Corporate/Corporate.aspx
[14] http://www.spcardmona.com.au/content/view/17/33/

- McCain Foods[15] produces a range of frozen meals, pizzas, vegetables, french-fries and potato specialties. Data on plant processing capacity or volume of vegetables processed is not available in the public domain.

- Moraitis wholesales and packs a large range of fresh produce including brushed, washed & red potatoes; brown, red & white onions; pumpkin; oranges; tomatoes; and melons, among others. Statistics (on volume of product handled and resultant waste) by the Victorian operations of Moraitis in the month of March'09 are detailed below:

Waste materials generated - by Format; Volume; and Seasonality
Confidential information removed

Information / data on horticulture waste streams generated by the other four players are not available in the public domain. This information was not sought via primary research (interviews) as it was beyond the scope of this project and the Client had communicated to the Project Consultants (on contract execution) that they wished to contact these Processors directly when they deemed it was necessary.

Current method of disposal of these waste streams - including waste management companies used, price paid per tonne etc.
Confidential information removed

Information / data on horticulture waste streams generated by the other four players are not available in the public domain. This information was not sought via primary research (interviews) as it was beyond the scope of this project and the Client had communicated to the Project Consultants (on contract execution) that they wished to contact these Processors directly when they deemed it was necessary.

4. Supermarkets Sector

Main Players

The Project Consultants gathered information on two key players in this segment:
- Coles; and
- Woolworths.

Location of plant / processing facility / point of waste generation;

Both the above chains have warehouses and stores spread all over Australia.

[15] http://www.mccainhealthychoice.com.au/About.aspx

Horticultural materials processed / handled - by Product & Volume;

A wide range of fresh, frozen, canned and processed fruits and vegetables are handled by both the supermarket chains. Data on volumes of products handled by the two groups is not available in the public domain and nor was it provided to the Project Consultants when contact was made with the two supermarkets on email and phone using a questionnaire.

Waste materials generated - by Format; Volume; and Seasonality;

Confidential information removed

Current method of disposal of these waste streams - including waste management companies used, price paid per tonne etc.

Confidential information removed

Environmental sustainability policy

- Coles: Information not available in the public domain.

- Woolworths[16]:
  - According to the Group's Corporate Responsibility Report 2008, WoW has identified several ways to work towards reducing its waste to landfill. One key initiative is to eliminate its organic waste from the general waste stream by 2015 (where receiving facilities are available).
  - 53 of its Sydney stores currently send their organic waste to Earth Power, Australia's first regional food waste to energy facility. The process produces biogas, which is used as fuel for engines to generate renewable energy. In its Sustainability Strategy 2007-15, WoW has committed to increasing this to 100 stores by 2010.
  - "In 2007-08, 5,354 tonnes of organic waste was sent to Earth Power. This generated an estimated 1,750 MWh in electricity."
  - "Another initiative for diverting food waste from landfill is its partnership with Foodbank. Foodbank is the largest hunger relief charity in Australia. Since 2004, WoW has been donating food and grocery products to Foodbank as a way of helping the community while reducing waste. Woolworths Distribution Centres donate food products with damaged outer packaging or short use by dates. These products are safe for human consumption but unsuitable for retail sale. Volunteers at Foodbank sort, store and distribute the product to accredited welfare agencies throughout Australia. Welfare agencies use the food and groceries in the preparation

[16] Corporate Responsibility Report 2008, http://crreport08.woolworthslimited.com.au/

of meals or distribute it in food parcels for those in need. Our stores donated just over 1,250 tonnes of food in the 2007–08 year."

- "WoW aims to eliminate organic waste from its general waste stream by 2015, subject to the availability of appropriate facilities. At present, 53 of its Sydney stores send source separated organic waste to the EarthPower facility in Sydney's west for processing into compost, fertiliser and green power. WoW will increase the number of Sydney stores using EarthPower in 2009–10 and investigate other similar facilities around Australia. However, at the present time the number of suitable facilities outside Sydney is limited. In recent years, technologies have been developed that divert waste from landfill and minimise environmental impacts by treating organic wastes, such as food, and processing them into useful resources, such as compost, fertiliser, green electricity and treated water. However, these facilities are still limited and not available everywhere. Long lead-times are required for new facilities to be approved and constructed and they require a critical mass of input material and long term contracts to be commercially viable. WoW will continue to investigate the feasibility of this option in consultation with its service providers."

5. Wholesale Markets Sector

Context

According to the Central Markets Association of Australia, the wholesale markets are a major distribution hub for horticultural produce in Australia. It is reported that 21.5 million Australians consume horticultural produce that has been handled by the various Central Markets.[17]

"A Central Market is the main wholesale fresh fruit and vegetable market serving a state or region. Central Markets provide an efficient and effective wholesale marketing distribution hub ensuring consumers have ready access to fresh fruit and vegetables. "

In Australia, Central Markets are located in Brisbane, Sydney, Melbourne, Adelaide, Perth and Newcastle.

Snapshot

The six Central Markets provide the industry with:

[17] Central Markets Association of Australia; http://www.sydneymarkets.com.au/documents/CMAABro.pdf

- Over 400 primary wholesalers / marketers;
- Total throughput of more than $ 6 billion;
- Total throughput volume of approximately 4 million tonnes;
- More than 11,000 market-based employees nationally;
- Investment of more than $1 billion in the horticulture industry by market owners and tenants".[18]

Given the scope of this project, the Project Consultants concentrated their efforts on the east coast of Australia and contacted the Central Markets in Sydney, Melbourne and Brisbane.

Main Players

- Melbourne Market Authority;
- Sydney Markets Ltd;
- Brisbane Markets Limited (operating commercially as Brismark, an unlisted public company).

Location of plant / processing facility / point of waste generation

Focusing on the east coast of Australia:

- Melbourne Markets: 542 Footscray Road, West Melbourne, Victoria – Melbourne Markets is moving to a new location at Epping in 2011.[19]

- Sydney Markets: 250-318 Parramatta Road, Homebush West, NSW

- Brisbane Produce Markets: situated at Rocklea, 11 kilometres from the Brisbane CBD

The Project Consultants did not survey the Newcastle Markets (NSW).

Horticultural materials processed / handled - by Product & Volume

- An estimated 2,500,000 tonnes of fresh fruits and vegetables are sold through Sydney Produce Market and Sydney Growers Market annually, valued at $ 3.0 billion[20].
- An average of over 600,000 tonnes (out of a total volume of 4 million tonnes for the Six Central Markets) of fresh fruits and vegetables pass through the Brisbane Produce Market each year- valued at $ 1.01 billion.[21]

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[18] Source: Brisbane Markets Limited, Brisbane Produce Market; The Central Market System; http://www.brisbanemarkets.com.au/cms/index.php/BPM-Brisbane-Produce-Market-Overview.html
[19] Source: Melbourne Markets Authority Annual report 2007/08; http://www.melbournemarkets.com.au/myfiles/AnnualReport07-08.pdf
[20] Source: Sydney Markets ; http://www.sydneymarkets.com.au/aboutus/market_facts.html
[21] Source: Brisbane Markets http://www.brisbanemarkets.com.au/cms/index.php/BML-Brisbane-Markets-Limited-Overview.html

Waste materials generated - by Format; Volume; and Seasonality;

- The Project Consultants were informed that certain specific data sought was deemed commercial-in-confidence and unavailable for public dissemination.

Current method of disposal of these waste streams - including waste management companies used, price paid per tonne etc.

- According to various sources, the main methods of disposal of what is termed "green" or "organic" waste are landfill or stockfeed.
- The disposal costs associated with green or organic waste is commercial-in-confidence and was not disclosed.

6. Waste Management Companies

The following waste management companies were interviewed by the Project Consultants:

JED Waste

Confidential

Veolia

Confidential

Thiess Services

- The Project Consultants contacted Thiess Services, Sydney, who supply waste disposal services to retail supermarket chains. Thiess did not respond to the questionnaire emailed by the Project Consultants.

7. Fruit and Vegetable Waste Management - Statistics & Strategies

Compost Australia (part of Waste Management Association of Australia), has collated the following statistics on food waste (organics) received / processed by State for the 2006/07 Financial Year:

Figure 5:

Material Processed	Unit	National Total	NSW & ACT Total	WA	SA	VIC	QLD
Food organics (food waste)	Tonne	79,272	48,920	575	3,981	25,796	NA

Source: Compost Australia, Recycled Organics Unit, 2007 Organics Industry Survey Results – Aggregated, Industry Statistics 2007

NSW and ACT top the list in the table above, followed by Victoria. This is in line with the fruit and vegetable processing activity established in these regions.

Furthermore, according to the Federal Department of the Environment, Water, Heritage and the Arts (DEH), Australia sends over 21 million tonnes of solid waste to landfill annually. From this, over 40% i.e. 8.4 million tonnes[22] constitutes putrescible organic material, which includes green organic and food waste. Research suggests that organic waste is of low density, could take up double the volume of landfill compared to other waste and is claimed to contribute to greenhouse gas emissions. This type of waste therefore, places a significant burden on landfill sites in Australia.

Reports also indicate that in 2000, DEH conducted an assessment of the organics recycling industry in Australia. The assessment highlighted the following impediments[23] restraining the industry nationally in dealing effectively with organic waste:

- "Poor market development and consumer awareness for recycled organic products, leading to low prices for processors and minimal profit margins, discouraging market entry;
- Lack of industry cohesion leading to low rates of technology transfer;
- Lack of suitable and uniform product and process standards leading to consumer suspicion and lack of product definition;
- Poor training of processing staff resulting in environmentally undesirable processing practices and poor product;
- The high cost of transporting recycled organic material to those areas where it can do the most good;
- Contamination of putrescible materials with non-putrescibles;
- Lack of research funding to assist the industry to maximise recycling of waste organic material profitably."

The above research is dated; however, industry information is scant as the infrastructure to gather data on food waste is not well developed in Australia as yet.

The Cost of Solid Waste

The Queensland Government released a study titled "Solid waste reduction and value adding" on their Industry Development website which discusses the "true cost of solid waste". The study[24] states that:

"The disposal of large amounts of solid waste to landfill is expensive, and is generally an in-efficient use of resources. Food processing companies in Australia are starting to realize the value of managing their solid waste to identify where

[22] Source: www.**environment**.gov.au/settlements/waste/**organics**.html
[23] Source: www.**environment**.gov.au/settlements/waste/**organics**.html
[24] Source: http://203.210.126.185/dsdweb/v4/apps/web/secure/docs/1657.pdf

product and revenue are being lost. Solid waste recycling rates in the food sector are high. A recent Australian Food and Grocery Council survey indicated that the average proportion of product sent as waste to landfill by food and grocery manufacturers in Australia is 4%, and the recycling and reuse of inorganic waste is around 80% (AFGC 2003). **The remaining 16% consists of organic material that is further utilised for products such as compost or stock feed.**

The true cost of generating and disposing of solid waste can include:
• treatment costs;
• collection costs;
• disposal costs;
• loss of product costs, including processing and raw material costs.

Waste collection and disposal in Australia is highly subsidised through a range of mechanisms. Thus, the true cost of these services to society is actually greater that what is currently charged to industry.

Reducing the loss of materials and improving the rate of reuse, recovery and recycling of valuable resources to reduce costs, increase revenue and avoid disposal of waste to landfill is a very important aspect of eco-efficiency."
These are some of the strategies being promoted by state governments for better waste management in support of eco-efficiency.

Reusing Solid Waste

A report[25] published by the Queensland Government, highlights that "if foodstuffs are to be reused, rigorous application of the Hazard Analysis and Critical Control Points (HACCP) food safety program is necessary".

They go on further and re-iterate that "Food processing often has waste that could provide stock with valuable roughage, energy and protein. While the disposal of food through animal feeding is common in the vegetable, bread baking and dairy processing sector, transport and collection costs are often prohibitive. Note that to ensure Australian meat products have access to domestic and international markets, food waste that contains animal matter (meat, meat products or imported dairy products) or vegetable matter contaminated by animal matter should not used as animal feed".

[25] Source: Queensland Government, Reusing Solid Waste And Product Recovery – R3, Eco-efficiency resources for the food processing industry, Direct reuse of waste, http://www.ecoefficiency.com.au/Portals/56/factsheets/foodprocess/waste/ecofoodwaste_fsr3.pdf

VI. PET (DOG & CAT) FOOD TOXICITY TO HORTICULTURAL PRODUCE

(a) What constitutes a balanced diet?

According to the National Research Council (USA) and based on data in the publication, Nutrient Requirements of Dogs and Cats*:* "Dogs need several different kinds of nutrients to survive: amino acids from proteins, fatty acids and carbohydrates, vitamins, minerals and water" [26].

- To ensure that ingredients of pet food meet the requirements of a "complete and balanced" diet, the Association of American Feed Control Officials (AAFCO), Dog and Cat Food Nutrient Profiles are based on Canine and Feline Nutritional Expert Subcommittees' " ...knowledge of published and unpublished research, as well as their personal expertise and experiences in practical formulation"[27] .
- These AAFCO Nutrient Profiles were established as much to mitigate against the risk of nutrient excess as they were to deficiency.
- It is important that the diets of dogs and cats are tailored to a) Growth and reproduction and b) Adult maintenance with some pet food labels indicating that they cater for all life stages.
- A balanced diet should eliminate excesses and allow dogs and cats to achieve and maintain good health.
- Understanding the AAFCO statements for nutritional adequacy can help customers choose a high-quality diet that provides complete and balanced nutrition for the appropriate life stage of their dog or cat.

According to CHOICE[28], no Australian standards exist for dry or canned dog food.

(b) What horticultural produce are they allergic to?

The Project Consultants interviewed two veterinary practitioners (see Annexure 1, point 11, Veterinary Practitioners).

In summary:

Dr Sarah Haldane (Victoria) said:

[26] Source: Your Dog's Nutritional Needs – A Science-Based Guide for Pet Owners; National Research Council of the National Academies; http://dels.nas.edu/dels/rpt_briefs/dog_nutrition_final.pdf
[27] John D Borogua & David C Twedt; Kirk's Current Veterinary Therapy XIV; Appendix III, AAFCO Dog and Cat Food Nutrient Profiles, © 2009, SAUNDERS Elsevier Inc
[28] Source: Pet food – a guide to dog and cat nutrition; http://www.choice.com.au/printFriendly.aspx?ID=105738

- Food allergy in pets is more often related to proteins (meat sources) than from fruits and vegetables;
- Toxic fruits, vegetables and nuts include: onions, grapes/raisins, macadamia nuts, potentially stone fruit seeds (cyanide containing);

Dr Jane Rickard (NSW) listed the following items that should be avoided in any dietary formulations:

- Macadamia nuts (dogs)
- Chocolate and Cocoa (dogs and cats)
- Coffee
- Tea
- Onions
- Garlic
- Green skin on potatoes
- Avocado plants
- Rhubarb
- Kelp (copper overload)
- Aflatoxins from peanuts / corn
- Toadstools

(c) Which fruits & vegetables provide anti-oxidants and other necessary nutrients?

- Vegetables do not add many calories and do not contribute to obesity – pumpkin, carrot etc are excellent sources of nutrition.
- Health issues such as gluten intolerance are growing in incidence for dogs.
- Cats require taurine and carnotine to ensure good health; dogs can be fed cat food but cats cannot be fed dog food.
- It is important to keep the calcium: phosphorous ratio in balance at 1:1. Too much phosphorous (from plants) and not enough calcium could lead to calcium deficiency.

(d) Any other relevant information useful to this project

Two pieces of information are relevant:

- It is important to be aware that dogs do not digest cellulose efficiently.
- Health issues such as gluten intolerance are growing in incidence for dogs.

VII. KEY FINDINGS & RECOMMENDATIONS

The Project Consultants would like to report the following key findings:

- In order for horticultural waste to be diverted towards pet food manufacture, such **waste** will need to be **segregated** at the point of waste generation (often, waste produce arrives at disposal companies in cartons and polystyrene containers) – the **quality of waste and length of time** will be important to consider from a quality control perspective;

- **Food safety issues** need to be considered both for the pets and Environmental Health & Safety issues for the handlers;

- **Seasonality and availability** of specific horticulture waste will need to be taken into consideration to **ensure reliable supply**;

- **The capacity for the recipient company to accept and process potentially large volumes of green waste** will need to be taken into account depending on the seasonality and availability of specific products;

- **Supply chain and storage of waste** from point of generation to point of processing will need to be clearly mapped out;

- **Transportation of waste (including cost of transport)** will be a key consideration as it is mostly water – will it be feasible to install dryers on the waste generation site or perhaps a fit-for-purpose **waste processing facility at the point of generation** to convert it into say powder or dried product for use in the pet food facility;

- **Good quality, contemporary and comprehensive data does not exist in the public domain** – horticulture waste is not segregated from other food organic waste such as meat;

- Industry is **circumspect and often unwilling** to share **information** which **is considered commercial-in-confidence**.

ANNEXURE I & II

Questions & Responses from interviews
Information held in confidence

Annexure III

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Appendix 2 Fruit and vegetables as a source of nutrients for companion animals

Fruit and vegetables as a possible source of nutrients for companion animals

Authors names held in confidence

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EXECUTIVE SUMMARY

The objective of this report was to determine the feasibility of adding whole fruit and vegetables as nutrient sources in pet food. The expectation was that a short list of materials would be identified that would provide high quality nutrients to cat and dog food. The Evaluation Process involved removing fruits and vegetables of low availability, low nutrient content and those that were significantly affected by thermal processing. This was undertaken to identify a short list of viable raw materials.

As a result of this Evaluation Process, it was found that no single fruit or vegetable material, in either its raw or processed state, was able to provide significant levels of nutrients to the diet. The majority of the fruits and vegetables assessed in this process were eliminated due to low nutritional content or significant losses in nutrients when they underwent standard food processing. Although lentils were found to provide reasonable levels of some key nutrients for dog diets, the inclusion level of this material would be limited by known anti-nutritional factors and would require food safety clearance before it could be introduced.

It is possible that some of the eliminated fruit and vegetable materials could be made suitable for use in pet foods providing their nutritional content could by conserved and concentrated.

INTRODUCTION

Studies in the United States of America (Baker & Czarnecki – Maulden, 1991) have placed dogs and cats residing in 30 and 36% of households respectively. In Australia, 64% of households have one or more pets, with dogs being more common than cats (Petnet 2004, cited by Denniss 2004).

Pet food represents one of the most rapidly growing areas of the feed industry (Baker & Czarnecki – Maulden, 1991). In the US alone pet food sales increased 329% in dollar terms to approximately $8 billion dollars between 1970 and 1989 (Baker & Czarnecki – Maulden, 1991). In Australia, pet owners spent more than $1.5 billion dollars in pet food and pet care products in 2003 (Denniss, 2004). A significant consumer trend towards purchasing more premium pet food has become evident over the past few years (Denniss, 2004).

In terms of complexity, pet food diets contain a greater variety of ingredients, flavour varieties and use of by-products than livestock diets. At present, the most common types of pet food servings for dogs and cats are dry, semi moist and canned products (Baker & Czarnecki – Maulden, 1991). The processing method used to prepare these diets (extrusion and thermal processing) often results in significant losses of nutritional value of the ingredients (Baker & Czarnecki – Maulden, 1991), requiring over-supplementation to meet the nutritional requirements.

Fruit and vegetables play a significant role in human nutrition, due to their low cost, wide availability and good nutritional value. Fruit and vegetables are typically high in vitamins, usually low in calories and fat and have no cholesterol, making them healthy additions to human diets (Gast, 1991).

Fruit and vegetables are also frequently used in wet pet food formulations at low inclusion levels (up to 5%) for aesthetic purposes and to a lesser degree in dry pet food formulations, mainly for functional benefits. They are often human-grade, premium quality materials (Confidential, 2008 *pers comm.*). By-products such as soybean meal and corn gluten meal are also used in pet food.

The inclusion of high levels of vegetable matter in cat diets is limited as cats do not have the dentition or digestive function to process vegetable matter. In contrast, dogs are considered omnivorous and are able to consume more vegetable matter in their diet. However, high levels of vegetable matter can impact on palatability and digestibility in both cats and dogs.

OBJECTIVES

The objective of this report is to determine the feasibility of adding fruit and vegetables, as nutrient sources, in pet food. It is expected that a short list of fruit and vegetables will be identified for further evaluation.

METHODOLOGY

Data sources

A review of public domain information pertaining to the nutritional values of fruit and vegetables and the nutritional requirements of cats and dogs was initially conducted. Key data sources included:

- United States Department of Agriculture (USDA) Nutrient Data Library Standard Reference, Release 22
- The Association of American Feed Control Officials (AAFCO) Official Publication 2009. Nutrient Profiles based on Dry Matter

In Australia, the pet food industry is self-regulated, with members of the industry taking an active role in establishing a code of practice for the manufacture and marketing of pet food. The Pet food Industry Association of Australia (PFIAA) code of practice bases its guidelines for pet food nutritional recommendations and standards on those formulated by AAFCO.

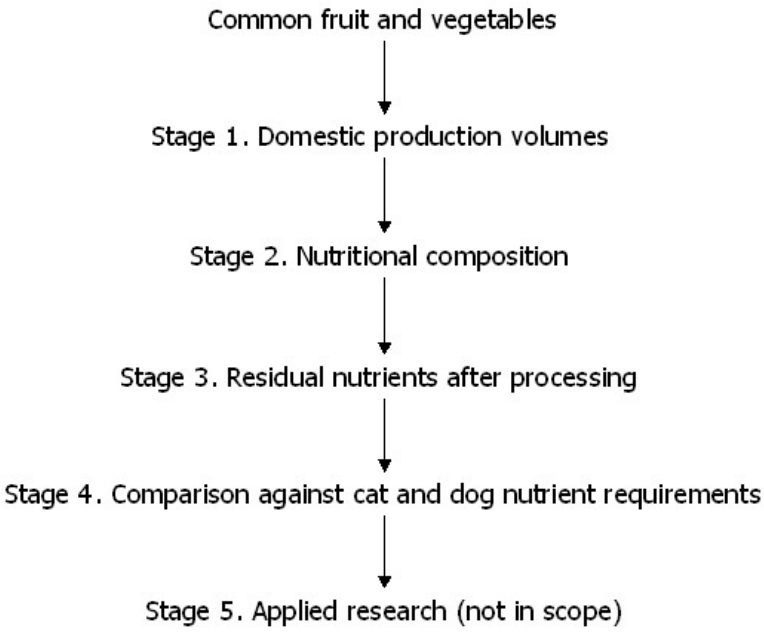
Through the comparison of the USDA Nutrient Data Library data with the AAFCO nutrient profiles, it was noticed that not all essential nutrients for cats and dogs are routinely reported for food samples listed in the USDA. For example, iodine has been identified in the AAFCO nutrient profiles as being essential for cat and dog nutrition, but it is not commonly measured in the samples in the USDA Nutrient Data Library. For such ingredients it was decided to exclude them from further investigation. Although not measured as part of this reference library it does not indicate the nutrient is absent, just that it is not recorded.

Overview of the Evaluation Process

A list of common fruit and vegetables was created and then each was assessed for their suitability as pet food ingredients according to the Evaluation Process identified in Figure 1. Specifically, individual fruit and vegetables were excluded in stages based on (1) low micronutrient concentration, (2) nutritional value after processing, (3) availability in Australia and (4) comparison against dog and cats nutritional values. It was further planned that other materials would be removed or selected due to applied research, after which viable materials could be subsequently commercialised (outside the scope of this report).

Although some materials may be excluded as part of the criteria above, it should not limit their consideration in future scientific research exploring potential functional benefits in addition to those high value micronutrients that will be considered in this report (section on Alternative application opportunities), which deliver enhanced nutrition to the cat or dog.

Figure 1: Evaluation Process used to identify a short list of fruit and vegetables



The following sections provide additional information on each of the stages in the Evaluation Process that were used in this report.

Selection of commonly available fruit and vegetables

At present, there are approximately 60 types of fruit and 30 types of vegetable commonly available in supermarkets in Australia. During the initial stages of the research project various resources (mainly journal articles related to research on fruit and vegetables) were used to produce a list of commonly available fruit and vegetables in the food industry.

This list of produce was reduced by selecting fruits and vegetables that:

- Were believed to be more commonly used in everyday life, i.e. no exotic fruits were selected
- Had no known toxicity effects, e.g. onions are considered toxic for dogs and were removed

Stage 1. Domestic production volumes

The Australian Bureau of Statistics (ABS) report on Agricultural Commodities for the period 2006-07 was reviewed to determine the production volumes of the short-listed fruit and vegetable produce. Additional data was sourced if there were no production volumes in the ABS report. Removing produce that had low production volume further refined the short-list of common fruit and vegetables.

Stage 2. Nutritional composition

The nutritional values of the selected fruit and vegetables were sourced from the USDA Nutrient Data Library and converted to the same units of measure used in the AAFCO nutrient profile based on dry matter.

This stage of the Evaluation Process involved identifying those materials where the concentration of the nutrient was amongst the three lowest measured in all the fruit and vegetable materials considered. The process was replicated for each individual nutrient and the number of incidences of low nutrient concentration tallied. Finally, all fruit and vegetable materials that had multiple incidences of low nutrients, greater than the average of all materials, were removed from the short list.

Stage 3. Residual nutrients after processing

Food processing losses can have a significant impact on the nutritional quality of the diet (Jackson *et al* 1999). In particular, processes that involve water, such as boiling, may induce leaching of water-soluble vitamins and minerals and reduce the concentration of the nutrient in the food (Jackson *et al* 1999). Water-soluble vitamins are less stable than fat-soluble vitamins against thermal processes and oxidation (Jackson *et al* 1999). Processes that result in dehydration of the food, such as baking or drying, will tend to increase mineral concentrations (Jackson *et al* 1999). Thermal processing also tends to increase mineral bioavailability, due to the destruction of plant anti-nutritional factors that inhibit absorption of the nutrients (Jackson *et al* 1999).

To extrapolate the nutrient losses that would occur as a result of pet food manufacturing, the impact of typical commercial food processing methods on the whole fruit or vegetables were reviewed. This approach was taken due to limited data on the impact of typical manufacturing processes in the pet food industry on the nutritive value of fruit and vegetables.

The USDA Nutrient Data Library was used to gather the nutritional data of fruit and vegetables prepared using various food processing methods (for example boiling, cooked). The impact of these processing methods on nutritional content was evaluated by comparing the change in individual nutrient levels between the raw and processed fruit or vegetable. This analysis was initially conducted on six randomly selected samples of fruit and vegetables to determine if there was a discernable pattern within methods of processing. Subsequently, the processing method that had the most significant impact on the overall nutritional value was then used to evaluate the overall change in nutritional profile across the fruit and vegetables short list.

Where the fruit or vegetable sample already had low nutrient values (determined in previous stage) and showed a trend towards a decrease in overall nutrient composition due to processing, it was removed from the sample set. Any produce that showed a decrease in overall nutrient composition with processing

but had a high nutrient value was retained in the sample set. Produce, which had high nutrient value and showed no or little decrease in overall nutrient composition were also retained in the sample set.

Stage 4. Comparison against cat and dog nutrient requirements

The AAFCO Official Publication (2009) provided cat and dog nutrient requirements. A copy of these tables can be found in Appendix 2. A description of the role that the individual nutrient plays in cat and dog nutrition can be found in Appendix 3.

The AAFCO (2009) nutrition values for dogs and cats were divided into two criteria. One based on basic growth and reproduction and the other on nutrition levels for adult maintenance. The general trend observed showed the requirement for puppies and kittens to be either greater than or equal to the nutritional requirement of the adult. As adult maintenance diets represent the most significant portion of the pet food manufactured, and the recipes of growth products are less flexible to change, it was decided that the adult maintenance nutrient profiles would be used in the evaluation of the fruit and vegetable samples. The nutritional profile of individual fruit and vegetables was compared against the AAFCO nutritional profiles to determine which fruit and vegetables would be suitable for inclusion in the diets of cats and dogs.

It was assumed that the fruit or vegetables chosen would be included at 5% of the animal's diet. This value was used as it represents the inclusion level of typical material with high fibre content and would also minimize the effects of any plant anti-nutritive factors on palatability, digestibility and nutrient bioavailability.

As it was recognised that individual fruit or vegetable materials were unlikely to deliver the complete daily requirement for that nutrient when included at 5% of the animal's diet, it was determined that acceptable sources would be noted. "Good" fruit and vegetable sources were those that would deliver 25% of the total nutrient requirement when the fruit or vegetable was included at 5% of the food.

Stage 5. Applied research

It is further planned that other materials will be removed or selected due to applied research, after which viable materials could be subsequently commercialized. Applied research could include nutritional analysis and feeding trials using cats and dogs. Activities related to Stage 5 do not form part of this report.

Alternative application opportunities (high value micronutrients)

Also present in a number of foods are nutrients that do not have an established minimum nutrient requirement for cats and dogs, but dietary supplementation with these materials has still been shown to be beneficial to pets. These include beta-carotene, lycopene, Vitamin C, phenols and polyphenols. These

nutrients are of higher commercial value than those used to meet the nutritional requirements of cats and dogs and will therefore be evaluated separately to the Evaluation Process used in this report.
As noted in the description of Stage 3, food processing can impact on the nutritional quality of the diet. It has been shown that thermal processing of grape pomace peels at temperatures above 100^{o}C can significantly reduce polyphenol content (Larrauri *et al* 1997). Conversely, thermal processing of carrots results in isomerisation of lycopene increasing its bioavailability (Mayer-Miebach *et al* 2005).

The total concentration of beta-carotene, lycopene, Vitamin C, phenols and polyphenols were reviewed for the raw fruits and vegetables in the list of materials remaining after Stage 1 of the Evaluation Process, which ensures only those with reasonable production volumes were assessed. The concentration of the individual nutrients was then compared against confidential information as supplied by a major petfood manufacturer.

Additionally, where available, the residual nutrient concentration after processing was also reviewed for these fruits and vegetables.

RESULTS

Evaluation Process summary

A short-list of 20 fruit and vegetables was produced that met the criteria of being commonly available in Australia and having no known anti-nutritional factors. Table 2 contains a summary of the results achieved using the Evaluation Process identified in Figure 1. The first column of Table 1 contains the list of samples that were selected for further evaluation using the process described in the Methodology section. The remaining columns of Table 2 contain the list of fruit and vegetable materials that remained after each stage of the Evaluation Process.

Table 2. Summary of the fruit and vegetable materials as they progress through the Evaluation Process identified in Figure 1.

Commonly available in supermarkets	**Stage 1. Domestic production volumes**	**Stage 2. Nutritional composition**	**Stage 3. Residual nutrients after processing**	**Stage 4. Comparison against cat and dog nutrient requirements**
Bananas	banana	banana	banana	
Strawberries	strawberry	strawberry		
Melon (honeydew)	melon (honeydew)			
Peach	peach			
Orange	orange			
Pineapple	pineapple			
Pear	pear			
Apple	apple			
Kidney beans				
Lentils	lentils	lentils	lentils	lentils
Spinach				
Carrots	carrots	carrots		
Broccoli	broccoli	broccoli	broccoli	
Cauliflower	cauliflower	cauliflower		
Snow peas				
Asparagus				
Lettuce	lettuce	lettuce		
Corn	corn	corn	corn	
Potato	potato	potato	potato	
Soybean				

Detailed Results

Stage 1. Domestic production volumes

Table 3 contains the Australian production volume and data source for each fruit and vegetable type listed in Table 2. Following a review of the production volumes, it was determined that kidney beans, spinach, soybeans, snow peas and asparagus had insufficient production volume to warrant further investigation and these materials were removed from the review. The second column of Table 2 contains the refined list of fruit and vegetables.

Table 3. Production volume of fruit and vegetables grown in Australia

Sample	2007 ABS data	Other data sources	Eliminated?
Kidney beans		none[a]	Yes
Lentils		131,000[b]	
Spinach		none[a,b]	Yes
Banana	213,193		
Carrots	271,464		
Broccoli	46,031		
Cauliflower	69,793		
Strawberries	28,559		
Snow peas		1,000[c]	Yes
Melons (honeydew)		82,990[d]	
Asparagus	5,609		Yes
Lettuce (green leaf)	271,251		
Peach	81,569		
Orange	470,673		
Pineapple	164,732		
Pear	134,764		
Apples	276,427		
Corn	62,575		
Potato	1,211,988		
Soybeans		none[a,b]	Yes

[a] The "none" value in Table 2 for soybean and spinach is interpreted from results found on Wikipedia which identified that although Australia is and can produce both soybean and spinach, there is not a sufficient volume to identify Australia as a leading producer.
[b] Data source Wikipedia
[c] Data source ANRA
[d] Data source US report on melons

Stage 2. Nutritional composition

Table 4 contains the record of the number of incidences of low nutrient concentration for each of the fruit and vegetable materials remaining after Stage 1. Based upon this information it was determined that melons (honeydew), peaches, oranges, pineapples, pears and apples had insufficient nutrient value to remain in the study and were removed from the list. The refined list can be found in the third column of Table 2.

Table 4. Number of incidences of low nutrient concentration

Sample	Essential amino acids	Minerals	Vitamins	Score	Eliminated?
Lentils	0	0	0	0	
Bananas	0	2	2	4	
Carrots	1	1	0	2	
Broccoli	0	0	2	2	
Cauliflower	2	0	4	6	
Strawberries	0	0	1	1	
Melon (honeydew)	7	6	2	15	Yes
Lettuce (green leaf)	1	1	2	4	
Peach	3	4	3	10	Yes
Orange	3	5	2	10	Yes
Pineapple	5	4	2	11	Yes
Pear	12	6	8	26	Yes
Apples	13	10	8	31	Yes
Corn	0	1	2	3	
Potatoes	1	1	4	6	
			Average	**8.7**	

Stage 3. Residual nutrients after processing

The impact of typical commercial processing techniques on the remaining fruit and vegetables was investigated by comparing nutrient loss or concentration between the raw and processed material on an "as is" basis. Table 5 displays the trend towards an increase (+) or decrease (-) in nutrient composition for each of the amino acids, minerals and vitamins. Lettuce, cauliflowers, carrots and strawberries were removed from the list. The refined list can be found in the fourth column of Table 2.

Table 5. Impact of typical commercial processing techniques on nutrient profiles of fruit and vegetables

Sample	Essential amino acids	Minerals	Vitamins	Eliminated?
Lentils	-	-	-	
Bananas	+	+	+	
Carrots	-	-	-	Yes
Broccoli	-	+	+	
Cauliflower	-	-	-	Yes
Strawberries	No data	No data	No data	Yes - perishable
Lettuce (green leaf) [a]	-	-	-	Yes
Corn	-	+	-	
Potatoes	-	-	+	

[a] As there is no data for lettuce, trend information from cauliflower was used instead
+ trend towards an increase in nutrient concentration
- trend towards a decrease in nutrient concentration

The following section describes the rationale behind removing or retaining each of the fruit and vegetables from the list.

Although lentils, corn, potatoes and broccoli showed an overall decrease in nutrient concentration due to processing they had a good nutrient profile and in the case of potato, the nutrient loss due to processing was minor. Therefore, these samples were retained in the list.

It should be noted that the typical processing method for bananas is dehydration, which would lead to an increase in overall nutrient composition on an “as is” basis, as shown in Table 5. Unprocessed banana has a poor amino acid profile compared to corn and carrots but a better mineral profile than both. It also had a similar or better vitamin profile to carrot, although it was not as good as corn. Bananas were retained in the sample list, as it was an intermediate between these materials.

Although lettuce was not further processed in the food industry, it typically has a quarter to a half of the nutrient concentration present in raw broccoli and cauliflower. Overall the nutrient profile of lettuce is closer to cauliflower. The exception is Vitamin A, of which lettuce has significantly greater concentrations (>10 times) compared to raw broccoli and cauliflower. Therefore, it can be assumed that similar changes in nutrient composition would occur to lettuce if it were processed in the same manner as cauliflower. As cauliflower showed an overall decrease in nutrient composition following cooking, it was removed from the sample set. The logic presented above also supported the removal of lettuce from the sample set.

The typical processing method for strawberries is freezing, although preservation of strawberries in syrups is also common. Preservation would have the most impact on nutrient profile, but is dissimilar to the processing methods used in the pet food industry and, therefore, it would not offer a suitable comparison. Strawberries were ultimately removed from the sample set, as they are highly perishable and have a limited shelf life.

Carrots were removed from the list, as they had a low nutrient concentration compared to other vegetables and also exhibited a loss in nutrients following processing.

Stage 4. Comparison against cat and dog nutrient requirements

The nutritional value of the fruit and vegetables for both cats and dogs was subsequently evaluated by comparing the contribution of the material to the nutrient requirements of the animals, when included at 5% of the diet. It was found that potatoes, corn, broccoli and bananas would not significantly contribute to the nutritional requirements of cats or dogs at this inclusion level, which lead to them being removed from the list. The refined list can be found in column 5 of Table 2. Table A1 in Appendix 1 contains the contributions of individual fruit and vegetable samples against the Adult Maintenance nutritional requirements for cats and dogs.

Raw lentils appear to be a good source of Vitamin B1 (thiamine), Vitamin B6 (pyridoxine), folic acid and histidine for dogs only, although losses would still occur during thermal processing. Apart from folic acid, lentils would not substantially fulfill the nutritional requirements of cats. It should also be noted that lentils contain a number of known anti-nutritive factors, including trypsin inhibitors, phytic acid, tannins and oligosaccharides, which may not be totally destroyed by thermal processing (Vidal-Valverde *et al* 1994). The presence of these anti-nutritional factors may therefore limit the inclusion level of lentils in dog food and would also require a food safety clearance before they could be introduced.

Alternative application opportunities (high value micronutrients)

In addition to understanding how fruit and vegetables might deliver basic nutrition to cats and dogs, this report aimed to understand the value of these materials in providing enhanced nutrition to cats and dogs through the presence of high value micronutrients with antioxidant properties. The concentration of phenols, lycopene and beta-carotene in the fruit and vegetable sample set, following Stage 1, were determined by reviewing the USDA Nutrient Data Library and other data sources. Table 6 contains the antioxidant content of these materials.

Table 6. Antioxidant content of commonly available fruits and vegetables

		Total phenols (Source Vinson et al 1998, 2001)		**Beta – carotene**	**Lycopene**
		umol/g	**umol/g**	**ug/100g**	**ug/100g**
		Dry weight	**Wet weight**		
Lentils	Raw			23	0
Bananas	Raw	42.3 ± 8.1	11.2 ± 2.1	26	0
Carrots	Raw	15.3 ± 7.3	1.6 ± 0.8	8285	1
Broccoli	Raw	40.6 ± 22.3	3.6 ± 0.8	361	0
Cauliflower	Raw	20.9 ± 8.8	1.8 ± 0.2	8	0
Peaches	Raw	27.9 ± 7.7	2.4 ± 0.7	162	0
Orange	Raw	18.9 ± 10.7	1.4 ± 0.8	71	0
Pears	Raw	41.4 ± 4.9	6.6 ±0.7	13	0
Apples	Raw	34.1 ± 4.8	6.4 ± 0.9	27	0
Corn	Raw	19.1 ± 0.1	4.9 ± 0.3	52	0
Potatoes	Raw			1	0
Strawberries	Raw	72.3 ± 11.0	4.6 ± 0.7	7	0
Lettuce	Raw	16.9 ± 8.1	0.8 ± 0.4	4443	0
Melons (honeydew)	Raw	11.4 ± 4.7	1.3 ± 0.5	30	0
Pineapple	Raw	11.9 ± 6.0	2.3 ±1.2	34	0

It was found that carrots and lettuce had the highest concentration of beta-carotene, whilst strawberries, pears, bananas and broccoli had the highest concentration of phenols on a dry matter basis. None of the fruit or vegetable materials assessed had significant quantities of lycopene, which is found in high concentration in tomatoes and watermelons (neither assessed in this report).

Confidential information removed

CONCLUSION

In conclusion, it was found that no single fruit or vegetable material, in either its raw or processed state, was able to provide significant levels of nutrients to the diet. The majority of the fruits and vegetables assessed using the Evaluation Process were removed due to low nutritional content or significant losses in nutrients after they underwent standard food processing.

Although lentils were found to provide reasonable levels of some key nutrients for dog diets (and beyond the project scope), the inclusion level of this material would be limited by known anti-nutritional factors and would require food safety clearance before being introduced.

It is possible that some of the eliminated fruit and vegetable materials could be made suitable for use in pet foods, providing their nutritional content could be conserved and concentrated.

APPENDIX

APPENDIX 1. Raw data tables

Table A1. Comparison of nutrient profile of fruit and vegetables remaining after Stage 3 against AAFCO nutrient requirements

Macronutrient	Units	Dog Adult Maintenance Minimum	Acceptable source for Dogs	Cat Adult Maintenance Minimum	Acceptable source for Cats
Protein	%	18		26	
Arginine	%	0.51	Raw lentils (19%)	1.04	
Histidine	%	0.18	Raw lentils (20%)	0.31	Raw lentils (11%)
Isoleucine	%	0.37	Raw lentils (15%)	0.52	Raw lentils (10%)
Leucine	%	0.59	Raw lentils (15%)	1.25	
Lysine	%	0.63	Raw lentils (14%)	0.83	Raw lentils (11%)
Methionine-cystine	%	0.43		1.1	
Methionine	%			0.62	
Phenylalanine-tyrosine	%	0.75	Raw lentils (13%)	0.88	Raw lentils (11%)
Phenylalanine	%			0.42	
Threonine	%	0.48		0.73	
Tryptophan	%	0.16		0.16	
Valine	%	0.39	Raw lentils (16%)	0.62	
Fat	%	5		9	
Linoleic acid	%	1		0.5	
Arachidonic acid	%			0.02	
Taurine (extruded)	%			0.1	
Taurine (canned)	%			0.2	
Calcium	mg/100g	600		600	
Phosphorous	mg/100g	500		500	
Ca:P ratio	mg/100g	1:01			
Potassium	mg/100g	600		600	
Sodium	mg/100g	60		200	
Chloride (Cl)	mg/100g	90		300	
Magnesium	mg/100g	40	Raw lentils (15%)	40	Raw lentils (15%)
Iron	mg/100g	8		8	
Copper (extruded)	mg/100g	0.73		0.5	
Copper (canned)	mg/100g			0.5	
Manganese	mg/100g	0.5		0.75	
Zinc	mg/100g	12		7.5	
Iodine	mg/100g	0.15		0.035	
Selenium	mcg/100g	11		10	
Vitamin A	IU/100g	500		500	
Vitamin D	IU/100g	50		50	
Vitamin E	mg/100g	4.55		2.73	
Vitamin K				10	
Vitamin B1 (thiamin)	mg/kg	0.1	Raw lentils (44%)	0.5	
Vitamin B2 (riboflavin)	mg/kg	0.22		0.4	
Vitamin B5 (pantothenic acid)	mg/kg	1		0.5	
Vitamin B3 (niacin)	mg/kg	1.14		6	
Vitamin B6 (pyridoxine)	mg/kg	0.1	Raw lentils (27%) Raw potatoes (15%) Boiled potatoes (15%) Raw banana (18%)	0.4	

Folic Acid	mcg/kg	18	Raw lentils (133%) Boiled lentils (50%) Raw corn (12%) Boiled corn (12%) Raw broccoli (17%) Boiled broccoli (30%)	80	Raw lentils (30%)
Biotin	mg/kg			0.007	
Vitamin B12 (cyanocobalamin)	mcg/kg	2		2	
Choline	mg/kg	120		240	

Table A2 Antioxidant content of commonly available fruits and vegetables

		Total phenols (Source Vinson et al 1998, 2001)		**Beta – carotene**	**Lycopene**
		umol/g	**umol/g**	**ug/100g**	**ug/100g**
		Dry weight	**Wet weight**		
Kidney Beans	Raw	35.9 ± 8.2	31.6 ± 5.2	NR	NR
lentil	Raw			23	0
Spinach	Raw	27.6 ± 13.4	1.7 ± 0.4	5626	0
banana	Raw	42.3 ± 8.1	11.2 ± 2.1	26	0
carrots	Raw	15.3 ± 7.3	1.6 ± 0.8	8285	1
broccoli	Raw	40.6 ± 22.3	3.6 ± 0.8	361	0
cauliflower	Raw	20.9 ± 8.8	1.8 ± 0.2	8	0
Snow peas	Raw			630	0
Asparagus	Raw	40.2 ± 13.3	2.8 ± 0.6	449	0
peach	Raw	27.9 ± 7.7	2.4 ± 0.7	162	0
orange	Raw	18.9 ± 10.7	1.4 ± 0.8	71	0
pear	Raw	41.4 ± 4.9	6.6 ±0.7	13	0
apples	Raw	34.1 ± 4.8	6.4 ± 0.9	27	0
corn	Raw	19.1 ± 0.1	4.9 ± 0.3	52	0
potato	Raw			1	0
Soybean	Raw			0	0
Strawberries	Raw	72.3 ± 11.0	4.6 ± 0.7	7	0
lettuce	Raw	16.9 ± 8.1	0.8 ± 0.4	4443	0
melon (honeydew)	Raw	11.4 ± 4.7	1.3 ± 0.5	30	0
pineapple	Raw	11.9 ± 6.0	2.3 ±1.2	34	0

APPENDIX 2. AAFCO nutrient guidelines for cats and dogs (per 1000kcal metabolisable energy)

Nutrient	Unit	CAT Adult Maintenance		CAT Reproduction / Growth		DOG Adult Maintenance		DOG Reproduction / Growth	
		RA	SUL	RA	SUL	RA	SUL	RA	SUL
Protein	g	65		75		51.4		62.9	
Arginine	g	2.60		3.10		1.46		1.77	
Histidine	g	0.78		0.78		0.51		0.63	
Isoleucine	g	1.30		1.30		1.06		1.29	
Methionine	g	1.55	3.75	1.55	3.75				
Methionine-Cystine	g	2.75		2.75		1.23		1.51	
Leucine	g	3.10		3.10		1.69		2.06	
Lysine	g	2.08		3.00		1.80		2.20	
Phenylalanine	g	1.05		1.05					
Phenylalanine-Tyrosine	g	2.20		2.20		2.09		2.54	
Threonine	g	1.05		1.83		1.37		1.66	
Tryptophan	g	0.40		0.63		0.46		0.57	
Valine	g	1.55		1.55		1.11		1.37	
Taurine - canned	mg	500		500					
Taurine - extruded	mg	250		250					
Crude Fat	g	22.5		22.5		14.3		22.9	
Linoleic acid	g	1.25		1.25		2.9		2.9	
alpha Linolenic acid	g								
Arachidonic acid	g	0.05		0.05					
EPA/DHA	g								

Nutrient	Unit	CAT Adult Maintenance		CAT Reproduction / Growth		DOG Adult Maintenance		DOG Reproduction / Growth	
		RA	SUL	RA	SUL	RA	SUL	RA	SUL
Calcium	g	1.5		2.5		1.7	7.1	2.9	
Phosphorus	g	1.25		2		1.4	4.6	2.3	
Magnesium	mg	100		200		110		110	
Sodium	g	0.5		0.5		0.17		0.86	
Potassium	g	1.5		1.5		1.7		1.7	
Chloride	g	0.75		0.75		0.26		1.29	
Iron	mg	20		20		23		23	
Copper - canned	mg	1.25		1.25		2.1		2.1	
Copper - extruded				3.75					
Zinc	mg	18.8	500	18.8	500	34		34	
Manganese	mg	1.9		1.9		1.4		1.4	
Selenium	µg	30		30		30		30	
Iodine	mg	0.09		0.09		0.43		0.43	
Vitamin A	IU	1250	187500	2250	187500	1429	71429	1429	
Vitamin D	IU	125.0	2500	188	2500	143	1429	143	
Vitamin E	IU	7.5		7.5		14	286	14	
Vitamin K	µg	300		300					
Thiamin B1	mg	1.25		1.25		0.29		0.29	
Riboflavin B2	mg	1		1		0.63		0.63	
Pyridoxine B6	mg	1		1		0.29		0.29	
Niacin	mg	15		15		3.3		3.3	
Pantothenic acid	mg	1.25		1.25		2.9		2.9	
Cobalamin B12	µg	5		5		6		6	
Folic acid	µg	200		200		50		50	
Biotin	µg	18		18					
Choline	mg	600		600		343		343	

APPENDIX 3. Review of individual nutrients required in cat and dog diets

The following information summarises the role the individual nutrients have in the cat and dog and the signs of deficiency or excess where relevant.

Individual nutrients are often grouped together on the basis of functionality. These groups include (1) protein and amino acids, (2) fats and fatty acids, (3) minerals and (4) vitamins. Other functional materials for example antioxidants and gelling agents may also be present in the material but in the case of the latter are not discussed in this review.

Cats are referred to as strict or obligate carnivores and derive their nutritional requirements from animal tissue. Cats do not have the dentition or digestive function and hence have limited ability to process vegetable matter. In contrast, dogs are considered omnivorous and are able to consume vegetable matter. Cats therefore typically have a higher requirement for amino acids than dogs.

Proteins and amino acids

Protein has several functions in the body (Tompa, 2009) including:

- As an enzyme, proteins catalyse biochemical reactions
- As cell receptors and immunoglobulins, proteins are involved in cellular communication and process regulation
- Structural or mechanical functions in the cell
- Carrier mediated transport of molecules across cell walls
- Source of amino acids by catabolism

Dietary protein provides both essential amino acids and dispensable amino acids for the synthesis of proteins in the body that are needed for growth, maintenance, gestation and lactation. Dispensable amino acids can by synthesised from other sources of nitrogen and carbon whilst essential amino acids cannot be synthesised. (National Research Council, 2006).

Cats have a higher requirement for dietary protein than dogs and are unable to down-regulate protein catabolism (National Research Council, 2006). The inability to down-regulate protein catabolism results in catabolism of muscle tissue when cats are not fed sufficient quantities of dietary protein.

The role and function of the individual amino acids are discussed in the section below. The National Research Council publication “Nutrient Requirements of Dogs and Cats” 2006 publication was used as the main reference material for this section. Where information was obtained from another source the appropriate reference is included in the text.

Arginine

Arginine is a glucogenic amino acid that is converted by the body into glucose. Arginine is considered an essential amino acid in cats and dogs. It is an intermediate in the urea cycle where ammonia is converted to urea. Arginine is also involved in the immune system and wound healing. If fed an arginine-free diet, cats and dogs exhibit a marked hyperammonemia, a metabolic disturbance characterised by an excess of ammonia in blood that can lead to death. Cats are especially sensitive to diets deficient in arginine, particularly when dietary protein is also restricted, and can lead to death in a matter of hours.

Histidine

Histidine is found in haemoglobin and myoglobin where it is involved in ligand binding of the iron molecule. It is a glucogenic amino acid (converted to glucose) and is a precursor to neuroactive compounds such as histamine. It is an essential amino acid. In dogs and cats a deficiency of histidine has resulted in weight loss and negative nitrogen balance, however these symptoms are common when any other amino acids are devoid within a diet. Normal turnover of haemoglobin is usually sufficient to provide an animal's histidine requirements.

Isoleucine

Isoleucine is an essential amino acid that is both ketogenic (converted to ketones) and glucogenic (converted to glucose) in nature. Deficiency in isoleucine is typically observed when there is an overall protein deficiency. Specifically in immature animals deficiency has been associated with weight loss, negative nitrogen balance (puppies) and epidermal problems (kittens).

Leucine and Lysine

Leucine and lysine are strong and weak ketogenic (converted to ketones) amino acids respectively. Both leucine and lysine are essential amino acid. Deficiency signs in dogs and cats are similar with weight loss and negative nitrogen balance recorded in deficiency experiments in the young.

Methionine and Cysteine

Methionine and cysteine are sulphur containing amino acids (SAA) that act as methyl group donors and are present in most proteins. Methionine is considered an essential amino acid and cannot be synthesised in the body. Methionine is an intermediate in the synthesis of cysteine, taurine, carnitine and phospholipids. Cysteine is a dispensable amino acid and can be synthesised from methionine though the conversion rate varies between species. The sulphide bonds formed between proteins provide rigidity and resistance to proteolysis.

Cats have higher dietary requirements for SAA than dogs because cats excrete a branched chain SAA (felinine) in the urine that has possible pheromone activity. Dogs can also utilize methionine more efficiently than cats (National Research Council, 2006). In diets methionine is generally the most limiting amino acid for cats and first or second limiting for dogs.

Methionine deficiency can result in weight loss, lethargy, dermatological disorders and sustainable metabolic problems.

Phenylalanine and Tyrosine

Phenylalanine is an essential amino acid that can be converted into tyrosine. Tyrosine is a dispensable amino acid. Phenylalanine and tyrosine can be converted into catecholamines (adrenalin, noradrenalin and dopamine). When diets deficient in phenylalanine were fed to dogs and cats weight loss was observed, however when diets deficient in tyrosine were fed no weight loss was observed.

Threonine

Threonine is considered an essential amino acid and is a glucogenic amino acid (converted to glucose). Threonine can be converted to pyruvate and subsequently to Acetyl CoA. Acetyl CoA is the feedstock for the Krebs' Cycle (Citric Acid Cycle) in the cell mitochondria, which is responsible for producing energy through oxidation of substrates. A deficiency in threonine has been observed to depress food intake and lead to weight loss. In kittens cerebellar dysfunction was observed.

Tryptophan

As with all the amino acids, tryptophan is needed in protein synthesis however it is also required in the production of Vitamin B3 (niacin) and the neurotransmitters serotonin and melatonin. The pathway to produce niacin in cats has low activity and hence cats are unable to produce significant quantities of niacin from tryptophan. Dietary deficiency leads to loss of appetite and weight loss.

Valine

Valine is a glucogenic amino acid (converted to glucose) and is a constituent of proteins. A deficiency of valine leads to weight loss.

Taurine

Taurine is considered an essential dietary nutrient for cats but a dispensable amino acid for dogs (Edberg, Deerfield & Rogers, 2007). Dogs are able to produce their own requirements of if fed adequate quantities of sulphur-containing amino acids (cysteine and methionine). In cats, the

inadequate conversion of from cysteine to taurine and the high physiological demand for taurine are responsible for taurine being essential in their diets. Taurine is not a true amino acid and is hence not found in protein. Taurine is involved in foetal development, growth and reproduction, sight and hearing, and heart function. It participates in a number of conjugation reactions increasing the water solubility of the compounds and enabling improved excretion and decreased intestinal absorption of these compounds.

Taurine is found in high concentrations in seafood (Spitize *et al*, 2003), birds and small mammals and is present in larger species at lower concentrations. High concentrations of taurine are present in algae, but absent or present in trace amounts in bacteria and higher plants. Seaweed contained highest amounts of taurine compared to land plants whilst fruits, grains, legumes, nuts, seeds and vegetables contained no detectable taurine (Spitze et al, 2003).

Taurine deficiency in dogs is commonly displayed as dilated cardiomyopathy. Deficiency in cats can result in retinal degeneration, heart disease, reproductive failure and development abnormalities. There are no reports of acute or chronic toxicity relating to the feeding large quantities free taurine to cats or dogs.

Lipids

Crude Fat

Dietary fats provide concentrated sources of energy; they contribute to palatability and influence the texture of foods. Their metabolic role is the ability to carry fat-soluble vitamins. Excess fat in the diets of dogs and cats can lead to problems with muscular work, affect hair coat condition and create unhealthy fat deposited in the body. Insufficient fat may impair reproductive efficiency and result in a deficiency in essential fatty acids (EFA). A deficiency in EFAs can impair wound healing, causing a dry dull coat, scaly skin, and cause an increase in skin infection and pyoderma. EFA are therefore considered an essential component of a mammals diet (Garton 1985) Puppies and kittens that are not fed adequate amounts of EFA can have developmental problems. Sources of dietary fats are derived primarily from land and marine animals and the seed oils of numerous plants.

AAFCO has established minimum requirements for crude fat, linoleic acid and arachidonic acid.

Linoleic acid

Linoleic acid is considered an essential fatty acid for cats, but not dogs and is part of the omega-6 polyunsaturated fatty acid family. Linoleic acid is the precursor compound in the pathway that produces the polyunsaturated fatty acid arachidonic acid. Linoleic acid forms part of the cell membrane and is found in large concentrations in oil seed plants such as sunflower and safflower. A deficiency in linoleic acid results in dandruff, dry hair and poor wound healing.

The enzyme, Δ6 desaturase, has low activity in cats and as a result cats cannot convert linoleic acid into arachidonic acid and other polyunsaturated fatty acids.

Arachidonic acid

Due to lack of a certain enzyme (Δ6 desaturase) cats are not able to produce arachidonic acid from omega-6 precursor linoleic acid. Arachidonic acid is only found in fats of animal origin and therefore either animal fat or a synthetic source of arachidonic acid must be included in the diet of cats. Arachidonic acid is found in the cell membranes and is prevalent in the brain and muscles. It has a role in cell signaling and is an intermediate in the production of prostaglandins. A deficiency in arachidonic acid leads to dandruff, dry hair and poor wound healing. In cats arachidonic acid is needed for maintenance of pregnancy and neonatal growth and development.

Minerals

Both dogs and cats have mineral requirements similar to those for other mammalian species. Minerals have a number of physiological roles including rigidity of internal skeleton and teeth (calcium and phosphorus), nerve impulses and muscle contraction (sodium, calcium, magnesium and potassium) and protein and hormone structure and function (iron, zinc and iodine).

Mineral deficiencies of many essential minerals have been produced experimentally and clinical signs have been described. Many of these deficiencies occur when fed improperly formulated homemade diets. The reference source for the information relating to mineral is sourced from pet education.com (Foster & Smith 2009).

Calcium, Phosphorous and Ca:P ratio

Calcium is required in the greatest amount by the body and is essential in the body for many functions including bone formation, blood coagulation, muscle contraction and nerve impulse transmission. There are a number of different bioavailable calcium sources available including bones, dairy products, leguminous plants and calcium can also be found in smaller amounts in cereal grains, meat, and organ tissues. Excess calcium is often blamed for to bone problems in young rapidly growing dogs and a deficiency may result in skeletal abnormalities such as rickets (Foster & Smith 2009).

Phosphorous is required at levels slightly less than calcium. Meat or organ meats are high in phosphorous but relatively low in calcium. Excessive dietary phosphorous may accelerate the progression of renal failure whilst phosphorous deficiency occurs very infrequently in dogs and cats and only been replicated in laboratory (Foster & Smith 2009).

Both calcium and phosphorus are required to maintain the growth and structure of the skeletal system. The calcium: phosphorous ratio is very important in an animal's diet and especially in growing animals. It is very important that calcium and phosphorous be fed at the correct ratio of around 1.2 parts of calcium for each 1 part of phosphorous (1.2:1) (Foster & Smith 2009). Many foods that are low in calcium are high in phosphorous, whilst other foods that are high in calcium are equally high in phosphorous. Therefore providing the correct calcium to phosphorous ratio in the diet can be difficult unless the proper minerals are added.

Potassium, Magnesium, Sodium and Chloride

Potassium is necessary for the proper functioning of enzymes, muscles, and nerves and thus found in high concentrations within cells. Potassium toxicity generally does not occur as long as the kidneys are functioning normally. The potassium level in the blood, however, can reach a dangerous level and may result in cardiac arrest. Potassium deficiency is most often due to an excessive loss of potassium rather than too little dietary intake (Foster & Smith 2009).

Magnesium is required for the absorption and proper use of certain vitamins and minerals including Vitamin C, Vitamin E, calcium, phosphorus, sodium, and potassium. It is necessary for proper bone growth and functioning of many enzymes in the body and production of protein. Magnesium is found in raw wheat germ, whole grains, soybeans, milk, and fish (Foster & Smith 2009).

Sodium and chloride help maintain the balance between fluids inside and outside individual cells of the body. Sodium aids in the transfer of nutrients to cells and the removal of waste products. Chloride helps maintain the proper acid/alkali balance in the body. Any excess intake of sodium or chloride is filtered through the kidneys and excreted into the urine. If good drinking water is not provided, however, the concentrations of sodium and chloride can become too high. Signs of sodium chloride toxicity include seizures, blindness, dehydration, loss of appetite, and death within 24 hours. A sodium or chloride deficiency is more likely to occur because of an excessive loss of these two minerals from the body. This can result from prolonged (or chronic) severe diarrhea and/or vomiting (Foster & Smith 2009).

Iron, Copper, Manganese, Zinc, Iodine and Selenium

Iron is found in haemoglobin and myoglobin and is responsible for the transport of oxygen throughout the body. Sources of iron are in liver, lean meats, fish, whole grains, and legumes. Inorganic sources of iron are typically less bioavailable than organic sources. Iron toxicity is extremely rare, however too much iron in the diet can interfere with the absorption of phosphorous. Iron deficiency can result in the development of anemia (lower than normal number of red blood cells) (Foster & Smith 2009).

Copper is an integral part of enzymes involved in oxidation processes including feroxidase that oxidizes the ferrous ion enabling it to be trapped by transferrin (protein) as part of haemoglobin synthesis.

Copper is necessary for the formation of collagen, bone and connective tissue, the development and maturation of red blood cells, as an antioxidant, and in the development of pigment in hair. Copper is found in liver, fish, whole grains and legumes. Most quality commercial dog foods are supplemented with copper to ensure adequate intake. Bedlington Terriers, Doberman Pinschers and West Highland White Terriers display a hereditary disorder, which causes copper to accumulate in the liver causing inflammation (hepatitis). The typical symptoms of copper toxicity in the liver include lethargy, vomiting, jaundice, and weight loss. Like iron, copper deficiency can results in the development of anemia (Foster & Smith 2009).

Manganese is essential for the proper use of protein and carbohydrate by the body, reproduction, and the action of many enzymes in the body responsible for the production of energy and making fatty acids. The highest concentration of manganese occurs in the liver with and the lowest concentrations are found in skeletal muscle. Manganese is present in whole grains, seeds, nuts, eggs, and green vegetables. Many pet food manufacturers also add supplemental manganese to their products. Manganese toxicity is basically unknown and its deficiency is equally rare in. When it does occur, newborn and young animals are more likely affected. The symptoms of manganese deficiency include poor growth, skeletal abnormalities, reproductive failure, and loss of equilibrium (Foster & Smith 2009).

Zinc has a critical role in regulating many aspects of cellular metabolism especially those with concerned with the maintenance of a healthy coat and skin (Watson, 1998). Zinc has particular importance in the rapidly dividing cells in the epidermis. Zinc is an integral component of metalloenzymes and as a cofactor for RNA and DNA polymerases. Zinc is also essential for the biosynthesis of fatty acids, is used in the inflammatory and immune systems and is involved in the metabolism of Vitamin A. Zinc is not found in high concentrations in plants. Zinc toxicity is rare and if it does occur it interferes with copper and iron absorption. Zinc deficiency in dogs most commonly occurs as a skin condition called zinc responsive dermatosis (Watson, 1998) (Foster & Smith 2009).

Iodine is necessary for the proper functioning of the thyroid gland and the production of thyroid hormones. Thyroid hormones regulate the rate of metabolism in the body and play an important role in normal growth. Iodine is found in fish and iodized salt (salt with iodine added). Commercial pet foods supplement iodine. In dogs an excess of iodine Dog results in depressed activity of the thyroid gland. In cats a similar study was preformed and the result was inconclusive. Iodine deficiency results in lower than normal production of thyroid hormones (Foster & Smith 2009).

Selenium was recognized as a toxic substance before it was identified as a necessary nutrient in animal diets. Selenium functions as an antioxidant and is involved in immune function, reproduction and thyroid hormone metabolism (Wedekind Yu & Combs, 2003). Selenium often works in conjunction with Vitamin E and certain enzymes to protect cells (Foster & Smith 2009). High-protein plants and meat products are good sources of selenium. Selenium toxicities in dogs or cats are rare, but can occur if the

dietary intake exceeds 0.9 mg of selenium for every pound of food eaten (on a dry matter basis) for prolonged periods of time. Signs of selenium toxicity include hair loss, lameness, anemia, and liver cirrhosis. Selenium deficiencies are extremely rare in dogs and basically unknown in cats. If a selenium deficiency would occur it is likely to lead to poor reproduction, puppy death, muscle weakness, and abnormalities of the heart muscle (Foster & Smith 2009).

Vitamins

Vitamins are required at very low concentrations to perform various metabolic functions. They are classed as either fat-soluble or water-soluble. Fat-soluble vitamins include Vitamins A, D, E and K. Water-soluble vitamins include the B vitamins complex, folic acid and biotin. Research on vitamins has revealed that the vitamin needs of cats and dogs differ little from those of pigs and rats. The exception worthy of note is requirements for vitamin A (cats), niacin (cats), thiamine (cats and dogs), and vitamin E (cats and dogs).

Vitamin A

According to the National Research Council (1985, 1986, cited by Heanes) Vitamin A is a necessary dietary requirement for dogs and cats. Cats unlike dogs require a dietary source of preformed vitamin A (Baker & Czarnecki – Maulden, 1991) as they are unable to utilise carotenoids to synthesis vitamin A. All Vitamin A ingested by animals originates from carotenoids synthesized by plants. Vitamin A is involved in the regulation of growth, cellular differentiation, vision, morphogenesis and immune response. Vitamin A is essential to maintain the integrity of epithelial tissues and is particularly important for keratinization (the eventually creation of hair). Toxicities result muscle weakness and bone abnormalities. Deficiencies lead to “night blindness”, retarded growth, poor-quality skin, influence hair development, and reproductive failure. Lack of Vitamin A in puppies directly relates to low growth rates, muscle weakness, poor vision and hair loss (Foster & Smith 2009).

Vitamin D

Vitamin D is important because of its relationship with calcium and its role in regulating calcium and phosphorous levels within the bloodstream. Vitamin D helps stimulate the kidneys’ ability to conserve calcium and extremely important in bone formation and nerve and muscle control. A major source of Vitamin D is ultraviolet radiation. The sun converts Vitamin D precursors into the active D form. This conversion takes place in the outer skin layers however small amounts of Vitamin D are also obtained directly through the diet; usually from liver or fish oils. Vitamin D toxicities are extremely rare. A dog fed Vitamin D in excess could have abnormal amounts of calcium deposited within the heart, various muscles, and other soft tissues. Deficiencies of Vitamin D rarely occur. Low levels of Vitamin D will cause a bone demineralization referred to as rickets (Foster & Smith 2009).

Vitamin E

Vitamin E is a natural antioxidant and together with selenium, is important for maintaining stability of cell membranes. It plays a role in the formation of cell membranes, cell respiration, and in the metabolism of fats. It is an antioxidant and protects hormones from oxidation. Foods rich in Vitamin E include plant oils such as safflower and wheat germ. Vitamin E is also highly concentrated in meats such as liver and fat. There are no known Vitamin E toxicities in the dog and cat.

Vitamin E deficiencies cause cell damage and death in skeletal muscle, heart, testes, liver (steatitis), and nerves. Animals that are deficient in Vitamin E may have ulcerated bowels, which may haemorrhage and degenerate (Brown Bowel Syndrome). In addition, the cells of the eyes and testes can be affected in deficient animals. Vitamin E needs of cats and dogs are not greatly different from those of other species under normal dietary circumstances, however diets containing high levels of fat, fish or fish oil require higher levels of vitamin E. This is due to Vitamin E in the product protecting the fats from oxidation and hence not being available to act as an antioxidant in the body.

Vitamin K

Vitamin K has a unique function and is essential for normal blood functions and without it blood cannot clot. Vitamin K exists in three forms and each form can be obtained form different sources. Vitamin K1 is sourced from green plants whilst Vitamin K2 is found in fish and is synthesised by intestinal bacteria. Vitamin K3 is a synthetic precursor of Vitamins K1 and K2. Vitamin K toxicity due to over supplementation has not been reported in animals. Vitamin K deficiencies in pets have not been documented except in instances of Warfarin toxicosis as the results of ingestion of rat poison (Foster & Smith 2009).

Vitamin B1 (thiamin)

Vitamin B1 or thiamine (thiamin) is required for the normal function of muscles and nerves because it converts glucose to energy. Thiamine is found in plants, vegetables, fruits, milk, fish, and other meats. Like all water-soluble vitamins, it is not stored within the body so it is extremely important that the diet have a sufficiently high amount. Toxicity is rare. A thiamine deficiency is generally associated with pets that are fed a large amount of raw fish resulting in exposure to thiaminase an enzyme that destroys thiamine or other anti-thiamine factors such as polyphenols. A deficiency of thiamin results in loss of appetite, weakness, loss of reflexes, loss of nerve control, and eventually death (Foster & Smith 2009).

Vitamin B2 (riboflavin)

Riboflavin or Vitamin B2 has been proven to be essential to normal growth, muscle development, and hair coat. Its biological function is to serve as a precursor to important coenzymes. Riboflavin is found naturally in organ meats and dairy products. It is lowest in grains, vegetables and fruits. Riboflavin

toxicity is rare if not nonexistent. Dogs fed a diet deficient in Vitamin B2 will have poor growth, eye abnormalities, collapsing or fainting, weakness in rear limbs, and possibly heart failure. A deficiency of riboflavin in the diet impacts other vitamins because flavin coenzymes are involved in their metabolism. These vitamins include folic acid, pyridoxine niacin and Vitamins K and D and Vitamin B5 (pantothenic acid).

Vitamin B5 (Pantothenic acid)

Vitamin B5 or Pantothenic acid enables the body to create usable energy from carbohydrates, fats, and proteins. It is found in sufficient quantities in most raw foodstuffs including meats and vegetables. Processing of foods will reduce the amount of pantothenic acid available to the dog or cat. There are no known toxicities. The symptoms of pantothenic acid deficiency include loss of hair, diarrhea and gastric (stomach) upsets. It has also been associated with abnormal graying, particularly in black-coated animals (Foster & Smith 2009).

Vitamin B3 (niacin)

Vitamin B3 or Niacin deficiency is generally encountered when owners formulate their own diets for their pets and do not include meat as part of the ration. Niacin has a role in helping enzymes to function properly. Niacin is found in adequate levels in meats and meat by-products and is very low in vegetables and grains. Forced injections of 2g of nicotinic acid per day resulted in convulsions and death on the 11th day. Black tongue' and 'sore mouth disease' are the terms used to describe a dog or cat suffering from a niacin deficiency. A pet suffering with black tongue will lose weight, fail to eat, and have red inflamed gums, lips, and inner cheeks. Bloody diarrhoea and death may follow. Because cats are unable to convert the tryptophan to nicotinic acid, their total requirement of niacin must be derived form dietary sources (National Research Council, 2006, Foster & Smith 2009).

Vitamin B6 (pyridoxine)

Vitamin B6 or pyridoxine is used in the utilization of amino acids. Pyridoxine functions in more than 100 reactions as a coenzyme. Vitamin B6 is found in many foods, but processing easily destroys it. There are no known toxicities. Deficiencies of pyridoxine lead to anaemia, poor growth, kidney stones, tooth cavities, skin lesions, and in advanced cases, death (National Research Council, 2006, Foster & Smith 2009).

Folic Acid, Vitamin B12 (cyanocobalamin) Biotin, Choline

Folic Acid and Vitamin B12 (cyanocobalamin) are utilised by the bone marrow for the production of red blood cells. Both folic acid and Vitamin B12 are usually included in the diet and are found in organ meats. Toxicities are of no concern and deficiency of either can lead to advanced anemia. In this type

of anemia the red cells are fewer in number but are larger than normal (macrocytic). The quantity of white blood cells may also be reduced (Foster & Smith 2009).

The role of Biotin is in maintaining healthy skin and hair and it is necessary for growth, digestion and muscle function. In some animals, it has been linked to litter size. Although biotin is widely distributed in foodstuffs its concentration is low compared to other water-soluble vitamins. Biotin is found in grains, but is not always of a usable quantity. Diets rich in corn or soybean are best, while those of wheat and barley are deficient. Beef liver supplies the richest source. Biotin toxicity is rare to nonexistent. Biotin deficiencies have been reported following the ingestion of raw egg whites. Raw egg whites contain an enzyme called avidin that destroys biotin. A dog or cat suffering from a lack of biotin may have poor hair, skin lesions, dried eye discharge, diarrhea, decreased litter size, and in advanced cases, a paralysis of the limbs.

Choline is not a true vitamin in the classical sense, because many animals are capable of synthesizing choline in the liver. Methionine may also be used to substitute for choline as a methyl donor. Choline has three main biological functions (1) as a methyl donor in phosphatidylcholine, (2) as a component of acetylcholine and (3) as a methyl donor for methylation reactions. In dogs, deficiency is displayed with a loss of body weight, vomiting, an increase in fat content of the liver and death. In cats food intake and body weight gain is depressed (National Research Council, 2006) (Foster & Smith 2009).

Other high value nutrients

Also present in a number of foods are nutrients that do not have an established minimum nutrient requirement but dietary supplementation with these materials has been shown to be beneficial to cats and dogs. These include beta-carotene, lycopene, phenols and polyphenols which function as antioxidants.

Antioxidants have become one of the most important topics of human nutrition (Pokorny, 2007). The main function of antioxidants is to prevent oxidation of the body (Pietta, 1999). Oxidation is the transfer of electrons from one atom to another. Oxidantion is an essential part of aerobic life and metabolism since oxygen is the ultimate electron acceptor in the electron flow system that produces energy. During oxidation the electron flow may become uncoupled and generate free radicals, which are very reactive and rapidly attack the molecules in nearby cells. Antioxidants limit the effect of free radicals on the body (Petta, 1999). Many fruits and vegetables are high in antioxidants and include green leafy vegetables, potatoes, apples, bananas, berries and olives (Pokorny, 2007). Minerals such as selenium zinc, iron, copper, and manganese also have an antioxidant function as do vitamins such as Vitamin C and E.

Beta-carotene

Beta-carotene and other carotenoids are derived from plants and are not internally synthesized by cats or dogs. Beta-carotene can serve as a precursor to Vitamin A in the dog but not in cats (National Research Council, 2006). Carotenoids have antioxidant and immune-enhancing properties. Foods high in carotenoids include carrots, pumpkin, spinach and liver.

Phenols/polyphenols

The consumption of fruit and vegetables is associated with a lowered risk of cancer and the possible reason for this trend is the presence of antioxidants. Vinsio *et al* (1998, 2001) studied the effects of the antioxidant group of phenols and polyphenols, in both fruit and vegetables. Polyphenols have recently been shown to have stronger antioxidant properties than vitamin antioxidants. Flavonoids are phenolic substances found in a wide range of vascular plants, with over 8000 individual compounds known. Flavonoids are the antioxidants of plants (Pietta 1999).

Lycopene

Lycopene is classified as a carotene and has antioxidant properties (Gerster 1997) (Sies & Stahl 1998). Lycopene is one of the major carotenoids in western diets and while other carotenes are distributed among selection of fruit and vegetables, Lycopene is found almost exclusively in tomatoes and tomato products. Lycopene is a natural pigment synthesized by plants but cannot be synthesized by animals (Gerster 1997). Losses of lycopene during food preparation such as cooking are minimal and preparation has results in an increase its bioavailability (Stahl & Sies, 1992 cited by Gerster, 1997).

Vitamin C (Ascorbic Acid)

Most animals including dogs and cats are able to synthesize their Vitamin C requirements from glucose and can obtain Vitamin C from dietary sources. Vitamin C is an antioxidant and is an enzymatic cofactor in the synthesis of collagen and carnitine. A deficiency in Vitamin C can result in scurvy.

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