Title:

Costs of food waste along the value chain: Evidence from South Africa

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Abstract

In a previous paper (Nahman et al., 2012), the authors estimated the costs of household food waste in South Africa, based on the market value of the wasted food (edible portion only), as well as the costs of disposal to landfill. In this paper, we extend the analysis by assessing the costs of edible food waste throughout the entire food value chain, from agricultural production through to consumption at the household level. First, food waste at each stage of the value chain was quantified in physical units (tonnes) for various food commodity groups. Then, weighted average representative prices (per tonne) were estimated for each commodity group at each stage of the value chain. Finally, prices were multiplied by quantities, and the resulting values were aggregated across the value chain for all commodity groups. In this way, the total cost of food waste across the food value chain in South Africa was estimated at

R61.5 billion per annum (approximately US$7.7 billion); equivalent to 2.1% of South Africa's annual gross domestic product. The bulk of this cost arises from the processing and distribution stages of the fruit and vegetable value chain, as well as the agricultural production and distribution stages of the meat value chain. These results therefore provide an indication of where interventions aimed at reducing food waste should be targeted.

Keywords

Cost of edible food waste

Food value chain

Food supply chain

Pre-consumer food losses

Post-consumer food waste

Economic valuation

Highlights

- We estimate the costs of food waste throughout the food value chain in South Africa
- The total cost amounts to R61.5 billion (US$7.7 billion) per annum
- This equates to 2.1% of South Africa's annual GDP
- 13% of this cost arises from food losses during fruit and vegetable processing
- Food losses during distribution of fruit and vegetables and of meat are also costly

1. Introduction

Definitions of food waste differ widely. For our purposes, we define food waste broadly to include losses that arise before food reaches the end-user (pre-consumer food losses), as well as food that is discarded by consumers (post-consumer food waste). This definition includes both the edible and inedible (peelings, bones, etc.) portions of the waste stream; although the current paper focuses specifically on the edible portion. Food waste therefore arises throughout the food supply chain, including during production, storage, transportation, processing, at retailers and in the kitchens of restaurants and households (Lundqvist et al., 2008). Globally, it is estimated that food waste throughout the food supply chain (including both pre- and post-consumer food waste) amounts to 50% of all food that is produced for human consumption (Lundqvist et al., 2008).

On a per capita basis, overall food waste throughout the supply chain is far higher in developed countries than in developing countries. For example, according to Gustavsson et al. (2011), food waste amounts to 280-300 kg/person/annum in Europe and North America respectively, compared to 170 kg/person/annum in sub-Saharan Africa. In developing countries, food waste arises mainly due to financial, managerial and technical limitations in harvesting techniques, storage and cooling facilities (exacerbated by difficult climatic conditions), infrastructure, packaging and marketing systems (Parfitt et al., 2010). By contrast, the causes of food waste in high income countries mainly relate to the tendency of consumers and the catering industry to buy more food than they need, and of farmers to 'leave food in the field' in response to either market forces or weather/pest-related damage (Gustavsson et al., 2011; Gunders, 2012; Institution of Mechanical Engineers, 2013). As such, in the European Union, for example, 42% of total food waste is generated by

households; 39% by the production and processing sector, 14% by the food service and catering sector, and 5% by the retail/wholesale sector (European Commission, 2010). By contrast, in sub-Saharan Africa, consumers are only responsible for approximately 3.5% of overall food waste, with the majority being generated during the pre-consumer stages of the food supply chain (Gustavsson et al., 2011). Consumers in Europe and North America waste, on average, 95 and 115 kg of food per person/year, respectively; while consumers in sub-Saharan Africa waste only 6 kg of food per person/year (Gustavsson et al., 2011). A study on food wasted in the United Kingdom showed that consumers throw away 31% of the food that they buy (Ventour, 2008).

From a social and environmental perspective, food waste is problematic for a number of reasons. Firstly, a substantial proportion of discarded food is still edible, implying that it could have been used to feed those in need, if it had been better managed or distributed (Nahman et al., 2012; Oelofse and Nahman, 2013). Secondly, even in the case of inedible food waste, disposal to landfill or by incineration implies the loss of a potentially valuable resource that could have been used in other processes (e.g. energy generation or composting). In addition, the decomposition of organic waste at landfill or by incineration leads to a range of environmental and social impacts. Finally, the production of food that ends up going to waste entails wasted resources and emissions in the food supply chain.

From an economic perspective, the costs of food waste tend to be under-valued (and therefore ignored by policy-makers), particularly in developed countries, where food represents only a small proportion of consumers' total budgets (Gunders, 2012; Institution of Mechanical Engineers, 2013). However, even in developed countries, the costs of food waste can be significant. In the UK, for example, households throw away 7 million tonnes of food, worth

about £10.2 billion, each year. This costs the average household £420 per year (Ventour, 2008). Similarly, "American families throw out approximately 25 percent of the food and beverages they buy. The cost estimate for the average family of four is $1,365 to $2,275 annually" (Gunders, 2012: 12). Looking at waste across the supply chain, Jones (2004) estimated that food waste in the USA amounts to $90–100 billion worth of food each year, of which households are responsible for approximately $48 billion; while Venkat (2011) estimates a total cost of $198 billion, of which consumers are responsible for $124 billion (63%).

In a previous paper (Nahman et al., 2012), the authors estimated the cost of post-consumer food waste (specifically, food waste at the household level) in South Africa at approximately R21.7 billion (approximately US$2.7 billion) per annum[1], or 0.7% of South Africa's annual gross domestic product (GDP)[2]. This included the costs of wasted edible food that could be used to feed the hungry, valued according to weighted market prices for income group-specific food baskets (obtained from the South African Consumer Price Index for Food (Statistics South Africa, 2011)); as well as both the direct financial and 'external' (social and environmental) costs of disposal to landfill (based on Nahman (2011)). Household waste quantities were estimated by extrapolating 2004 per capita waste generation trends per income group for South Africa to the latest available estimate of the population size per income group. Thereafter, the proportion of food waste within the overall household waste stream was estimated by extrapolating the results of waste characterisation studies in three South African cities to the national level. However, a number of caveats were raised by Nahman et al. (2012) as to potential difficulties in making these extrapolations. In particular, owing to the lack of waste characterisation studies in South Africa that identified 'food

[1] R = South African Rands. 1 US Dollar = approximately 8 South African Rands (Average over January-October 2012).
[2] South African GDP for 2011 at current prices was R2 964 billion (Statistics South Africa, 2012b)

waste' as a distinct category, it was necessary in some cases to base the extrapolations on broader categories such as 'putrescibles' or 'organic waste,' which included other waste items (such as animal carcasses and garden waste) in addition to food waste, which would lead to an over-estimate of food waste quantities.

Furthermore, Nahman et al. (2012) provided a number of recommendations with respect to key areas in which the research needed to be extended; namely (1) by incorporating the inedible portion of household food waste, (2) by addressing food waste throughout the value chain, and (3) by including the costs of other impacts associated with food waste, such as wasted emissions and resource use throughout the value chain. In particular, it was argued that post-consumer food waste only represents a small proportion of overall food waste in developing countries (3.5% for sub-Saharan Africa according to Gustavsson et al. (2011), and 4.14% for South Africa according to Oelofse and Nahman (2013)); and therefore that excluding pre-consumer food losses was a significant omission. It was therefore deemed necessary to conduct further research aimed at valuing food waste along the entire food supply chain in South Africa, in order to complete the analysis.

This follow-up paper extends the analysis conducted in Nahman et al. (2012), by developing a methodology and reporting on results of an assessment of the costs of food waste throughout the entire food value chain[3] in South Africa, from agricultural production through to food waste at the household level (with a specific focus on edible food waste).

A three-stage process was adopted in quantifying the costs of food waste throughout the food value chain in South Africa. First, food waste at each stage of the value chain was quantified

[3] Note that we generally use the term 'food value chain' as opposed to 'food supply chain' in this paper; although the two terms are synonymous in this context.

in physical units (tonnes) for various food commodity groups. Second, weighted average representative prices (per tonne) were estimated for each commodity group at each stage of the value chain. Finally, prices were multiplied by quantities, and the resulting values were aggregated across the value chain for all commodity groups, to obtain the total cost of food waste in South Africa. Each of these stages is described in more detail below.

2. Quantifying food waste throughout the food value chain

Food waste throughout the value chain was quantified using a similar approach to Oelofse and Nahman (2013), which is somewhat different to the approach adopted in Nahman et al. (2012). First, estimates were obtained from Gustavsson et al. (2011) regarding the proportion of food entering each stage of the value chain that is lost or wasted, for various food commodity groups in sub-Saharan Africa (Table 1). These estimates were derived using a mass flow model, based on data on food production and food waste from the Food and Agriculture Organization of the United Nations (FAO), as well as other sources. Note that the data refers only to *edible* food waste. Furthermore, note that the 'distribution' stage includes wholesalers, supermarkets and retailers; while the 'consumption' stage refers to waste at the household level.

Table 1: Proportion (by mass) of food entering each stage of the value chain that is lost/wasted (Source: Gustavsson et al., 2011)

Commodity group	Agricultural production	Post-harvest handling and storage	Processing and packaging	Distribution	Consumption
Cereals	6.0%	8.0%	3.5%	2.0%	1.0%
Roots and Tubers	14.0%	18.0%	15.0%	5.0%	2.0%
Oil seeds & Pulses	12.0%	8.0%	8.0%	2.0%	1.0%
Fruits and Vegetables	10.0%	9.0%	25.0%	17.0%	5.0%
Meat	15.0%	0.7%	5.0%	7.0%	2.0%

Fish and Seafood	5.7%	6.0%	9.0%	15.0%	2.0%
Milk	6.0%	11.0%	0.1%	10.0%	0.1%

Then, data on actual quantities (tonnes) of each commodity group entering each stage of the value chain in South Africa were obtained from Food Balance Sheets published by the Statistics Division of the FAO (FAOSTAT, 2012). The FAO data is provided both at the level of individual commodities, as well as for broader commodity groups, using similar categories as Gustavsson et al., making it relatively easy to match the FAO data with the commodity groups presented in Table 1. Food quantities were calculated by taking an average over the last three years for which data from the FAO was available (2007-2009), in order to account for year-on-year variation. The quantity of food waste at each stage was then calculated by multiplying the quantity of food entering each stage of the food value chain for each commodity group (as per the FAO data) by the proportion that is lost or wasted (as per Table 1). The resulting quantities are presented in Table 2.

Table 2: Quantities of food waste (in thousands of tonnes) at each stage of the value chain (Calculated based on data from FAOSTAT, 2012; Gustavsson et al., 2011)

Commodity group	**Agricultural production**		**Post-harvest handling and storage**		**Processing and packaging**		**Distribution**		**Consumption**		**Total food waste (1,000 tonnes)**
	Food entering	**Food Waste**	Food entering	**Food Waste**	Food entering	**Food Waste**	Food entering	**Food Waste**	Food entering	**Food Waste**	
Cereals	13 140	**788**	12 352	**988**	11 363	**398**	14 441	**289**	14 152	**142**	**2 605**
Roots and Tubers	2 015	**282**	1 733	**312**	1 421	**213**	2 144	**107**	2 037	**41**	**955**
Oil seeds & Pulses	1 198	**144**	1 054	**84**	970	**78**	1 340	**27**	1 314	**13**	**346**
Fruits and Vegetables	8 463	**846**	7 616	**685**	6 931	**1 733**	5 799	**986**	4 813	**241**	**4 491**
Meat	2 549	**382**	2 167	**15**	2 151	**108**	2 802	**196**	2 606	**52**	**753**
Fish and Seafood	673	**38**	635	**38**	597	**54**	568	**85**	483	**10**	**225**
Milk	3 102	**186**	2 916	**321**	2 595	**3**	3 182	**318**	2 864	**3**	**831**
Total		**2 667**		**2 444**		**2 585**		**2 008**		**501**	**10 205**

For example, for the quantity of food entering the agricultural production stage (Table 2, column 2), the FAO data corresponding to domestic production were used (FAOSTAT,

2012). For each commodity group, the quantity of food waste at this stage (Table 2, column 3) was calculated based on the relevant percentages presented in Table 1, column 2 (e.g. for 'cereals,' the quantity of food waste at the agricultural production stage = 6% of 13,140,000 = 788,000 tonnes). The quantity of food entering the post-harvest handling and storage stage (Table 2, column 4) was then calculated as the quantity of food entering the agricultural production stage (column 2), less food waste at the agricultural production stage (column 3). Food waste at the post-harvest handling stage (Table 2, column 5) was then once again calculated based on the relevant percentages in Table 1, column 3; and so on for each successive stage in the value chain.

Aggregating across the value chain for all commodity groups, the total quantity of food waste across the value chain in South Africa amounts to 10.2 million tonnes per annum. This is slightly higher as compared to Oelofse and Nahman's (2013) estimate of 9.04 million tonnes. This difference can largely be explained by the fact that, unlike Oelofse and Nahman, the current paper takes imports and exports into account in the analysis. Specifically, this was done by adding imports and subtracting exports (also obtained from the FAO Food Balance Sheets) at the distribution stage[4]. This explains why, unlike for the other stages, the quantity of food entering the distribution stage does not equal the quantity of food entering the previous stage less food waste at the previous stage; since in addition to subtracting food waste, imports also had to be added and exports subtracted. It also explains why, for certain commodities (namely those for which South Africa is a net importer, and where net imports outweigh food waste quantities), the quantity of food at the distribution stage exceeds the

[4] It is acknowledged that this approach represents a simplification, since some imported food types require some level of further processing locally, while for other imports this is not the case. However, given the complex pattern of variances between different types of products in this regard, as well as uncertainty regarding the extent to which food waste associated with further processing of imported foodstuffs is already included in the data for processing and packaging presented in Tables 1 and 2, and the lack of data regarding food waste associated specifically with further processing of imports, it was deemed necessary to ignore this issue for the sake of clarity.

quantity of food produced domestically in the agricultural production stage, despite food losses occurring between these two stages.

Figures 1 and 2 show, respectively, the relative contribution of each commodity group and each stage in the value chain to the total mass of food waste generated in South Africa. It can be seen that, in terms of the contribution of different commodity groups, fruit and vegetables contribute the largest portion to overall food waste quantities in South Africa, followed by cereals. On the other hand; in terms of food waste at different stages of the value chain, there is a more or less even spread among the four pre-consumer stages, with each of these stages contributing between 20 and 26% of the overall mass of food waste; while post-consumer food waste only contributes 5% to the total.

INSERT FIGURE 1 ABOUT HERE

INSERT FIGURE 2 ABOUT HERE

The proportions illustrated in Figures 1 and 2 are useful for identifying specific commodity groups and stages in the value chain where the bulk of the overall amount of food waste in South Africa originates. However, because they are based purely on the mass of food waste, these proportions do not necessarily reflect the relative significance of the food waste problem associated with each commodity group or stage. Because of the value-adding that occurs throughout the supply chain, a tonne of food lost in the agricultural production stage is not as significant from an economic perspective as a tonne of food lost during the distribution stage, for example. Similarly, because of differences in market prices, a tonne of vegetables that goes to waste is not as problematic from an economic perspective as a tonne of wasted

meat. The quantities of food waste for each commodity group and at each stage of the value chain therefore need to be weighted by representative market prices, in order to more fully reflect the associated economic impacts. Representative prices for each commodity group at each stage of the value chain are estimated in the following section.

3. Estimating representative prices

Representative prices were estimated by defining representative commodities for each commodity group, and by tracing value-added prices for each of these commodities throughout their respective value chains. Representative commodities were selected on the basis of domestic production quantities in South Africa, again as per the FAO Food Balance Sheets. For example, maize and wheat were selected as representative commodities for the 'cereals' group, as these two commodities together make up 96% of the total production quantity of 'cereals' in South Africa; as opposed to commodities such as rice, which are largely imported.

Table 3 presents the list of representative commodities selected for each commodity group. To indicate the degree of representivity, 2009 production of each representative commodity, as a percentage of 2009 production for the commodity group as a whole, is presented in parentheses[5]. Table 3 also provides a brief description (as well as the source) of the prices used for each stage of the value chain for each representative commodity. Table 4 presents the resulting prices (ignore the last two columns for the time being). Note that all prices were based on the latest available market information as at August 2012.

[5] 2009 is the most recent year for which the production data was available from the FAO Food Balance Sheets

Table 3: Description and source of prices for each representative commodity at each stage of the food value chain.

Commodity group	Representative commodities (2009 production as % of commodity group total production)	Description and source of representative prices				
		Agricultural production	**Post-harvest handling and storage**	**Processing and packaging**	**Distribution**	**Consumption**
Cereals	White and Yellow maize (83%)	2011 average farm gate price (NAMC, 2012)	2011 average SAFEX spot silo price for maize (SAFEX, 2012)	SAFEX price plus total milling & packaging cost, minus distribution cost (SAFEX, 2012)	Processing and packaging price plus distribution costs plus wholesaler mark- up (NAMC, 2012)	Retail price (NAMC, 2012)
	Wheat (13%)	2011 average farm gate price (NAMC, 2012)	2011 average SAFEX spot silo price for wheat (SAFEX, 2012)	SAFEX price plus total milling & packaging cost minus distribution cost (SAFEX, 2012)	Processing and packaging price plus distribution costs plus wholesaler mark-up (NAMC, 2012)	Retail price (NAMC, 2012)
Roots and Tubers	Potatoes (78%)	Average farm gate price (PotatoesSA, 2012)	Average producer price (PotatoesSA, 2012	Average producer price plus average processing and packaging costs for table and processing potatoes (all cultivars) (PotatoesSA, 2012)	Average Johannesburg and Cape Town market price for a 10kg pocket (all cultivars) (Cape Town Market, 2012; Joburg market, 2012)	NAMC retail price (no cultivar specified) (NAMC, 2012)
	Onions (19%)	Average farm gate price (Department of Agriculture, Forestry and Fisheries, 2012a)	Average producer price (Department of Agriculture, Forestry and Fisheries, 2012a)	Average producer price plus average processing and packaging costs for onions (all cultivars) (NAMC, 2012)	Average Johannesburg and Cape Town market price for a 10kg bag (all cultivars) (Cape Town Market, 2012; Joburg market, 2012)	NAMC retail price (no cultivar specified) (NAMC, 2012)
Oil seeds & Pulses	Sunflower (52%)	Farm gate price for sunflower seed (NAMC, 2012)	2011 average SAFEX spot price for sunflower (SAFEX, 2012)	Average market price for oil and oilcake (SAFEX, 2012)	Average market price for oil and oilcake plus distribution cost (NAMC, 2012)	Retail price (NAMC, 2012)
	Soya beans (33%)	Farm gate price for soya beans (NAMC, 2012)	2011 average SAFEX spot price for soya beans (SAFEX, 2012)	Average market price for oil and oilcake (SAFEX, 2012)	Average market price for oil and oilcake plus distribution (NAMC, 2012)	Retail price (NAMC, 2012)
Fruits and Vegetables[a]	Tomatoes (6%)	Farm gate price (Department of Agriculture Forestry and Fisheries, 2012b)	Farm gate price plus on-farm sorting and packaging costs (Department of Agriculture Forestry and Fisheries, 2012b)	Bulk storage price (NAMC, 2012)	Average price for a B6 carton on the Johannesburg and Cape Town market (Cape Town Market, 2012; Joburg market, 2012)	Retail price (NAMC, 2012)
	Citrus (25%)	Farm gate price (Citrus Growers Association, 2012)	Farm gate price plus on-farm sorting and packaging costs (Citrus Growers Association, 2012)	Bulk storage price (Citrus Growers Association, 2012)	Export price plus distribution cost (Citrus Growers Association, 2012)	Retail price (Citrus Growers Association, 2012)
Meat	Whole fresh chicken (52%)	Farm gate price (South African Poultry Association, 2012)	Feedlot price (South African Poultry Association, 2012)	Abattoir prices (NAMC, 2012)	Wholesale prices (NAMC, 2012)	Retail price (NAMC, 2012)
	Beef (29%)	Farm gate prices (South African Feedlot Association, 2012)	Feedlot prices (South African Feedlot Association, 2012)	Abattoir prices (RMAA, 2012)	Wholesale prices (NAMC, 2012)	Retail price (NAMC, 2012)
	Lamb (7%)	Farm gate price (NAMC, 2012)	Average price for class A, B and C carcass (NAMC, 2012)	Abattoir prices (RMAA, 2012)	Wholesale prices (NAMC, 2012)	Retail price (NAMC, 2012)
	Pork (12%)	Farm gate price (NAMC, 2012)	Feedlot price (South African Feedlot	Abattoir price (RMAA, 2012)	Wholesale price (NAMC, 2012)	Retail price for pork chops

			Association, 2012)			(NAMC, 2012)
Fish and Seafood	Deep water hake (71%)	Average Hout Bay (Cape Town) harbour price	Linearly extrapolated to retail price because of absence of information			Retail price (NAMC, 2012)
Milk	Milk (100%)	Raw milk at the farm gate (Milk Producers' Organisation, 2012)	Raw milk collection and transport to processing plant (Milk South Africa, 2012)	Processing and quality assurance and bottling (Milk South Africa, 2012)	Marketing and distribution by processor (Milk South Africa, 2012)	Retail price (NAMC, 2012)

[a] Compared with the other commodity groups, the representivity of the two commodities (citrus and tomatoes) in the 'fruits and vegetables' category appears relatively low. These two commodities were chosen because citrus is the most significant contributor to production among the fruits, and tomatoes the most significant among the vegetables. Because of the large variety of commodities within each of these sub-categories, the relative contribution of each commodity to the total is relatively low. Indeed, the next highest contributor in each sub-category was relatively insignificant. It was therefore not deemed worthwhile adding additional representative commodities, as the overall representivity would not have been significantly improved.

Table 4: Prices for representative commodities at each stage of the food value chain

Commodity group	Representative commodities	Unit	Agricultural production	Post-harvest handling and storage	Processing and packaging	Distri-bution	Consump-tion	Weighting based on domestic production	Weighting based on total supply
Cereals	Maize	R/t grain	1 005	1 275	1 977	2 206	3 101	86%	75%
	Wheat	R/t grain	1 848	2 217	2 952	3 173	3 525	14%	25%
Roots and Tubers	Potatoes	R/t	2 100	2 300	3 432	3 900	8 200	80%	81%
	Onions	R/t	2 000	2 600	3 080	3 500	7 000	20%	19%
Oil seeds & Pulses	Sunflower	R/t	5 000	6 225	18 675	19 982	21 333	61%	65%
	Soya beans	R/t	4 500	5 625	16 875	18 056	16 500	39%	35%
Fruits and Vegetables	Tomatoes	R/t	3 500	4 300	8 213	9 333	14 000	20%	45%
	Citrus	R/t	3 708	3 708	3 708	4 100	5 916	80%	55%
Meat	Chicken	R/kg	14	17	23	25	30	53%	55%
	Beef	R/kg	16	25	29	35	55	29%	27%
	Lamb	R/kg	25	40	52	75	90	7%	6%
	Pork	R/kg	14	18	22	29	43	12%	12%
Fish and Seafood	Hake	R/kg	25	30	35	40	45	100%	100%
Milk	Milk	R/l	3	3	4	6	7	100%	100%

Representative prices for each commodity group at each stage of the food value chain were then calculated, using a weighted average of the prices of the representative commodities within each group (in Rands per tonne). Weights were based on relative 2009 production of the representative commodities within each group (see last two columns of Table 4). For example, in the case of cereals, maize production accounted for 86% of the combined production of the two representative commodities within this group, and wheat the other 14%. Thus, the representative price for cereals at the agricultural production stage, for

example, was calculated by weighting the prices for maize and wheat at this stage (respectively R1005 and R1848 as per Table 4) by the proportion of relative domestic production for these two commodities (86% and 14% respectively, as per the second last column of Table 4); giving rise to a weighted average representative price of R1123 (see Table 5).

The same procedure was repeated for all commodity groups and all stages throughout the value chain. However, note that for the first three stages of the value chain, weights were based on relative 2009 domestic production (second last column of Table 4); while for the latter two stages they were based on relative 2009 total supply (i.e. domestic production plus imports less exports) (last column of Table 4). The resulting representative prices for each commodity group at each stage of the food value chain are presented in Table 5.

Table 5: Representative prices (2012 Rands per tonne) for each food commodity group at each stage of the value chain

Commodity group	Agricultural production	Post-harvest handling and storage	Processing and packaging	Distribution	Consumption
Cereals	1 123	1 407	2 113	2 445	3 206
Roots and Tubers	2 080	2 360	3 362	3 825	7 976
Oil seeds & Pulses	4 804	5 990	17 970	19 310	19 646
Fruits and Vegetables	3 666	3 826	4 608	6 461	9 564
Meat	15 047	20 603	26 545	31 519	41 818
Fish and Seafood	25 000	30 000	35 000	40 000	45 000
Milk	3 000	3 100	4 450	6 350	7 450

4. The costs of food waste in South Africa

The final step in valuing the costs associated with food waste was to multiply the quantities of food waste for each commodity group at each stage of the value chain (Table 2) by the appropriate representative price associated with each commodity group at each stage (Table 5). The resulting values are presented in Table 6.

Table 6: Costs of food waste throughout the value chain in South Africa (in thousands of 2012 Rands)

Commodity group	Agricultural production	Post-harvest handling and storage	Processing and packaging	Distribution	Consumption	Total (Thousand Rands)
Cereals	885 241	1 389 970	840 498	706 094	453 674	4 275 477
Roots and Tubers	586 814	735 983	716 636	410 081	324 916	2 774 431
Oil seeds & Pulses	690 445	505 045	1 393 923	517 629	258 051	3 365 093
Fruits and Vegetables	3 102 702	2 622 700	7 983 722	6 370 082	2 301 683	22 380 890
Meat	5 753 134	312 479	2 855 605	6 182 060	2 179 439	17 282 718
Fish and Seafood	959 025	1 142 350	1 879 166	3 408 000	434 520	7 823 061
Milk	558 420	994 422	11 550	2 020 358	21 333	3 606 083
Total	12 535 782	7 702 949	15 681 100	19 614 305	5 973 616	61 507 753

The total cost of edible food waste throughout the value chain in South Africa therefore amounts to R61.5 billion per annum (approximately US$7.7 billion). This is equivalent to 2.1% of South Africa's annual GDP (Statistics South Africa, 2012a). Of this, approximately R6 billion arises at the consumer (household) level. This is significantly less than Nahman et al.'s (2012) estimate of R21.7 billion for post-consumer food waste; although this can be explained by the fact that entirely different methods and data were used in quantifying this waste (see Sections 1 and 2). Specifically, it is worth noting the caveat mentioned in Section 1 regarding the likelihood that the previous estimate of R21.7 billion was an over-estimate.

In per capita terms, this cost is relatively low compared to developed countries. For example, assuming a total cost of US$7.7 billion and a population of 52 million[6], the cost of food waste per capita in South Africa amounts to US$148. By comparison, previous estimates in the USA (Jones, 2004; Venkat, 2011) equate to between $285 and $628 per capita[7]. However, relative to GDP, the cost of food waste in the US amounts to between 0.6% and 1.3% of GDP[8], as compared to 2.1% in South Africa.

5. Discussion and policy recommendations

Analogous to Figures 1 and 2, Figures 3 and 4 show, respectively, the relative contribution of each commodity group and each stage in the value chain to the total cost of food waste generated in South Africa. As expected, bringing market prices into the picture (Figures 3 and 4) gives more weight to those commodity groups (e.g. meat, fish and seafood) and stages (e.g. distribution and consumption) where the associated market prices are higher, as compared to the results shown in Figures 1 and 2. More specifically, Figure 3 shows that although meat, together with fish and seafood, contributes only 9% to total food waste quantities (Figure 1), the higher price of these commodities as compared to other food groups implies that they contribute 41% to the total cost of food waste in South Africa. Similarly, Figure 4 shows that, although the distribution and consumption stages together contribute only 25% to total food waste (Figure 2), the higher prices associated with these later stages in the value chain imply that these two stages contribute 42% to the total cost of food waste in South Africa.

[6] As per http://www.statssa.gov.za/publications/Census%202011_data_supplied_to_National_Treasury.asp
[7] Assuming a population of 315 million, as per http://www.census.gov/popclock/
[8] United States 2011 GDP at current prices = $15 trillion, according to http://data.worldbank.org/country/united-states

INSERT FIGURE 3 ABOUT HERE

INSERT FIGURE 4 ABOUT HERE

Figures 3 and 4 therefore provide a more accurate reflection of those food commodity groups and stages in the value chain which contribute most to the economic significance of the food waste problem in South Africa. On the whole, Figure 3 shows that, despite the relatively low unit price of fruits and vegetables relative to meat and seafood, the sheer volume of fruit and vegetable waste in South Africa implies that this commodity group remains the most significant from an economic perspective (that is, the higher quantity of food waste in this commodity group outweighs the lower price per unit). Nevertheless, owing largely to the higher market prices associated with meat and seafood, these commodity groups also contribute significantly to the overall cost of food waste in South Africa. On the other hand, Figure 4 shows that all five stages of the value chain in South Africa contribute to the overall costs of food waste in the country; with the processing and packaging and distribution stages together contributing toward the bulk (57%) of the costs.

These findings provide useful information regarding where interventions aimed at alleviating the food waste problem in South Africa should be targeted in order to be most effective. They suggest that interventions should be targeted at all stages of the meat and fruit and vegetable value chains, and at the processing and packaging and distribution stages of the value chain for all commodities. Furthermore, looking again at Table 6, it is possible to provide more specific recommendations, by focusing on specific stages of the value chain for specific commodity groupings (i.e. by looking at specific cells in the table rather than simply at the row or column totals). For the sake of clarity, the data in Table 6 is illustrated graphically in

Figure 5, which shows the cost of food waste (in billions of 2012 Rands) in each stage of the value chain for each commodity group.

INSERT FIGURE 5 ABOUT HERE

Figure 5 suggests that interventions should first and foremost be targeted at the processing and packaging stages of the fruit and vegetable value chain; since food waste at this stage alone costs just under R8billion per annum; i.e. 13% of the total cost of food waste in South Africa, or 0.3% of annual GDP. Other such 'low-hanging fruits' include the distribution stage of the fruit and vegetable value chain, as well the agricultural production and distribution stages of the meat value chain.

It is worth noting that, in some cases, waste streams from higher-value-per-unit commodity groups such as meat have attracted the development of financially viable secondary industries which use this waste as an input in their production processes; whereas the lower value-per-unit nature of fruit and vegetable waste has not justified the development of financially viable industries. Opportunities therefore exist to support innovation and green technology development in these areas.

6. Conclusions and recommendations for further research

This paper extends the analysis conducted in Nahman et al. (2012), by assessing the costs of edible food waste throughout the value chain in South Africa. Based on the value-added prices of a range of representative commodities throughout their respective value chains, we

estimate these costs at R61.5 billion per annum (approximately US$7.7 billion), equivalent to 2.1% of annual GDP.

Furthermore, by disaggregating these costs to the level of specific points in the value chain for specific commodity groups, recommendations can be made regarding the priority areas that should be targeted for interventions aimed at alleviating the food waste problem in South Africa. Broadly speaking, intervention is required at all stages of the meat and fruit and vegetable value chains, and at the processing and packaging and distribution stages of the value chain for all commodities. More specifically, interventions should first and foremost be targeted at the processing and packaging stages of the fruit and vegetable value chain, which alone accounts for R8billion per annum, i.e. 13% of the total; as well as the distribution stage of the fruit and vegetable value chain, and the agricultural production and distribution stages of the meat value chain.

However, a number of gaps in the research remain. Firstly, in this analysis, we have ignored the costs associated with disposal to landfill. This issue is complicated by the fact that discarded food materials will be re-used or disposed of in different ways in different stages of the value chain. For example, discarded food materials at the harvesting stage may be simply left in the field, or utilised as compost, rather than disposed of at a landfill site. This issue will therefore be brought back into the analysis in future research.

There is also a need to address the inedible portion of food waste, as well as the impacts associated with emissions and resource use embedded in the production of food that ultimately ends up being wasted. The issue of inedible food waste relates to the fact that this portion of the food waste stream cannot be valued at the same market prices used to value

edible food waste; since inedible food waste by definition cannot be used to feed the hungry. However, inedible food waste can nevertheless be used as an input into other processes, such as composting, bio-energy generation, or the production of animal feed; and therefore has value in its own right. In our future research, we will develop a methodology for valuing inedible food waste as an input into these processes, in order to provide a more complete assessment of the costs of food waste in South Africa.

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Figure captions

Figure 1: Relative contribution of food waste quantities in each commodity group to the total quantity of food waste in South Africa (%, by mass)

Figure 2: Relative contribution of food waste quantities in each stage of the value chain to the total quantity of food waste in South Africa (%, by mass)

Figure 3: Relative contribution of the cost of food waste in each commodity group to the total cost of food waste in South Africa (%, by value)

Figure 4: Relative contribution of the cost of food waste in each stage of the value chain to the total cost of food waste in South Africa (%, by value)

Figure 5: Cost of food waste in each stage of the value chain for each commodity group (R' billions).