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The impact of fresh produce specifications on the Australian food and nutrition system: a case study of the north Queensland banana industry

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Abstract

Objective: To use the north Queensland banana industry as a case study to examine the extent to which cosmetic standards set by retailers influence the amount of edible waste generated on-farm and the effect of this on the sustainability of the Australian food and nutrition system.
Design: Waste audits were performed on-farm at a banana packing shed to quantify the amount of fruit discarded due to cosmetic imperfections. These data, together with production records provided by the Department of Primary Industries and Fisheries and interviews with growers, were used to inform a nutritional analysis, a life cycle assessment and an economic analysis to quantify nutritional, environmental and economic impacts.
Setting: North Queensland, Australia
Subjects: Banana farms and packing shed.
Result: Between 10 and 30 % of the north Queensland banana crop is discarded on-farm. Of this, 78 % was found to be due to cosmetic imperfections, which equates to an industry total of 37 000 tonnes per annum. This waste represents a loss of 137 billion kilojoules with accompanying macro- and micronutrients. The life cycle assessment indicated that approximately 16 300 tonnes of carbon dioxide emissions, 11·2 gigalitres of virtual water as well as other natural resources are embodied in the waste. There is an industry-wide, economic loss of approximately $AU 26·9 million per annum.
Conclusions: The majority of on-farm banana waste is caused by arbitrary cosmetic standards set by retailers, resulting in significant nutritional, environmental and economic losses. Public health nutritionists have a role to play across the entire food chain to minimize the impacts of waste on the food system.

Keywords
Banana
Food waste
New nutrition science
Product specifications
Sustainability

The environment is nutrition's invisible infrastructure[1]. It provides the ecosystem goods and services, such as the movement of nutrients and water through the biogeochemical cycles, the provision of energy from the sun and the formation of soil, that have enabled humans to grow enough food to support a global population of seven billion. However, the consistent and constant availability of supply upon which the food system has relied since the industrialization of agriculture in the early to mid 20th century is now faced with a physical and economic climate where it will be harder to achieve this goal[2]. Climate change, water shortages and a decline in oil production are all predicted to cause declines in agricultural productivity, and ultimately affect the access, availability and affordability of basic, nutritious foods[3,4]. Concomitantly there is an increasing demand for food and feed as a result of population growth and rising affluence in emerging economies. As a result the FAO has indicated that food production needs to increase by 70 % in the next 40 years, while simultaneously reducing the usage of resources such as fertilizers, water and fuel that are fundamental to the ability of modern agriculture to be highly productive[5]. While there is no doubt that a growing population will need more food, what is questioned is whether this is achievable through increased production. An alternative approach would be to start with addressing the efficiency of the food system by reducing the estimated 50 % of food that is wasted as it moves from paddock to plate[6].

While reducing household food waste has been the focus of a number of recent campaigns[7,8], the amount of unnecessary food waste that occurs at farm level is an

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Table 1 General appearance and minor defect product specifications for hybrid Cavendish bananas[16]

GENERAL APPEARANCE CRITERIA	
Colour	With receival colour (inner whorl) stage 4·0 summer (01 Nov–31 Mar), stage 5·0 winter (01 Apr–31 Oct); uniform colour within cartons
Visual appearance	With normal-bright bloom
Sensory	Firm, not soft, nil foreign smells or tastes
Shape	Slightly arched, with blunted butt end and intact, undamaged necks. Nil with double pulps or sausage shapes
Size	Finger length, measurement is over curvature, pulp to pulp, across the back of the banana: X Large, 220–260 mm; Large, 200–220 mm. Clusters 3–9 fingers (ideal 5–9 fingers)
Maturity	Finger maturity thickness: measured at right angles to the curve of the fruit at a point one-third from its flowering end. Girth 30–40 mm
MINOR DEFECTS	
Physical/pest damage	With dry brown scab (insect damage) or with scars (due to hail, bird damage) affecting areas $>2\,cm^2$ (per cluster) With reddish-brown blemishes (banana rust) affecting areas $>2\,cm^2$ With dark sap stains affecting $>4\,cm^2$ (per cluster)
Physiological disorders	With reddish-brown discolouration (maturity bronzing) affecting areas $>4\,cm^2$ (per cluster)
Skin marks/blemishes	With superficial bruises (<1 mm deep), abrasion or rub damage (tan/brown/black) affecting $>4\,cm^2$ (per cluster)

area that has received little attention. The type of food loss that occurs at the farm level varies greatly depending on the type and durability of the crop[9]. This includes both quantitative and qualitative losses such as loss in edibility, nutritional quality, caloric value and consumer acceptability of the product[10]. While some of this waste is due to a lack of nutritional quality or food safety concerns, too often it is because the food exhibits physical attributes that are considered to be flaws by principal retailers[11]. As a consequence, a significant portion of the food produced is discarded before it leaves the farm.

The Australian banana industry has been chosen as a case study for a number of reasons. First, a high percentage (70 %) of total banana production is sold to the two major Australian retailers[12], indicating that the specifications set by the retailers would have a significant impact on the industry. Second, bananas are one of the few horticultural products that supplies 100 % of the Australian domestic market, with minimal quantities exported[13]. This makes the task of accounting for inputs and outputs simpler and more accurate.

In 2009, Australia's 800 banana growers produced over 20·7 million, 13 kg cartons of bananas[12]. Approximately 90 % of these are grown in north Queensland, with minor growing areas in south-east Queensland, northern New South Wales and to a lesser extent in the Northern Territory and Western Australia[14]. The north Queensland industry is highly successful, as the tropical climate allows for year-round production, making it the only fruit grown 365 days a year in Australia. Previous research has indicated that somewhere between 10 and 30 % of total banana production is discarded before it leaves the farm, with the majority of this waste linked to a failure to meet cosmetic standards outlined in product specifications set by retailers[15]. Product specifications for bananas are set by the two major Australian grocery retailers and the central wholesale markets. All three sets of specifications for Cavendish bananas have the same requirements established for general appearance, major defects, minor defects and consignment criteria.

The consignment and major defect criteria play an important role in maintaining a safe and publicly transparent food supply. They specify the need for production systems to meet strict food safety standards (Food Standards Australia New Zealand, Hazard Analysis and Critical Control Points), comply with quarantine regulations and meet benchmarks set for refrigeration and labelling. The criteria covering major defects ensure that produce is free from pests and diseases that pose a threat to human or environmental health. The minor defects and general appearance sections set high cosmetic criteria for colour, shape, size and visual appearance with little impact on food safety or health. These specifications are outlined in Table 1[16]. If bananas sent to retailers do not meet these standards, they are rejected and sent back to the grower at the grower's expense, unless supply is low in which case the specifications are reviewable.

The objectives of the research described in the present paper were to quantify the amount of edible waste generated on-farm as a result of product specifications and to investigate the implications of this for the sustainability of the Australian food and nutrition system. The relevance to public health nutrition is highlighted, and recommendations made as to the role that nutrition professionals can play in minimizing this waste.

Methods

Ethics approval from the Queensland University of Technology Human Research Committee was obtained prior to commencing primary data collection. An initial interview was held with a representative from the Australian Banana Growers Council (ABGC), the industry body funded by the compulsory levy paid by growers to pay for promotions, research and development. The purpose of this interview was to obtain contact details of banana growers in north Queensland. The author contacted the selected growers by telephone and briefly explained the research project to them, and then requested their participation in a face-to-face

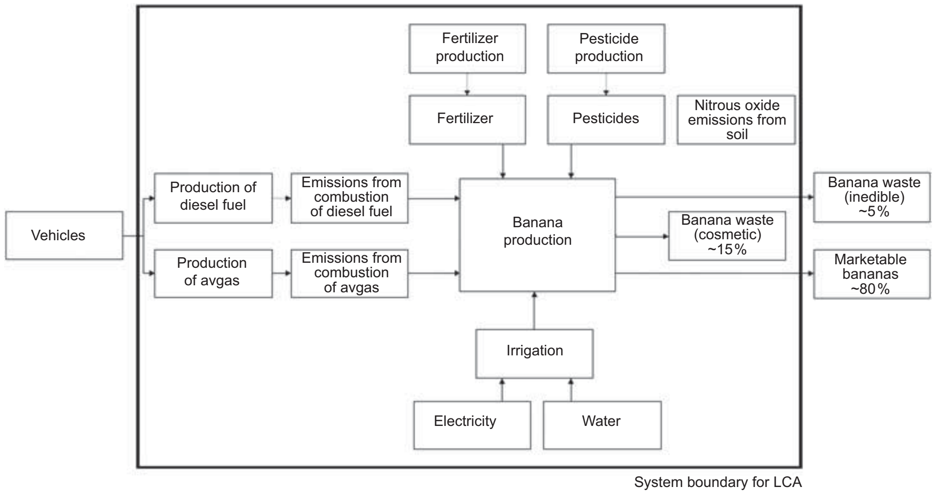

Fig. 1 System boundaries of the life cycle assessment (LCA) of banana production in north Queensland

interview. All data collected were de-identified and presented as aggregate data to protect the respondents' identity.

Waste audit

Convenience sampling from the list of farmers provided by ABGC was used to select a banana farm with an on-site packing facility that supplied major retailers. Over the period of an 8 h shift, the waste stream at the shed was sampled and tallied using a pre-formulated tally sheet. The categories used to tally the bananas were based on the ABGC classification system[17] which is used by staff in packing sheds throughout north Queensland to classify bananas and determine which are deemed satisfactory to send to market. Bananas that were discarded due to the presence of a cosmetic imperfection and nothing else were classified as 'edible', with the remainder of discards classified as 'inedible'. The waste audit was conducted once in summer (December 2008) and then again in early spring (September 2009) to account for potential seasonal variation. The results presented are an average of the two audits.

Nutritional analysis

The total production of bananas from north Queensland was obtained from the *2008–09 Agricultural Commodities* report[14] and the results from the waste audit used to estimate the total amount of waste that was attributable to bananas not meeting cosmetic standards for the north Queensland industry. The weight of an average banana (136 g) was then used to estimate the amount of selected nutrients contained in the waste[18]. The Australian Recommended Daily Intakes (RDI)[19] and the *Australian Guide to Healthy Eating*[20] were then used to determine the opportunity costs of the wasted fruit in terms of the number of people for whom the waste bananas could provide daily requirements.

Life cycle inventory

Life cycle assessment (LCA) is a tool used to understand and evaluate the environmental impacts in the growing, processing and distributing of products[21]. The International Organization for Standardization's ISO 14040:2006[22] framework for LCA was used to guide the LCA for banana production. For the purposes of this research only the life cycle inventory (LCI) was required, therefore no formal impact assessment was conducted. The north Queensland industry-wide total of bananas discarded due to cosmetic imperfections was chosen as the functional unit. The aim was to quantify the embedded resources and pollution in this portion of the bananas so as to highlight the environmental impacts of the cosmetic standards. The scope of the analysis included greenhouse gas (GHG) emissions, energy, abiotic resources and water use. The system boundaries set for this case study are illustrated in Fig. 1.

The Queensland Department of Primary Industries and Fisheries (DPI&F) in Cairns gave written consent to use their production figures for bananas. These data were compiled by DPI&F through consultation with growers from north Queensland. The data include the average quantities and costs of the basic inputs required to grow bananas in north Queensland industry. The author validated these data in face-to-face interviews with five growers, with some minor modifications made based on their recommendations. A local agricultural produce store was visited to validate the costs and application rates of the various agrichemicals, and two aerial spraying contractors contacted to gather information on the volume and type of fuel used to spray a hectare of banana plantation.

These data were then entered into SimaPro™ Life Cycle Assessment software version 7·1 (Product Ecology Consultants, Amersfoort, The Netherlands) which converted the raw data into an LCI using the Ecoinvent database contained within the software package. This provided a list of the cumulative inputs and outputs that

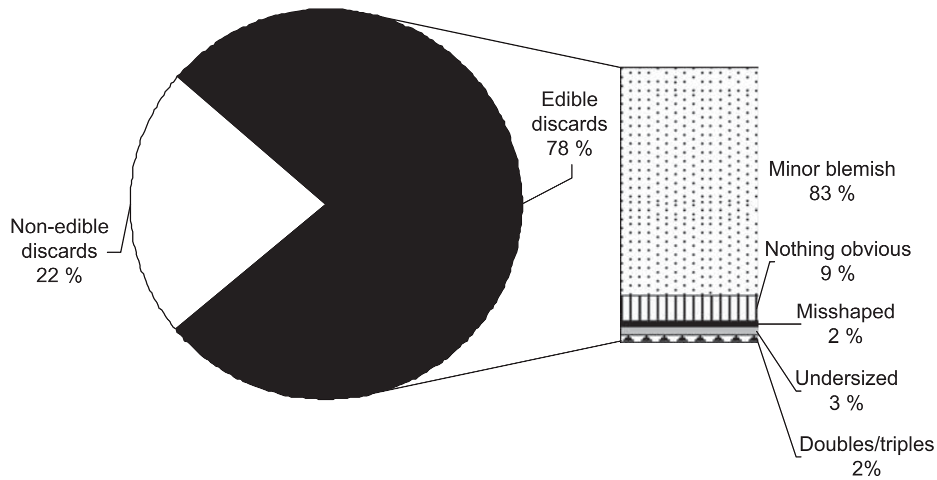

Fig. 2 Classification of banana waste from waste audits

had gone into the production of one functional unit throughout its life cycle. To calculate the emissions from various on-farm activities, the Australian Department of Climate Change[23] emissions factors were used and values converted to carbon dioxide equivalents (CO_2-e) using the Global Warming Potential figures generated by the Intergovernmental Panel on Climate Change[24].

Economic assessment

Using the DPI&F production figures and the statistics mentioned, the total costs incurred by the north Queensland banana industry in 2008 were calculated. Based on a conservative estimate of 20 % waste, and the results from the waste audit, the percentage of total production wasted due to cosmetic imperfections was calculated. A dollar value was then assigned to the edible fraction of the waste as a proportion of the total costs of on-farm production.

Results and discussion

Waste audit

A total of 4138 waste bananas were inspected in the first audit, with a larger sample of 9761 in the following audit. The reasons for discarding bananas varied, with only 22 % of bananas being genuinely unsellable (Fig. 2). The majority of the waste (78 %) was considered edible as it was discarded due to minor exterior imperfections. Based on the estimate of total waste being 20 %, this equates to 15 % of total production being discarded on the basis of cosmetic appearance. Minor blemishes made up 83 % of the edible waste, with other characteristics such as size, shape and the formation of 'doubles' or 'triples' making up a further 7 %.

To put these results into perspective, in 2008–2009, 264 725 tonnes of bananas were grown in north Queensland. Fifteen per cent of total production equates to 37 000 tonnes of edible bananas being discarded on-farm due to cosmetic imperfections. Based on the weight of an averaged sized banana (136 g), this is equivalent to providing 373 000 Australians with the recommended two servings of fruit per day[20] for an entire year.

It is important to note that some farmers do utilize this 'waste' in a number of ways including feeding to livestock, selling to local processors to pulp, selling at roadside stalls, making compost, spreading back in the paddock as mulch, or simply dumping in a fallow field to rot. However, there is little to no financial return to farmers, and given the large amount of inputs required to produce bananas, this is not an efficient use of finite natural resources.

Nutritional costs

Opportunity costs are associated with this waste in terms of the number of people it could potentially feed. Table 2 gives a summary of the lost nutritional potential of the wasted fruit in terms of the number of days' worth of RDI the waste could provide and the number of people this would feed for a year.

While it is recognized that bananas alone would not be able to supply a person with optimal nutrition for an entire year, the above calculations demonstrate the extent of the waste in terms of lost human nutritional benefits. From a global perspective, bananas are one of the most traded commodities in the world, and an important source of nutrition and income for many developing countries. Approximately 98 % of bananas are grown in developing countries such as India, the Philippines and Brazil, with 20 % of total global production traded on the world market[25]. Of this, the developed nations of Japan, the European Union and North America import more than 70 %. Given that supermarkets dominate the retail sector in these developed countries[26] and have similar cosmetic standards in place[27], it is fair to assume that the levels of edible waste generated on-farm in the banana-producing

Table 2 Nutritional value of wasted bananas and associated opportunity costs

Nutrient	Unit	Amount in average banana*	Amount in waste bananas†	RDI/AI‡	Opportunity cost (million days)§	Opportunity cost (people/year)‖
Energy	kJ	505	137 billion	10 300¶	13·3	36 500
Protein	g	1·50	408 million	55·0	7·42	20 300
Fibre	g	3·50	952 million	28·0	34·0	93 200
K	mg	487	132 billion	3300	40·1	110 000
Mg	mg	37·0	10·1 billion	370	27·2	74 500
Se	μg	1·40	380 million	65·0	5·86	16 100
Folate	μg	27·0	7·34 billion	400	18·4	50 300
Vitamin C	mg	8·70	2·37 billion	45·0	52·6	144 000

RDI, Recommended Daily Intake; AI, Adequate Intake.
*Based on a 136 g banana with 36 % inedible skin.
†Based on the 15 % of production considered to be edible = 37 000 t/year = 272 million average bananas/year.
‡Based on an average of the male and female Australian RDI for adults aged 31–50 years.
§Measured in terms of the number of days' worth of RDI the waste bananas could provide.
‖Measured in terms of the number of people for whom the waste could provide the RDI for an entire year.
¶Based on the average energy requirements for male and female adults aged 19–60 years as outlined in the *Australian Guide to Healthy Eating*[20].

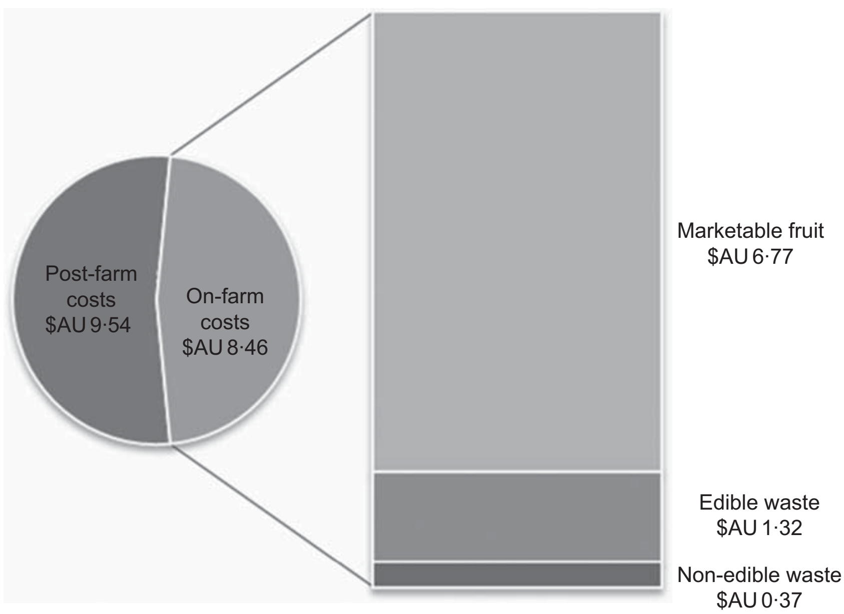

Fig. 3 Breakdown of production costs for a 13 kg carton of bananas (average total cost $AU 18)

countries are similar to those found in the north Queensland industry. Depending on how the waste is managed in these countries, it is possible that the unnecessary and unrealistic expectations of supermarkets (and indirectly consumers) in the developed world are translating into economic and nutritional losses to those in the developing world, many of whom are already food insecure.

Environmental costs

The results of the LCI indicated that the use of fossil fuels to power vehicles, generate electricity and produce pesticides were the major sources of environmental damage. The GHG emission from the 37 000 tonnes of edible waste bananas was 16 300 tonnes of CO_2-e, which is equal to the annual emissions from 3130 medium-sized cars[28]. The virtual water content of the waste was calculated to be approximately 11·2 gigalitres, most of which was attributable to the water used directly on the crops via irrigation (blue water) or rain (green water). The waste also embodied non-renewable resources including 987 tonnes of oil, 746 tonnes of coal, 1.26 million m^3 of natural gas and 477 tonnes of phosphate ore, the majority of which were attributable to fertilizers. In light of the challenges facing the global food supply system, this unnecessary waste of non-renewable resources, water and the GHG emission is unsustainable.

Economic costs

The average cost of production was estimated by DPI&F and the growers interviewed to be about $AU 18 per carton. This was calculated based on the total cost of inputs to the farmer, divided by the volume of produce

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sold to market. Therefore these calculations also include the costs to produce the waste fruit. Figure 3 shows the breakdown on these costs, with the costs attributable to the edible portion of the waste based on the conservative estimate of 15 % of total production. Based on these data, for every carton of bananas sold, the bananas that are discarded due to cosmetic imperfections represent a loss of \$AU 1·32 to the farmer. This equates to an industry total of \$AU 26·9 million for the year 2008. Since banana growers are price takers (i.e. changing supply has little influence on price at market), it is unlikely that farmers are able to pass these extra expenses on to the consumer by demanding a higher price. This loss of return on investment ultimately affects the viability of smaller growers. The concentration of agricultural practice has significant social, economic and ultimately health sequelae.

Implications for public health nutrition

The present case study, while limited in its scope, illustrates the significant environmental, nutritional and economic impacts associated with the cosmetic standards set for fruits and vegetables by the major retailers. Given that bananas represent only 7·5 % of annual edible horticultural production[14] in Australia and a meagre 0·235 % of global banana production[12], it would be fair to assume that the implications of product specifications are far greater than the values obtained herein. In light of the claims made by the FAO that food production needs to increase by 70 % over the next 40 years, this is clearly an area of concern for public health nutritionists as it threatens the infrastructure that supports the food system and ultimately the health of populations.

To address these problems, a broader approach to nutrition needs to be adopted. The Giessen Declaration[29] calls for a more integrated approach to nutrition, embracing a paddock to plate understanding of the food system. Such an approach recognizes the interrelationship between biological, social and ecological health. Public nutrition action needs to occur within the production, consumption and waste paradigms with a coordinated approach across the food system. By focusing concerted effort on all three areas, sustainable and equitable solutions can be generated. Areas in which public health nutritionists are and could have an impact include reconnecting consumers with food production[30], social marketing to improve acceptance of cosmetic imperfections and value-added processing of fruit deemed unfit for market.

Limitations

The choice of convenience sampling and the small sample size were limiting factors in the present study. Since only one packing shed was audited, the results do not account for variations in production and packaging techniques used by other businesses. There was no equipment available to weigh the waste stream at the packing shed, so the amount of waste was estimated based on the capacity of the containers used to collect the waste, which also included the peduncles (stems). The estimates can therefore be assumed to slightly over-represent the actual amount of banana waste. Allowing a 10 % error margin, it is likely that the values obtained still fall within the estimated 10 to 30 % of total fruit production.

Due to a lack of data relating to particular fertilizers and pesticides available on the Ecoinvent database, a number of chemicals used on-farm were excluded from the LCI. The actual range of chemicals used by farmers is much broader and therefore the results of the LCI are a conservative estimate.

Conclusions

As demonstrated by the current case study, the unnecessary waste of edible food due to cosmetic standards results in an increase in the costs of production, a loss of potential nutritional benefits and a waste of the resources embodied in the fruit. In a carbon-constrained environment with finite natural resources and an increasing population, this waste is simply not efficient or sustainable. Action needs to occur to not only increase production but to also minimize waste. Further research is needed to quantify the amount of waste that occurs throughout the supply chain and to determine how best to influence policies and programmes for waste minimization.

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