CARBON FOOTPRINT FOR AUSTRALIAN AGRICULTURAL PRODUCTS AND DOWNSTREAM FOOD PRODUCTS IN THE SUPERMARKET

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ABSTRACT

This paper presents the carbon footprint for a range of agricultural raw materials that are used extensively in food production. The focus of the paper is to consider how Life Cycle Assessment can be used to inform consumer choice of food to minimise global warming impact, with several food products serving as examples. A 'cradle-to-farm gate' life cycle assessment (LCA) was undertaken for agricultural products and a 'cradle-to-supermarket shelf' LCA for the foods. Amongst the animal based products, ruminant livestock co-products destined for meat (lambs, steers and cast for age animals) have a significantly higher carbon footprint (4.5-14.5 kg CO_2-e/kg live weight) compared to mono-gastric livestock, that is pigs and chickens (1.9-4.2 kg CO_2-e/kg live weight), largely attributed to the level of methane production in ruminants. Amongst crop products, the carbon footprint is influenced by the yield per hectare, level of fertiliser use and nitrous oxide emissions related to nitrogen fixing in legume crops and ranged from 0.11-0.40 kg CO_2-e/kg grain. Per kilogram of food product, fresh lamb and beef (19.4 and 25.2 kg CO_2-e, respectively) have the highest carbon footprint, fresh pork is intermediate (6.3 kg CO_2-e) followed by fresh chicken (2.9 kg CO_2-e), with vegetable based food (and the processed pet foods) having the lowest carbon footprint per unit of weight (range of 0.9 to 1.3 kg CO_2-e). The life cycle assessment demonstrates the relatively high greenhouse gas emissions associated with livestock ingredients, particularly from ruminant systems, compared to plant-based ingredients. It also highlighted the relative contributions that different phases of the supply chain make. For highly processed foods such as bread, the milling and baking phases contribute more than the on-farm phase, while for fresh beef and lamb the on-farm emissions make up the majority of the carbon footprint.

Keywords: meat, grain, household greenhouse gas emissions, diet, consumer choice

1. INTRODUCTION

Food consumption comprises a significant proportion of household greenhouse gas (GHG) emissions, with estimates of 15% to 28% total household emissions attributed to food [1, 2], while in the economy overall food makes up 29% of GHG emissions [3]. A significant number of consumers believe that individual action is important for GHG mitigation [4]. To enable informed choice by consumers, information is required on the GHG emissions for agricultural systems producing food ingredients, allowing consumers to shift their environmental impact through choice of diet.

Along the value chain, food manufactures and retailers are asking the same questions. To understand and improve their own environmental performance, food manufacturers are seeking information on the relative performance of the ingredients that they are using; while major international retailers are introducing environmental labelling [5, 6, 4].

This paper reports the carbon footprint for a selection of food products. The ingredients used in these products originate from a range of major agricultural production systems, systems that also feed into many other food supply chains. The goal of the paper is to consider how Life Cycle Assessment can be used to inform consumer choice of food to minimise global warming impact, with several food products serving as examples.

2. MATERIALS AND METHODS

ISO-compliant lifecycle methodology [7] was used to undertake a 'cradle-to-supermarket shelf' life cycle assessment (LCA) for fresh bread, tinned lentils, fresh meat and two pet food products for the impact category of global warming. A partial 'cradle-to-farm gate' LCA was undertaken for all of the co-products produced in the agricultural systems from which the food product ingredients were sourced. A full description of the methods can be found in Eady et al., in preparation [8].

In summary, production and financial parameters describing the farming systems were drawn from published data [9] and production models such as PigBal [10] and APSIM [11]. The operational descriptions of primary processing enterprises (abattoir, meat and fish processing, grain milling) were drawn from industry publications and the literature. Final processing into pet food was based on the Mars Petcare Australia pet food facilities at Wodonga, Victoria, and Bathurst, NSW. GHG emissions from farming enterprises were calculated as per the carbon accounting methodology used for the national accounts in Australia [12]. Wastewater GHG emissions were estimated using methodology for national accounts.

Consistent with PAS2050 guidelines [13], construction of infrastructure, farm and factory establishment, changes in soil/vegetation carbon and carbon in farm products were not included in the system boundary. The functional unit (FU) chosen for each primary product and food product was 1 kg, except where the product is a live animal that typically moves to another enterprise for further production.

The issue of how to allocate inputs to the outputs generated from an enterprise arises when the enterprise produces interrelated products. In this study, many of the animal products are interrelated at both the farm level, with the production of different classes of livestock, and at the processing level, where different sections of the carcass make up a range of distinctly different co-products. One approach is to allocate inputs based on a biophysical relationship such as mass-adjusted gross chemical energy content. However, this approach is not appropriate where co-products differ in their constitution, for example, wool versus meat in a Merino sheep enterprise and high value meat cuts versus meat/bone/feather meal. Therefore, where multiple products are produced, allocation of environmental impacts was made on an economic basis, that is, in proportion to the relative gross income each co-product contributes. This approach is commonly used where attributional modelling of LCA seeks to describe the environmental flows for a particular product [15], as is the case with this LCA. System expansion and a consequential modelling approach were not used; this approach requires a comprehensive understanding of supply and demand for a range of possible substitutes and in some instances (e.g. surplus heifers for breeding) there is no logical substitute product. In general, animal co-products were modelled as multi-output processes and crops were modelled as single output processes, with stubble being retained on-farm.

For the pet foods, data for final processing were based on the Mars Petcare Australia pet food facilities at Wodonga, Victoria, and Bathurst, NSW. For the other food products processing data were drawn from the literature. Inputs, reference flows, product fractions and allocations for animal products, crop products and primary processing are summarised by Eady et al. (in preparation) [8].

SimaPro® proprietary LCA software (Pré Consultants 2007) was used for the LCA modelling and background data were sourced from Life Cycle Inventory (LCI) libraries incorporated into the software, and included the Australasian Unit Process LCI (Centre for Design 2010) [16], Ecoinvent 2.0 unit processes (2007), and LCA Food DK Library. These libraries were used to characterise GHG emissions for non-agricultural raw materials, their processing into components, transport, and energy inputs. LCI built by CSIRO for a number of agricultural processes such as animal transport, shearing, soil tillage and crop harvesting were also used as background data.

3. RESULTS

The GHG emissions for livestock products and crops are given in Table 1. Ruminant livestock co-products destined for meat (lambs, steers and cast for age animals) had a significantly higher carbon footprint compared to mono-gastric livestock (pigs and chickens), largely attributed to the level of methane production in ruminants. The lower carbon footprint of wool from cross-bred sheep compared to Merinos (8.9 versus 28.7 kg CO_2-e) is attributed to the lower per head production and economic contribution of cross-bred wool within the prime lamb enterprise, compared to Merino wool which contributes a much higher financial return to the fine-wool enterprise. The GHG emissions for mono-gastric livestock are largely related to production of feed (fertilizer and fuel use) and manure management.

Amongst crop products, the carbon footprint is influenced by the yield per hectare, level of fertiliser use and nitrous oxide emissions related to nitrogen fixing in legume crops. Hence, field peas have a relatively high carbon footprint (low yielding legume) whereas barley (high yielding and low fertiliser use) has a relatively low carbon footprint.

Table 1 Greenhouse gas emissions for livestock and crop production at farm gate

Product Functional Unit	GHG emissions (kg CO_2-e)
Prime lamb production co-products	
1 kg greasy wool - 28 micron	8.9
1 kg live weight - 65 kg X-bred ewe	4.5
1 kg live weight - 40 kg prime lamb	7.9
Merino wool production co-products	
1 kg greasy wool – 21 micron	28.7
1 kg live weight - 50 kg Merino ewe	6.22
1 weaner Merino wether (6 months of age)	162
1 hogget Merino ewe (18 months of age)	391
Grass feed beef production co-products	
1 kg live weight - 440 kg steer	10.1
1 weaner heifer (9 months of age)	1,820
1 kg live weight – 833 kg cull bull	13.7
1 kg live weight – 426 kg cull cow	14.4
Pig production co-products	
1 kg live weight - 100 kg finisher pig	3.9
1 kg live weight - 158 kg cull sows	2.2
Meat chicken production	
1 kg live weight - 2.5 kg meat chicken	1.7
Crop production	
1 kg wheat	0.27
1 kg sorghum	0.27
1 kg barley	0.11
1 kg safflower	0.26
1 kg sunflower	0.34
1 kg field peas	0.40

Table 2 presents the 'cradle-to-supermarket shelf' LCA for GHG emissions for a small range of food products, based on some of the primary products given in Table 1.

Per kilogram of food product, fresh lamb and beef have the highest carbon footprint; pork is intermediate followed by fresh chicken, with plant-based food and the processed pet foods having the lowest carbon footprint per unit of weight (Table 2).

Table 2 Whole of life cycle greenhouse gas emissions for a range of food products

Food Product	Carbon footprint (kg CO_2-e/kg product on supermarket shelf)
Bread	0.9
Tinned lentils	1.0
Beef, fresh boned meat	25.2
Lamb, fresh boned meat	19.4
Pork, fresh boned meat	6.3
Chicken, whole fresh	2.9
Whiskas Ocean Fish ®	1.3
Pedigree Meaty Bites ®	0.9

The contribution from each sector of the supply chain (on-farm, primary processing, secondary processing, packaging, transport to supermarket and refrigerated storage in the supermarket) is shown in Figures 1-7; lamb and beef are virtually the same pattern so only beef is presented.

The on-farm contribution of GHG emissions to each product ranges from 25% for bread to 96% for fresh beef, and is the largest contributing sector for all foods except for bread, where baking contributes the highest proportion of emissions (Figures 1 to 7). Within the plant-based products and pet foods (Figures 1, 2 and 6, 7), post-farm gate processing (milling, baking, tinning) contributes proportionally more to the total carbon footprint for each product, compared to the post-farm processes for fresh meat products (Figures 3, 4, and 5).

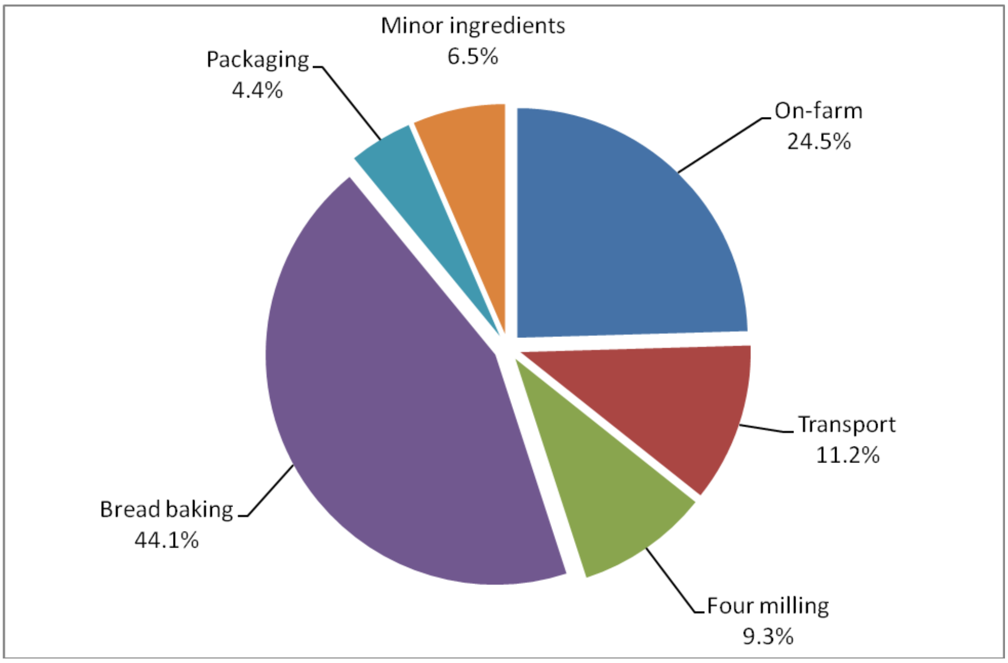

Figure 1 Relative contribution of sectors or the supply chain to the carbon footprint of fresh bread on the supermarket shelf.

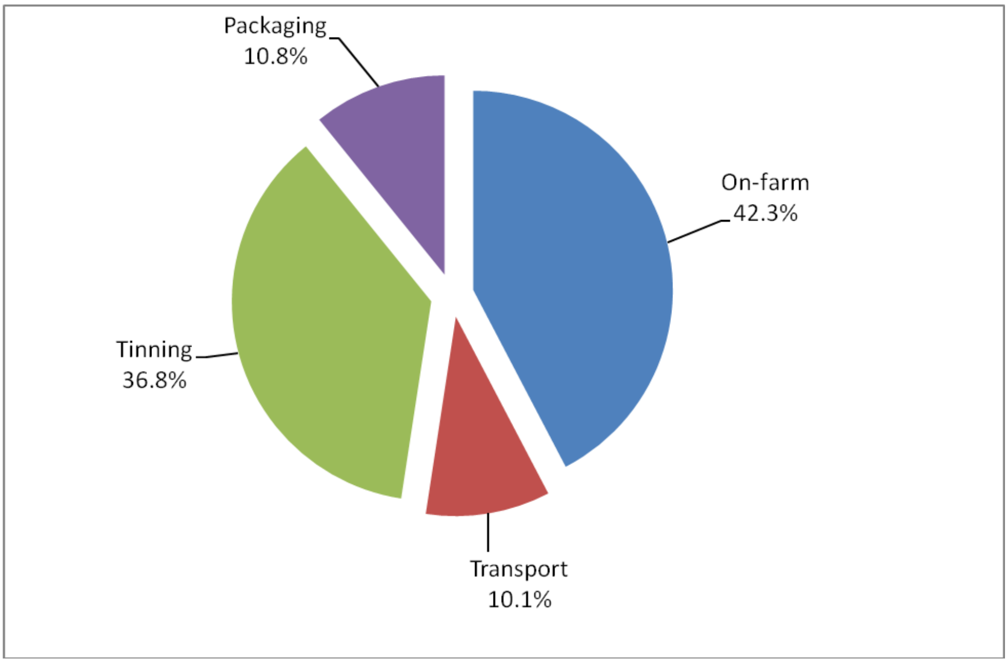

Figure 2 Relative contributions of sectors of the supply chain to the carbon footprint of tinned lentils on the supermarket shelf.

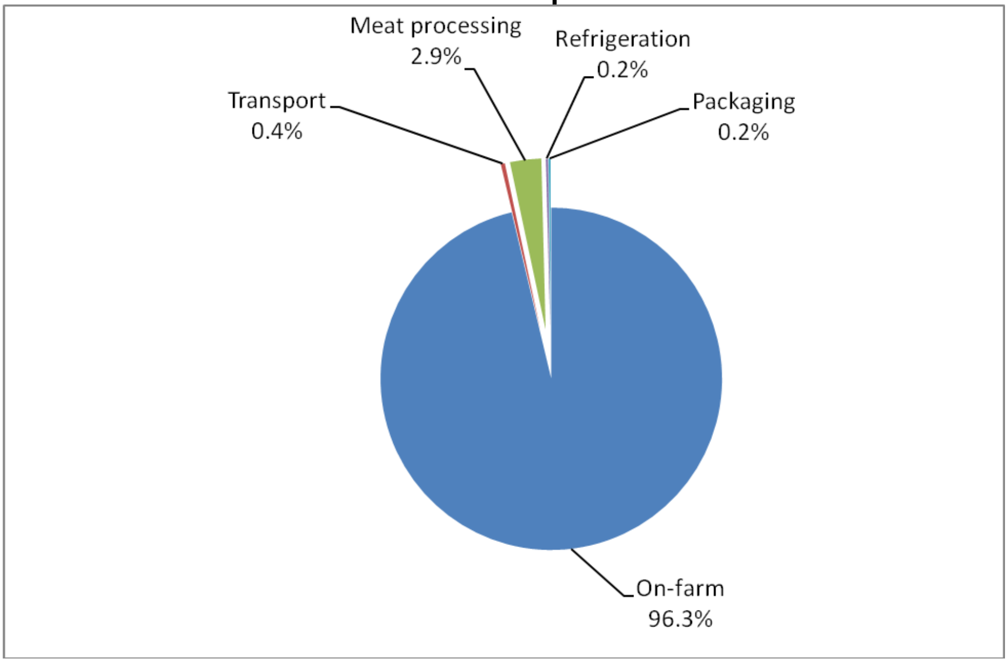

Figure 3 Relative contributions of sectors of the supply chain to the carbon footprint of fresh beef on the supermarket shelf.

Comparing the fresh meats, the meat processing contribution is a higher proportion of the total carbon footprint for pork and chicken (Figures 4 and 5) compared to beef (Figure 3), reflecting the considerately lower on-farm emissions associated with pig and broiler production. This pattern flows on to the comparison of pork and chicken, with processing being a greater contributor in a relative sense to fresh chicken production.

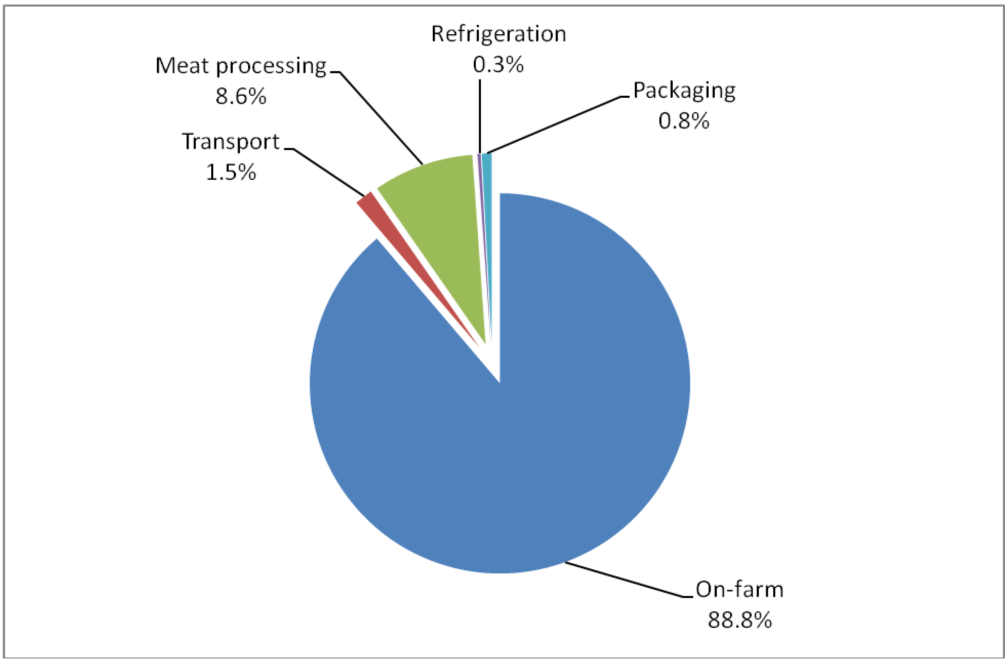

Figure 4 Relative contributions of sectors of the supply chain to the carbon footprint of fresh pork on the supermarket shelf.

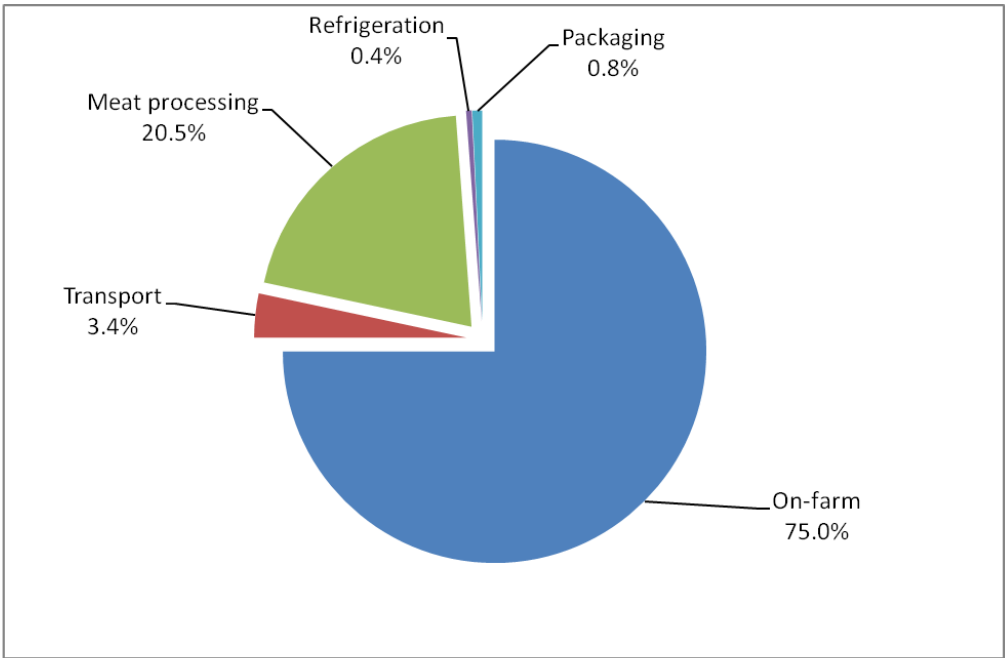

Figure 5 Relative contributions of sectors of the supply chain to the carbon footprint of fresh chicken on the supermarket shelf.

Comparing the two pet foods (Figures 6 and 7), the main difference is the proportion of GHG emissions contributed by packing, with the dry pet food plastic packaging for a 20kg pack contributing a relatively small proportion compared with the tinned 400g pack for the wet cat food.

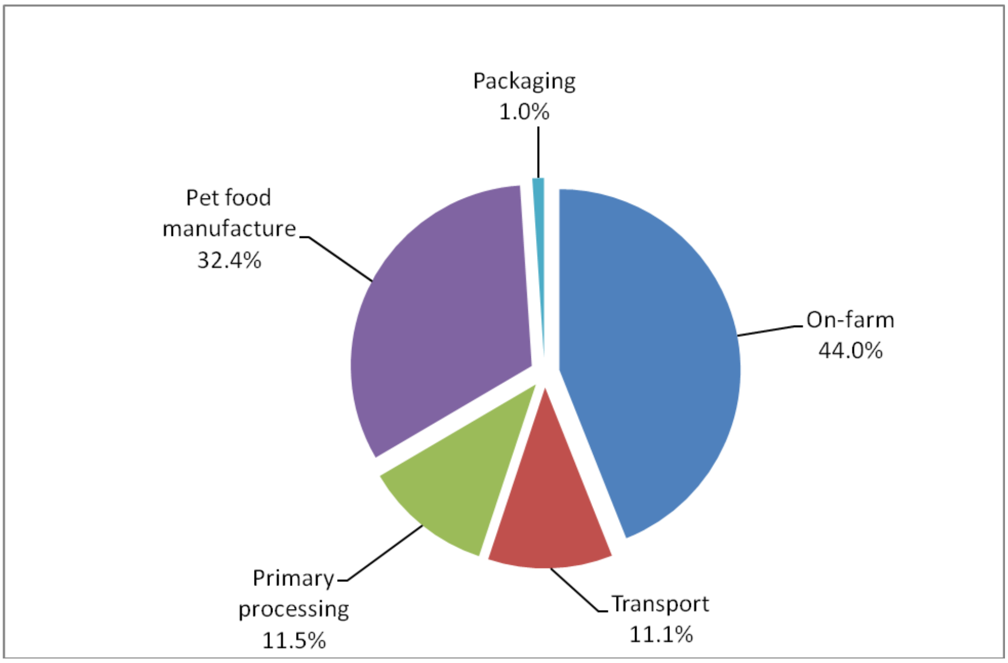

Figure 6 Relative contributions of sectors of the supply chain to the carbon footprint of Meaty Bites ® on the supermarket shelf.

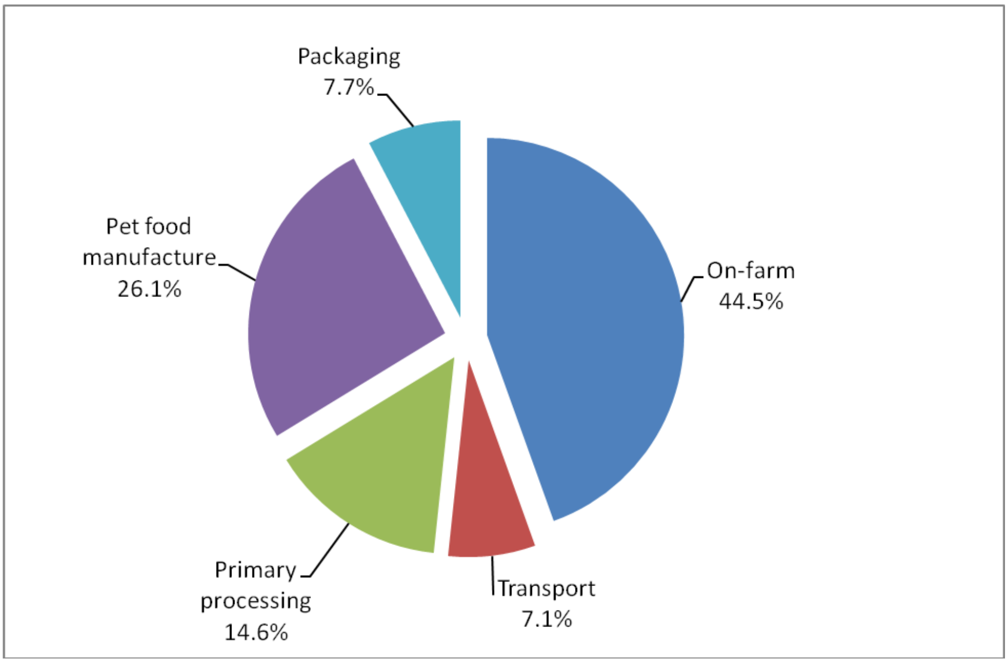

Figure 7 Relative contributions of sectors of the supply chain to the carbon footprint of Whiskas Ocean Fish ® on the supermarket shelf.

4. DISCUSSION

In summary, the life cycle assessment demonstrated the relatively high GHG emissions associated with livestock products, particularly from ruminant systems, compared to plant-based ingredients, a result that is consistent with similar studies [14]. With regard to individual agricultural products, the carbon footprints from this study can be compared to other estimates for Australian production systems and internationally (Table 3). It should be recognised that production systems, LCA system boundaries and allocation methodologies vary between studies. Hence, figures should be used as indicative ranges rather than ascribing an absolute value for a particular product. However, the ranges begin to give a sense of the relative values that can be used for food ingredients, and sensitivity analysis can be used to investigate the impact of changes in these values to the overall result.

Table 3 Carbon footprint (CF) results for a range of livestock and crop products

Function unit	CF (kg CO_2-e)	Production system
1 kg greasy wool - 19.5 µm	26.3	Mixed sheep cropping, south west Western Australia [17]
1 kg greasy wool -17.5 µm	30.6	Finewool Merino, northern tablelands NSW [18]
1 kg lwt - 50 kg CFA Merino ewe	2.8	Mixed sheep cropping, south west Western Australia [17]
1 kg lwt - 50 kg CFA Merino ewe	3.0	Finewool Merino, northern tablelands NSW [18]
1 kg lwt – NZ prime lamb[a]	6.1	Prime export lamb, New Zealand [19]
1 Merino wether (12 mths of age)	246	Mixed sheep cropping, south west Western Australia [17]
1 Merino wether (14 months)	149	Finewool Merino, northern tablelands NSW [18]
1 hogget Merino ewe (18 months of age)	229	Mixed sheep cropping, south west Western Australia [17]
1 hogget Merino ewe (18 months of age)	95	Finewool Merino, northern tablelands NSW [18]
1 kg live weight finished beef steer	14.5	Grass-fed beef, central Queensland [20]
1 kg live weight[b] finished beef steer	7.1	Grass-fed organic beef, Victoria [21]
1 kg live weight[b] finished beef steer	7.3	Feedlot finished beef, central NSW [21]
1 kg live weight[b] finished beef steer	11.7	Feedlot finished, western Canada [22]
1 kg live weight finished yearling	13.0	Conventional production, Ireland [23]
1 kg live weight finished yearling	11.1	Organic production, Ireland [23]
1 kg live weight finished steer/surplus heifers	8.9	Grazing and winter barn with forage silage feed, Sweden [24]
1 kg live weight cull beef cow	12.8	Grass-fed beef, central Queensland [20]
1 kg live weight finisher pig	2.4	Deep litter housing for growers, southern Australia [25]
1 kg live weight finisher pig	4.2	Conventional production, northern Australia [25]
1 kg live weight finisher pig	2.3	Conventional production, France [26]
1 kg live weight finisher pig	3.5	Organic production, France [26]
1 kg live weight finisher pig	4.0	Red Label production (similar housing to organic), France [26]
1 kg live weight finisher pig	2.3	Conventional production, Canada [27]
1 kg live weight finisher pig[c]	3.8	Conventional production, United States [28]
1 kg live weight broiler chicken	1.4	Conventional production, United States [29]
1 tonne wheat	429	Conventional production, Canada [14]
1 tonne wheat	306	Mixed sheep cropping, south west Western Australia [17]
1 tonne wheat	206	Single crop production, Western Australia [30]
1 tonne barley	270	Mixed sheep cropping, south west Western Australia [17]

[a]Meat consumed converted to live weight assuming meat yield of 40%.
[b]Hot slaughtered carcass weight converted to live weight assuming 1.4 kg CO_2-e/t HSCW for processing and 53% dressing percentage.
[c]Meat consumed converted to live weight assuming meat yield of 64%.

In terms of meat, the carbon footprint at farm gate would be about 10.5 kg CO_2-e/kg live weight for beef, 7 kg CO_2-e/ kg live weight for lamb, 3.3 kg CO_2-e/ kg live weight for pigs and 1.7 kg CO_2-e/ kg for chicken. Until there are published Australian estimates for meat chickens it is difficult to judge if the estimate in this study is representative. These values may be updated over time as more estimates are published, but the relative ranking of meat products is unlikely to change.

With regard to broad-acre crop products, an assumed carbon foot print in the vicinity of 280-290 kg CO_2-e/tonne of raw ingredient would be a sensible figure to use until more estimates are available for individual crops. If the ingredient for a specific food product is wheat from Western Australia then a sensible figure might be 256 kg CO_2-e/tonne. The difference between the lower and upper values for WA wheat is largely driven by the level of nitrogen fertiliser use, so if this was known specifically for the raw ingredient, the figure could be adjusted. The goal for the future is to build similar inventory for other major wheat producing regions of Australia.

Garment manufacturers using fine Merino wool from Australia should factor in about 28-29 kg CO_2-e for the greasy wool at farm gate when estimating a carbon footprint for their product.

To make useful comparisons of food products, we need to move from a per unit weight basis (as in Table 2) to a different functional unit, related to the nutritive value of the product. For instance, one would need to consume approximately 10 times the weight of lentils to obtain the same protein intake as beef, or 2 times the weight for an equivalent amount of energy. However lentils also provide a greater proportion of other essential dietary elements such as fibre and complex carbohydrates.

In terms of determining the carbon footprint at the food product level, there is not enough data available yet on Australian food for this type of detailed menu planning, and it is inappropriate to use data from other countries due to the emissions profile of energy (particularly electricity) inputs and large differences in farming systems. However, to enable households to track GHG emissions associated with food, and adjust their food choices towards a lower carbon diet, there needs to be data for a wide range of food items, or general groupings of items with similar carbon footprints. A generic message about food groups and sources may be more informative to consumers than a carbon footprint on each and every individual product.

Following along these lines, various principles have been suggested for lower carbon diets – diets with less meat and cheese, more in-season vegetables and more locally produced and fresh foods [31] but such recommendations need to be tested under Australian systems before they can be assumed to be valid. The general assumption amongst the public is that a backyard-grown tomato will have a lower carbon footprint than one bought in the supermarket, but this assumes the considerable yield advantages and efficiencies of broad acre production, with optimised nutrient and water use, do not compensate for the emissions associated with the distribution system.

Once a useful body of information is know for food items, there is good evidence that diets can be chosen that have 2-4 times less fossil fuel input [31]. For pet owners, it is useful to have information from a life cycle assessment of the impact of their pet's food. For Whiskas Ocean Fish®, a wet, canned product predominantly based on animal ingredients, the carbon footprint was 1.3 kg CO_2-e/kg of product or 390 g CO_2-e per 300 g daily food allowance for a 4 kg cat. For Pedigree Meaty Bites®, a dry formulation with 75% plant-based ingredients, the carbon footprint was 0.9 kg CO_2-e/kg of product or 396 g CO_2-e per 440 g daily food allowance for a 25 kg dog.

It is not appropriate to directly compare the two pet food products on a weight basis as they have distinctly different formulations; one is a wet product and the other dry, and one is largely animal ingredient based while the other is 75% plant ingredients. However, the results do give indicative emissions profiles for each type of pet food; in general a dry formulation is going to have a lower carbon footprint and a formulation with more plant ingredients is going to have a lower carbon footprint. For pet owners this gives some pointers as to how to choose the lowest carbon footprint option.

The results for food products can also be used by manufacturers to benchmark their products and explore alternative raw ingredients or processing techniques to reduce the product carbon footprint. In terms of reviewing the formulation of each product to reduce GHG emissions, knowledge of the carbon footprint for primary ingredients (as shown in Table 1) can guide the assessment. The task then for food manufacturers (and the home cook) is to optimise the nutritive value, palatability, texture, ingredient cost and GHG emissions profile to achieve a balanced outcome for the customer/family, business/home budget and environment.

5. CONCULSION

GHG emissions associated with livestock products, particularly from ruminant systems, are relatively high compared to broad-acre crop products such as wheat and legumes. The part of the supply chain contributing most to the carbon footprint of a product in the supermarket will vary depending on the level and energy cost of processing. With highly processed foods such as bread, the processing and baking phases contribute more than the on-farm phase, while with fresh beef and lamb the on-farm emissions make up the majority of the carbon footprint. This study looks at a limited range of products; a comprehensive inventory of food products, converted to a meaningful nutritive functional unit, is needed to enable future research and informed decision making.

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