Australian Food Processing Industry and Environmental Aspects-A Review

Nirenkumar Pathak, Prasanthi Hagare, Wenshan Guo, and Huu-Hao Ngo

***Abstract*—**A Dynamic and thriving Australian manufacturing sector is critical to the long-term health of the economy and the nation. This review presents current scenario of the Australian food processing sector and its contribution to the economy. The review also includes details of major sub-sector profiles and key players in the food manufacturing sector with environmental aspects. Industrial pollutants, waste characteristics and their sources in food processing sectors are discussed. This review further focuses on the possible remedies to control environmental pollution generated by Australian food industries to meet the statutory requirements. Finally, challenges and opportunities for food processing industry are briefly addressed.

***Keywords*—**Economy, Food Manufacturing, Environment, Pollution.

I. Introduction

IN Australia, the manufacturing sector makes a vital and significant contribution to the economy. The sector has been growing at an average rate of 0.9% for more than a decade, employs almost 1 million people and accounts for 8.7% of GDP in 2011 [1]-[2]. The Australian manufacturing industry is incredibly diverse and includes businesses involved in processing food to producing pharmaceutical products to smelting steel [2]. According to Australian Manufacturing workforce study (2014) the largest subsector contributions to total manufacturing gross value added (chain volume measures) were Food, Beverage and Tobacco Products (23.5 per cent), Machinery and Equipment (20.6 per cent) and Petrol, Coal, Chemical and Rubber Products (18.2 per cent). Food, Beverage and Tobacco Product Manufacturing being the largest subsector has performed reasonably well over the past 20 years to 2013 with an average annual growth of 1.3 per cent (Fig.1) [3]-[4].

Within Australia, as around the world, there is an increasing recognition of the links between food production and the environment. As with other manufacturing industries, the food industry is now facing increasing pressure to ensure that their activities are environmentally sensitive, but there is also an increased internal pressure to maintain or increase profitability in the face of fierce competition [5]. This paper gives a brief overview of major food processing sectors such as meat processing, dairy industry and wine production and its environmental issues.

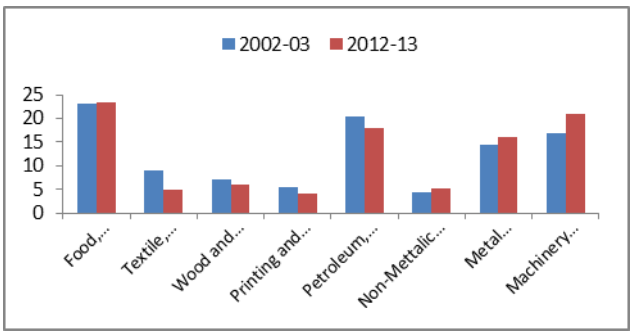

Fig. 1 Subsector contribution to manufacturing value added, 2013

II. Food and Beverage Manufacturing Industry

Food and beverage manufacturing includes all processed, packaged, shelf-ready food and beverages commonly found in supermarkets and other retail outlets, and the ingredients which go into their manufacture [6]. It includes the manufacture of meat and meat products, processed seafood, dairy, processed fruit and vegetables, oils and fat, grain mill and cereal products, bakery products, sugar and confectionery products, beverages and tobacco [6]-[7]. Food and beverage manufacturing industry is comparable in size to the Australian mining sector and is more than four times larger than the automotive sector [8]. The Food and beverage manufacturing industry has an annual turnover of more than $110 billion and contributes to almost four per cent to GDP. It employs more than 296,000 people, half of whom work in rural and regional Australia [8]. Table I illustrates the number of enterprises operating in a number of food and beverage sub-sectors. Wine manufacturing continued to have the largest number of enterprises and was one of the predominant sectors with approximately 29.3 per cent of businesses in the food and beverage sector. At the same time, meat and meat product manufacturing accounted for 16.0 per cent [6].

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TABLE I
FOOD AND BEVERAGE MANUFACTURING SECTOR-NUMBER OF ENTERPRISES [6]

	Number of enterprises			
Sector	2009-2010	2010-2011	2011-2012	2012-2013
Meat and meat product manufacturing	1108	1117	1030	1003
Dairy product manufacturing	411	411	409	403
Fruit and vegetable processing	248	239	229	219
Oil and fat manufacturing	222	219	209	205
Grain mill and cereal product manufacturing	107	105	105	106
Bakery product manufacturing	404	415	426	433
Other food manufacturing	1872	1912	1865	1842
Soft drink manufacturing	76	76	76	77
Beer and malt manufacturing	132	135	136	136
Total	6428	6497	6312	6255

The Australian food manufacturing sites are distributed across the country with a concentration of sites located primarily along Australia's eastern seaboard, in the state of Victoria (VIC), New South Wales (NSW) and Queensland (QLD), especially in rural and regional areas [6] [8]-[10]. The eastern seaboard where the majority of the population is concentrated is a lush and fertile area, with a climate ranging from temperate to tropical. This coastal zone supports major industries such as agriculture and fisheries which leads to the growth of majority of food processing industries in eastern states [39]. Nearly 60 per cent of Australia's processed food businesses are located in Victoria and NSW [10]. Almost two thirds of all jobs are located in New South Wales (29 per cent) and Victoria (32 per cent), followed by Queensland (17 per cent) and South Australia (11 per cent) [6]. NSW has a high number of dairy, cereals, snack food, processed fruit and vegetable and meat producers. Higher number of confectionery, processed fruit and vegetable and dairy producers is concentrated in VIC. QLD has a large numbers of juice, processed fruit and vegetable and sugar producers [9]. In the following discussion some of the food processing subsectors and their environmental issues are reviewed in detail.

A. *Meat Processing*

Meat processing is a major industry in rural and semi-rural Australia. The major meat products include beef & veal, sheep & goat and pork & poultry [11]. Meat and meat product manufacturing product group continues to comprise the largest share (25.1 per cent) of the total food processing sector turnover during 2011-12. The group recorded the greatest growth at 6.5 per cent. It contributed approximately 49,000 jobs during 2012-13, approximately 1,000 less than in 2011-12. Factors such as an increase in poultry consumption, beef production and a rise in production and prices of bacon, ham and smallgoods manufacturing supported by the increasing availability of pig meat imports led to the growth in meat and meat product manufacturing [6]. Meat processing is undertaken in all states and territories in Australia. The operations are highly concentrated around the eastern states lead by Queensland (45.3 per cent), New South Wales (24.2 per cent) and Victoria (14.8 per cent). Queensland accounts for almost half the cattle livestock herd, approximately 11.2 million in 2010. The region is also home to the country's largest corporate beef cattle farms. Factors that encourage the abattoirs settlement in proximity to rural areas include the lower cost of land, municipal by-laws, lower transport costs for processors and reduced time livestock is held in transit [12]. The climate is also a favourable factor as the three eastern mainland states are dominated by a humid subtropical zone, with some tropical and oceanic climate zones. Significant amounts of precipitation occur in all seasons in most areas [13].

Major water uses in the meat and meat product manufacturing industry may include: livestock watering, washing/rinsing/hosing, product and/or equipment cooling, refrigeration systems, boilers and as an ingredient in meat products [14].Meat processing industry uses chemicals such as ammonia (total), chlorine, acetic acid, hydrochloric acid, nitric acid, phosphoric acid and sulphuric acid. Acetic acid is used in animal decontamination while other acids are used for cleaning and scale removal [14]. Thus, similar to any industrial process, the meat processing industry is also associated with significant effluent management issues that can negatively impact on the environment. The meat industry already converts many meat processing by-products (e.g. blood, bone, manure, skins, fat, hair and offal) into saleable products [15]. The various types of wastes generated from meat processing industry and their impacts on the environment are summarized in Table II. The environmental issues associated with meat processing industry include, but are not limited to, odour problems, wastewater treatment including nutrient removal and management of solid wastes [11].

Air emission control technologies, such as electrostatic precipitators, fabric filters or baghouses, and wet scrubbers, are commonly installed to reduce the concentration of particulates in process off-gases before stack emission [13].

Meat processing industries produce significant volumes of wastewater during slaughtering and cleaning operations with a high pollutant load consisting of paunch, manure, fats, oils and grease (FOG), and uncollected blood. These components contribute to a high-strength waste which must be treated to reduce these organic pollutants [16]. Table III shows typical characteristics of the wastewater from meat processing industry in Australia [16].

Typical treatment methods for abattoir wastewater involve a primary stage (e.g. dissolved air flotation (DAF)) to remove fats and suspended solids, and anaerobic treatment used for high strength organic wastewater. However, this treatment process leads to issues such as odour emissions and the generation of methane, which is a potent greenhouse gas (GHG). Subsequently, the Australian red meat processing

TABLE II
POLLUTION SOURCES IN MEAT PROCESSING INDUSTRY [11] [13] 15]

Wastes	Sources of pollution
Gaseous	Ammonia loss from refrigeration system, emissions from fuel burning .
Liquid	spills or leaks of acids or chlorine products, slaughtering operations (such as blood losses, emulsified fat, soluble protein) and wash down processes conveying water and general processing operations.
Solid	plastic and cardboard packaging, bone, manure, hair, paunch contents from gut cutting, faecal materials from stock, yards and casings operations, fat from rendering and gut processing operations, and suspended solids from washdown.

industry is beginning to install covered anaerobic pond technology in an effort to confront and solve these two most pressing problems. When compared to uncovered anaerobic ponds, covered anaerobic ponds offer significant advantages such as odour control, intensification of the decomposition process and BOD removal, an increase in feed rate and the potential for capturing methane-rich gas as a fuel source for bio energy and the reduction in GHGs [16]. Application of constructed wetland systems is not common for meat processing effluent treatment in Australia. Typically treated effluent is disposed of by way of land irrigation or discharge to the sewer system [11].

TABLE III
WASTEWATER CHARACTERISTICS FROM MEAT PROCESSING INDUSTRY

Parameter mg/L	a Abattoir wastewater	b Southern meats (sheep)
BOD	1600-3000	1600-5500
COD	4200-8500	3100-11500
FOG	100-200	290-2670
TSS	1300-3400	1150-5700
TN	114-148	180-440
NH4-N	65-87	18-135
Alkalinity	350-800	340-700
VFA	175-400	61-600

For the meat processing industry land emissions will occur if wastewater is being used for irrigation. It is anticipated that ammonia will be the main National Pollution Inventory (NPI) - listed constituent of the wastewater [13]. Operators of meat premises and pet food works may be required to hold a permit issued by a planning authority under the Land Use Planning and Approvals Act 1993. Conditions of operation detailed in the permit are legally binding. Operators are also subject to regulation under the Meat Hygiene Act 1985 as enforced by the Meat Hygiene Section of the Department of Primary Industries, Water and Environment (DPIWE). In addition, the Environmental Management and Pollution Control Act 1994 (EMPCA) contains provisions for the prevention of environmental harm and nuisance [17].

B. Dairy industry

According to Dairy Australia report (2013), Australian dairy is a $13 billion farm, manufacturing and export industry. With a farm gate value alone of $4 billion, the Australian dairy industry enriches regional Australian communities.

Australia's 6700 dairy farmers produce around 9.5 billion litres of milk a year. The Australian dairy industry directly employs 43,000 Australians on farms and in factories, while more than 100,000 Australians are indirectly employed in related service industries [18]-[19]. The major manufactured product streams are: drinking milk—fresh and UHT long-life; skim milk powder (SMP)/buttermilk powder (BMP)/butter; butter/casein; cheese; whole milk powder (WMP); other consumer products, such as yogurts, custards and dairy desserts; and specialised ingredients, such as whey proteins, nutraceuticals, etc.(Table IV).

TABLE IV
WASTEWATER CHARACTERISTICS FROM MEAT PROCESSING INDUSTRY

Year	Butter*	AMF(CBE)	SMP	WMP**	Whey products
2011/12	100,551	19,164	230,286	140,424	64,645
2012/13 (p)	99,035	19,193	224,061	108,838	63,440

*Includes butter blends as CBE, **Includes infant powder

Cheese is consistently the major product stream utilising around one third of Australia's milk production in 2012/13 and has remained around this level for a number of years. Drinking milk and skim milk powder/butter production were the two next largest users of milk; each taking just over a quarter of the total milk produced in Australia. Nearly 60% of manufactured product (in milk equivalent terms) is exported and the remaining 40% is sold on the Australian market; the only exception is drinking milk where 96% is consumed in the domestic market. The Australian dairy manufacturing sector includes farmer-owned co-operatives, public, private and multinational companies. The largest co-operative is Murray Goulburn accounting for nearly 33% of national milk output. Other major Australian dairy companies that cover a diverse range of markets and products are Bega Cheese, Fonterra (Riverina Fresh), Lion Dairy & Drinks, Parmalat, Norco, Dairy Farmers Milk Cooperative, Bulla Dairy Foods Ltd, Longwarry Food Park [19]-[21]. The various types of wastes generated from dairy and their impacts on the environment are summarized in Table V.

Dairy manufacturing generally creates significant liquid waste: a rule of thumb is that a plant with an intake of 1 million litres of milk generates approximately 1.7 million litres of waste water [28]. The range of ratios for wastewater to raw milk of 0.4-3.2 indicates that there is an opportunity for some factories to reduce the volume of wastewater generated [29] by employing good housekeeping practices and cleaner production techniques. Table VI shows the characteristics of wastewater from a dairy in Australia.

Wastewater from Australian dairy industry is commonly disposed of by irrigation (58%) or directly to the sewer (37%). This wastewater is usually treated by dissolved air flotation (DAF) and skimming processes for fat and solid removal. Biological treatment such as SBR, anaerobic digestion in a Bulk Volume Fermentor (BVF) and aerated lagoons are also in use [27]. Whey in the wastewater stream can be reduced

TABLE V
TYPE OF WASTES AND SOURCES FROM DAIRY INDUSTRY [22] - [27]

Wastes	Sources of pollution
Gaseous	Emissions from the burning of fuel (natural gas) on-site generates carbon monoxide, sulfur dioxide, oxides of nitrogen, particulate matter (PM10), total VOCs.
Liquid	Factory wastewaters include condensate from the dryers, effluent from bioreactors with a higher solids content, oily residue, lubricants from gearboxes of processing machinery. salty whey from the washing of vats, drains having strong odour and acidity, wastewater from cleaning and flushing of processing equipment consists of product residue and high in fat and salt. Cleaning and waste treatment chemicals (Sodium hydroxide, Nitric, phosphoric, hydrochloric, acetic and citric acids, strong oxidants or bleaches such as peroxyacetic acid, sodium hypochlorite and chlorine dioxide (sanitising equipment), chlorine bleaches may produce toxic organochlorine compounds that contaminate the wastewater, enzymes and detergents (cleaning cool surfaces).
Solid	Heavy black sludge is created and strong butyric acid odours are caused by the decomposition of casein, non-organic wastes through product packaging and maintenance generally consist of plastics, metals, cardboard, wood and paper. Organic wastes such as reject dairy product, sludge, batteries, and the solids from equipment and the floors.

TABLE VI
CHARACTERISTICS OF AUSTRALIAN DAIRY PLANT WASTEWATER [27] [30]

Item	pH	BOD (g/m3)	Fat, %	N, g/m 3	P, g/m 3	Electrical Conductivity, µS/cm
Cheese/milk powder, effluent	10.6	1500	--	0.01	35	2600
Cheese/evaporated milk, Clean stream	--	12	--	--	--	880
Cheese/evaporated milk, dirty stream	8-12	700-1700	0.005-0.03	50-70	10	2600
Cheese	6.9	2800	0.1	150	42	3500
Whey	4.6	35000	0.08	1400	640	--

by adapting new membrane technologies like Ultrafiltration, Micro filtration etc. [23]. The discharge of all wastewater is closely monitored and regulated under EPA or local water authority trade waste agreements [25]. Dairy effluent is a natural fertiliser and soil conditioner and, if managed effectively, can enhance pasture growth and improve soil structure. Condensate from the milk evaporation process is a relatively clean wastewater stream and has been reused for decades [31]. The recycled water is not suitable for all uses without further treatment but it is typically used for boiler feed water and membrane plant washing [27]. Membrane technology is adopted to recover cleaning chemicals and water. Other water streams that are relatively clean that can be recycled include defrost water, boiler blowdown, flushing water and pump sealing water [27].

Finally, effluent treatment creates sludge, and the sludge may be used as animal feed or for compost. Whey, previously considered a waste product, is now sold in various forms and components such as protein concentrates and lactose, as well as some speciality ingredients including lactoperoxidase (an anti-microbial enzyme) and lactoferrin (anti-microbial protein) [27]. Murray Goulburn market a mineral product that is extracted from cheese whey [27] [31]. Over the past three years dairy companies have halved the amount of waste to landfill and recycled waste produced. About 85% of Australia's milk supply is processed by companies that have signed on to the Australian Packaging Covenant [18]. The majority of organic wastes have the potential to be reused as compost or as a feedstock for animals.

C. Wine manufacturing

Australia is consistently one of the top ten wine producing countries in the world and is one of the few countries that produce all of the major wine styles [32]. Beverage wine production was 1.23 billion litres in 2012–13 [33]. Australian wines can now be found for sale in over 100 countries. In fact, Australia is one of the main exporters of wine in the world and the United Kingdom now imports more wine from Australia than it does from France [32]. China has grown to be Australia's fourth-largest market in terms of value of wine exports [10]. South Australia and Victoria tend to produce a higher proportion of premium wines than other states. Conversely, New South Wales produces a higher proportion of low unit value wines. Reliable rainfall, warm summer conditions and good soil conditions make these areas optimal for grape vines [10]. In South Australia and Victoria cool climate and long autumn days provide grapes with a long growing season and a relatively dry ripening period, resulting in wines of distinctive elegance and finesse compared to warm climate in New South Wales. South Australia accounts for 47.5 per cent of production, next most significant state is New South Wales, which accounts for approximately 28.8 per cent of wine manufacturing output followed by Victoria accounting for 18.5 per cent of wine production [10]. Typical processes in the manufacture of wine are set out as: de-stemming/crushing; juice clarification/maceration; pressing; fermentation; wine clarification; wine stabilisation; fining; maturation/storage; and blending / bottling and sources of pollutants are reported in Table VII.

TABLE VII
SOURCES OF POLLUTANT FROM WINERY [34,35]

Wastes	Sources of pollution
Air	Emission from boiler, evaporation from barrel use, refrigerant emissions (ammonia and ethylene glycol) emission of SO_2 from wine manufacturing (fugitive), total VOCs.
Water	Ethyl acetate, methanol, acetic acid, ethanol, sulfuric acid, wine loss, washing operations during the crushing and pressing of grapes, rinsing of fermentation tanks, barrels and other equipment or surfaces, wash water containing alkali salts (caustic soda) to remove tartarate and other organic acids from insides of equipment and ion exchange processes.
Solid	General waste, spent marc, spent resins from ion exchanger.

The unique combination of wine styles, processing operations and cleaning practices result in each winery generating wastewater with unique characteristics, especially during vintage. Vintage is a 6–20-week period in which

harvesting and crushing of wine grapes and fermentation of grape juice to wine take place. The remainder of the year is non-vintage. Wineries can produce up to five kilolitres of effluent per tonne of grapes processed [35]. The organic carbon compositions of wastewater produced by wineries are tartaric, lactic and acetic acids, also found are glucose, fructose, glycerol and ethanol. So it is clear that sugars, organic acids and alcohols dominate the organic carbon composition of wastewater produced by wineries. The chemical analyses of winery wastewater indicate that the organic acids play a more prominent role in the acidity of the wastewater, whereas the high concentration of sugars contributes largely to COD [36]. Table VIII shows the composition of winery wastewater in Australia.

TABLE VIII
TYPICAL COMPOSITION AND CHARACTERISTICS OF WINERY WASTEWATER (ALL VALUES, EXCEPT PH, IN MG/L [37]

Subjects	Value
Chemical oxygen demand (COD)	13,230–23,170
Biochemical oxygen demand (BOD)	9260–18,360
Total sugars	8100–13,200
Suspended solids	650–1340
Total phosphorus	96.3–176
Total ammonia-N	6.0–21.1
Total Kjeldahl-N	332–415
pH	3.5–4.1

Conventional methods for treatment of winery wastewater include chemical, physical and biological processes. The chemical and physical methods are evaporation–condensation with or without combustion, microfiltration, ultrafiltration and inverse osmosis. In addition, biological methods, such as anaerobic digestion and aerobic treatment using attached-film systems, activated-sludge and lagoon are also popular processes in wineries [35] [37].

The Australian wine industry is subject to a number of pieces of Commonwealth and State legislation. The legislation specific to the Australian wine industry is the Australian Grape and Wine Authority Act 2013 and the Australian Grape and Wine Authority Regulations 1981. These provide for, among other things, the Label Integrity Program and the Register of Protected Geographical Indications and other terms. Food Standards Australia-New Zealand (FSANZ) administers the Food Standards Code which provides for standards relating to health, safety and food and beverage industry requirements. The Winemakers' Federation of Australia (WFA) administers the EntWine environmental accreditation scheme for Australian wine producers. EntWine is a voluntary scheme that allows winemakers and wine grape growers to receive formal certification of their practices according to recognised standards [38].

III. CHALLENGES AND OPPORTUNITIES FACING AUSTRALIAN FOOD MANUFACTURING INDUSTRY

Over the last five years, the Australian food manufacturing industry has come under intense pressure. A range of factors for such pressure include a highly concentrated retail market, a strong Australian dollar, labour scarcity pressures, escalating energy prices and high yet volatile commodity prices [9]. The food and grocery retailing industry is highly competitive with a small number of supermarket retailers in a dominant position. Leading supermarket retailers have engaged in extensive price based promotional strategies to drive sales growth. The increase in trade spend has come at the cost of suppliers' marketing and research and development spend which may have a long-term impact on growth, sustainability and innovation [6]. According to KPMG's Competitive Alternatives study, Australia ranks second only to Japan for cost of doing business in the manufacturing sector. Australia's poor ranking is driven by increase in labour, energy and exchange rate appreciation. Over the last 5 years, the wage price index increased by 13.5 points in December 2008 to 113.3 in December 2012. In recent years industry reduced direct labour costs through plant closures, capacity consolidation and productivity improvements [6]. Energy costs in Australia are the highest of mature markets and have risen by 70 per cent between 2008 and 2012. Meanwhile, the competitiveness of Australia as a manufacturing country has been negatively impacted by the foreign exchange rate with the AUD appreciating nearly 60 per cent from March 2009 [6].

At the same time, opportunities are emerging as new products and channels appear, but it is critical for sector participants to have a strategic focus on how to best nurture these prospects [6]. Increasing productivity is probably the most important and achievable target the industry can pursue to face challenges and pursue opportunities. Productivity improvements can be achieved through: adopting emerging technologies such as gene technology, nanotechnology and irradiation, achieving greater economies of scale through growth, raising labour productivity by facilitating skills development and training opportunities [9], investing in R&D that leads to the development of new processing technologies and working collaboratively with agriculture suppliers to increase agricultural productivity to lower the costs of agricultural inputs [10]. The strategic options government should exercise are: removing regulatory impediments through regulatory reform i.e. removing infrastructure bottlenecks which impede transport and logistics efficiencies of food and grocery products, creating incentives to encourage investment in innovation, eliminate unnecessary duplication and complexity in environmental reporting, support industry to become more energy efficient [9].

IV. CONCLUSION

The food and beverage processing sector is the largest employer within the manufacturing sector and has recorded relatively strong growth. A range of factors influencing economy of food processing industry are considered. Major industrial pollutants and their sources in three major subsectors, meat processing, dairy and winery are reported. The environmental management practices implemented to abate the pollution and cleaner production measures taken in Australian food processing are discussed.

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