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Review of grain devitalisation methods

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Executive summary

The report has been commissioned by Meat & Livestock Australia (MLA) in consultation with the Australian Lot Feeders' Association (ALFA), with support from Dairy Australia, Australian Pork Limited (APL), and the Chicken Meat Federation. This desktop study provides the industry with a better understanding of the options and opportunities for importing bulk grain and plant-based stockfeed where these imports are being sought to offset a supply shortfall (or excessive cost pressures) brought about by droughts in Australia's east-coast production regions.

The Australian intensive livestock industries (feedlot cattle, pigs, poultry and dairy) require a reliable and affordable source of feedstock for their enterprises. Australian domestic grain production volumes generally provide adequate supply for these industries (aside from the importation of soymeal, which is not produced in significant volumes in Australia). However, there have been sporadic periods where drought has limited the supply of locally available grain, requiring importation (from interstate or overseas) to maintain supply. This report investigates grain treatment techniques and the capacity for these techniques to meet Australian biosecurity requirements (for foreign grain importation) now and into the future.

The principal challenge associated with importing bulk grain or plant-based stockfeed is the requirement to devitalise (or 'sterilise') the product in order to minimise any biosecurity risk associated with pests and pathogens. Devitalisation treatments need to ensure that any grain or weed seed material is rendered non-viable and incapable of germinating, any insect pests are killed, and pathogens are rendered non-viable. Importing bulk grain is considered to carry greater risks than plant-based stockfeed, as the latter has generally undergone processing and thus devitalisation. The other key risk management requirement relates to transit. Prior to devitalisation it is important to ensure there is no spillage in transit (this is particularly important for bulk-grain). Post treatment (including any devitalisation), bulk gain and plant-based stockfeed still needs to be handled appropriately to avoid the possibility of additional contamination.

The desktop review examined possible sources of bulk grain or plant-based stockfeed and whether existing and emerging devitalisation methods were suitable in achieving government importation requirements, whilst at the same time considering the commercial viability of the methods. In addition, the review considered previous MLA reports on devitalisation based on EDN fumigation (MLA, 2015) and other related MLA reports (2001; 2003; 2007; 2017a).

The authors concluded that to meet import biosecurity requirements a combination of treatments and supply chain management factors are critical (e.g. product source, ultimate destination and in-transit management). However, risk management feasibility alone does not account for the commercial viability of such an undertaking, which is largely determined by the grain or stockfeed price differential. The other key consideration is the commercial case for any domestic treatment facility that historically has not been required more than a few months each decade.

The review team has found that changes in technology, animal production systems, climate change and domestic grain production have all contributed to a range of new opportunities and threats. The report finds that there are several potential opportunities to better position the intensive animal industries for future droughts and their resultant supply-price outcomes.

The report identifies an opportunity for a multi-product processing facility to be established and operated from within a port quarantine zone that can leverage the upgraded inland rail system that passes through the regions where the end-users are located, i.e. the intensive livestock industries that use bulk grain or plant-based stockfeed. This would effectively take what was formerly a bulk grain importation issue (as a ‘raw’ product it carries both pest and pathogen as well as supply-chain contamination risks) and convert it to a plant-based stockfeed ingredient issue (the primary risks are associated with post-processing supply chain contamination). The viability of such a facility would rely on having at least some of the capacity being utilised constantly, with the ability to expand capacity when domestic supply conditions become tight.

Recommendations have been provided for MLA (and the other animal production industries) that will assist in clarifying future opportunities and threats, increase the transparency and clarity around importation protocols, and identify knowledge gaps where further investment would benefit the industry.

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Acronyms

ABARES	**Australian Bureau of Agricultural and Resource Economics and Sciences**
ACCC	Australian Competition and Consumer Commission
ACP	Atmosphere Cold Plasma
AGIC	Australian Grains Industry Conference
ALOP	Appropriate Level of Protection
APHIS	Animal and Plant Health Inspection Service
APVMA	Australian Pesticides and Veterinary Medicines Authority
AV	Agriculture Victoria
BICON	Biosecurity Import Conditions (database)
CABI	Centre for Agriculture & BioScience International (Legal name CAB International)
DA	Department of Agriculture (previously Department of Agriculture and Water Resources)
DPIRD	Department of Primary Industries and Regional Development (WA)
ECHA	European Chemicals Agency
EDN	Ethanedinitrile
EU	European Union
GRDC	Grains Research and Development Corporation
HCN	Hydrogen Cyanide
IRA	Import Risk Analysis
kt	kilo tonne
MeV	Megaelectronvolt
MLA	Meat and Livestock Australia
MRL	maximum residue level
NSW	New South Wales
NSWDPI	New South Wales Department of Primary Industries
PHA	Plant Health Australia
PPQ	Plant Protection and Quarantine
PSD	Production, Supply and Distribution online database
QLD	Queensland
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
SA	South Australia
TAS	Tasmania
TGA	Therapeutic Goods Administration
UK	United Kingdom
US	United States (of America)
USDA	United States Department of Agriculture
UV	Ultraviolet
VIC	Victoria
WA	Western Australia
WOAH	World Organisation for Animal Health

1 Objectives

This report consists of a desktop review combined with industry interviews and investigation to provide a situational analysis of the current challenges to bulk grain and plant-based stockfeed importation as well as identifying existing and emerging devitalisation methods and the scalability and commercialisation of methods. The review focuses on global devitalisation techniques and the capacity for these techniques to meet Australian biosecurity requirements.

This report aims to:

(1) Review Australian Department of Agriculture and Water Resources import process, import quotas, duties, tariffs and biosecurity requirements for feed grain.
(2) Define Australian Department of Agriculture and Water Resources certification and inspection requirements for grain importation by country of origin (feasible import markets).
(3) Conduct a global desktop review to identify existing and emerging devitalisation methods for feed grain.
(4) Determine the scalability and commercial adoption of methods for feed grains (e.g. treatment time, treatment rates, cost, registration, adoption rate, residue risk).
(5) Review applicable biosecurity treatment methods to enable importation of feed or foodstuffs (such as those existing for, but not limited to, dried distillers grains, soybean meal, copra meal, palm kernel meal in animals, human foodstuffs).
(6) Determine domestic supply chains that import viable grain to an approved-arrangement premise at an Australian domestic port and devitalise grain at an approved processing mill.
(7) Determine international supply chains that devitalise grain, or have potential to do so, at the country of origin, prior to importing processed grain to Australia.

For the purpose of this review, the term devitalisation (of either bulk grain or plant-based stockfeed) is a treatment that:

1. Sterilises any seed (whether that is the bulk grain of interest or any weed seeds present) that results in all seed being non-viable or cannot germinate
2. Kills any insect pests
3. Ensure any disease-causing pathogens are rendered non-viable

2 Methodology

This desktop review used internet search, literature/publication review, email and telephone interviews to assess bulk grain and plant-based stockfeed importation requirements and devitalisation methods, processes and commercial drivers. Contacts included (but were not limited to) state and federal government agencies, stockfeed users and manufacturers, grain traders, technology companies, biosecurity experts, and universities.

In order to evaluate potential technologies, processes and their potential opportunities and impediments to commercial use, Colere Group have utilised the licensed PatSnap™ Innovation Intelligence Platform Software and Dr Jorge Mayer’s expertise in IP law and FTO assessment for this analysis.

3 Background

The demand for feed grain is estimated to vary between 10 and 14 million metric tonnes (FGP, 2018). The scale depends on a complex combination of supply (localised production restraints) and demand (the combined needs of all animal production systems). Access to affordable feed grain is particularly critical to conserving the profitability and productivity of the intensive animal industries in Australian agriculture. Significant reductions in localised supply can contribute to excessively high grain prices, threatening the economic viability of many operations.

For the intensive animal industries, the crux of the issue stems from the barriers to accessing material from outside their immediate surrounds. At a high level these are essentially either high freight costs or biosecurity limitations. The pest and disease-free status of Australian production regions is a significant advantage both for grain production and access to export markets, and therefore they are closely protected. The importation of plant material of any type (into Australia, or even interstate) is considered a substantial threat to this status and is therefore protected through regulations anchored in legislation. One of the most heavily regulated areas is around the importation of bulk grains (unprocessed), which are required to be brought in through a full quarantine assessment process including proof that risks around pathogens, pests and weeds are being managed to the required standards. Historically, therefore, only very limited quantities of bulk grain have been imported into Australia and linked to severe drought conditions (MLA, 2003).

3.1 Previous MLA reports

FLOT.116 – Evaluation of Feed Grain Supply and Demand in Australia (MLA 2001); a critique of the ABARE “Projection of regional feed demand and supply in Australia” report due to concerns that an inaccurate representation of the feed grain supply and demand situation in Australia could have serious implications for the intensive livestock industries in satisfying industry growth targets, international competitiveness now and into the future.

FLOT.123- Review Options to Reduce Feedstuff Supply Variability in Australia (MLA 2003); provided an evaluation of the options available to address the recurrent feedstuff shortage issue as a basis for decision-making on the future direction of the beef cattle feedlot, sheep, dairy and pork industries.

B.FLT.0127 - Devitalisation of feed grain by fumigation (MLA 2015); investigated the specific potential of the fumigant EDN for the combined role of grain devitalisation and pest/pathogen elimination.

B.FLT.0137 Ethanol by-products and maize supply chain study tour to USA (MLA 2007); investigated the potential of these by-products as sources of future feedstuff for the intensive animal industries based on an emerging Australian ethanol market.

B.FLT.0162 - Feedlot grain processing review (MLA 2017a); a recent and useful guide to feedlot processing technology and methodologies that could have application in managing biosecurity risks.

3.2 Demand - Domestic Animal Consumption

The combined usage of grain by various animal industry sectors makes it collectively the largest consumer of Australian grain. Regionally, consumption is concentrated in NSW, QLD and VIC. The combined beef, poultry meat and dairy in those three states accounted for 60% of the total 13.538 million tonnes of total estimated grain consumption for the 2017/18 period, respectively (shaded amounts).

Table 1. Australia feed grain consumption profile (kt)

Sectors	QLD	NSW	VIC	SA	WA	TAS	TOTAL	
Major users								
Beef	2,159	1,225	232	100	156	41	**3,913**	**29%**
Poultry Meat	629	1,185	597	623	198	29	**3,261**	**24%**
Dairy	174	259	1,696	142	145	212	**2,628**	**19%**
Pig	382	291	298	415	237	10	**1,633**	**12%**
Poultry Layer	281	312	274	35	81	15	**998**	**7%**
Minor users								
Horse	113	168	112	24	19	7	**443**	**3%**
Sheep	16	80	56	38	118	1	**309**	**2%**
Aquaculture	20	5	2	6	6	125	**164**	**1%**
Other	23	40	57	10	15	45	**190**	**1%**
TOTAL	**3,797**	**3,565**	**3,324**	**1,393**	**975**	**484**	**13,538**	
	28%	**26%**	**25%**	**10%**	**7%**	**4%**		

Adapted from FGP (2018)

The annual Feed Grain Partnership Australian Feed Grain Supply and Demand Report has tracked the growth of grain consumption in those three states over the last decade. It estimates that the animal industries on the east coast use 8.5-9 MMT feed grain annually, which can result in a deficit of 1-2MMT whenever east coast production drops under 12MMT (taking into consideration other major uses for flour, malt and as retained seed). That relationship is well illustrated by the combined domestic consumption estimates of wheat, barley and sorghum, compared with cattle on feed and the chicken meat industry consumption (Figure 1). An important future consideration regarding imports is whether the demand from the major animal industry grain users will ever exceed 'normal season' production levels rather than only during drought periods. A 10-year linear prediction of cattle-on-feed numbers suggests this is possible.

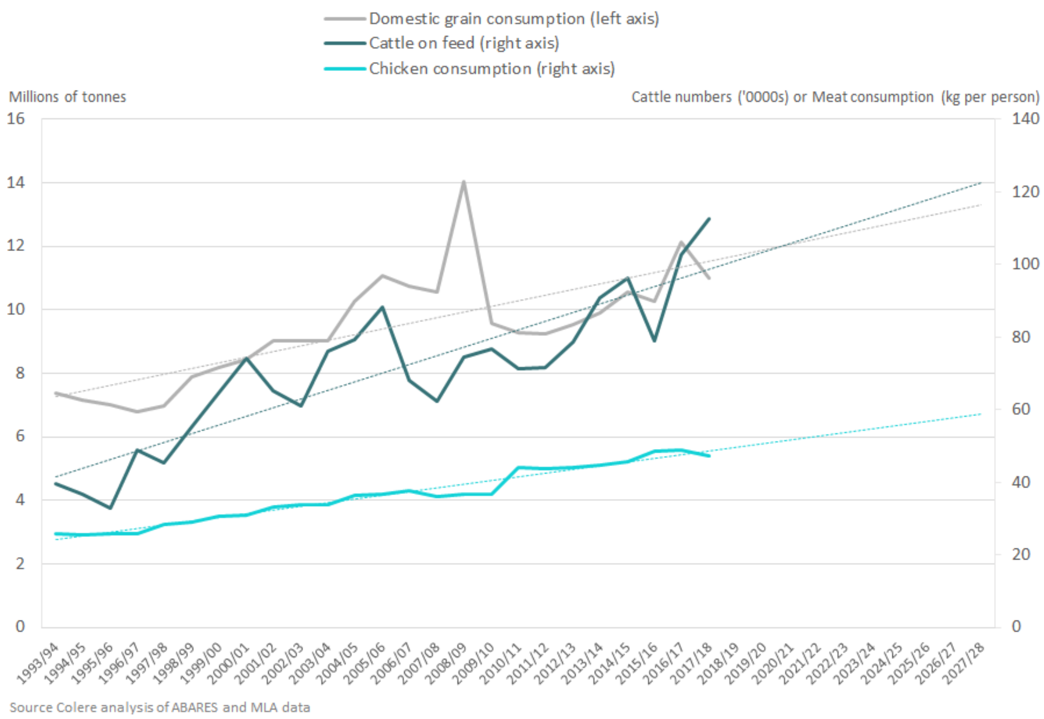
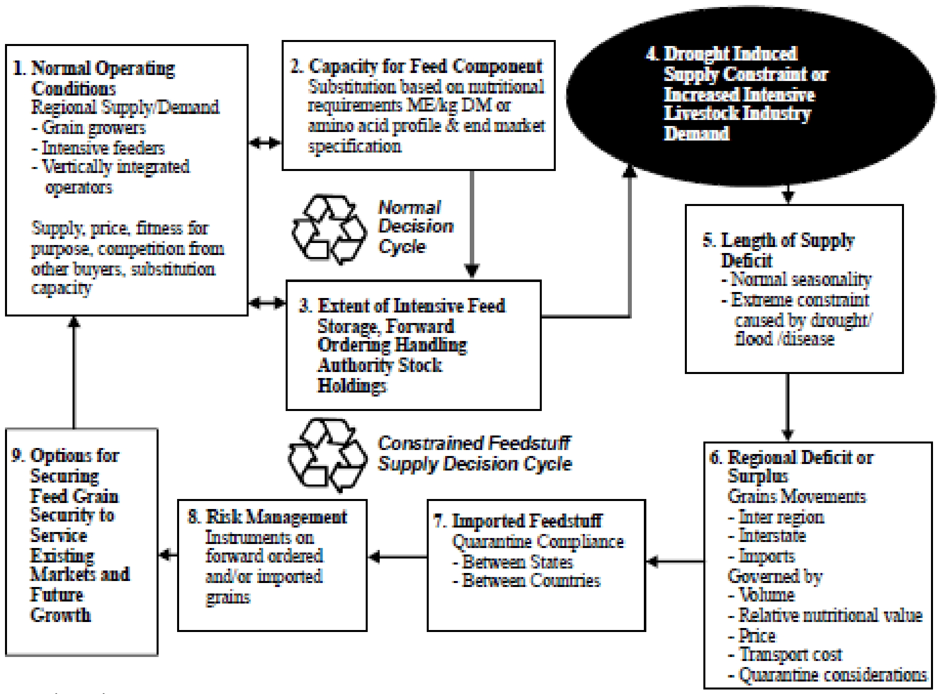


Figure 1. Relationship between Australian grain consumption and selected animal metrics

As **Error! Reference source not found.** shows, the normal cycle (when grain stocks are sufficient) sees the valuation of grain based on relative needs of the industries and their ability to store, hedge, substitute and transport the grain. When drought (supply limitations) or an increased demand (in one industry/consumer relative to others), new factors in the decision-making process of grain users are introduced.



Source MLA (2001)

Figure 2. Factors impacting feed grain decisions

Widespread drought across grain-producing regions logically reduces total supply, but significant on-farm grazing and baling of crops, as well as grain feeding, further reduces market supply as mixed farmers opt to use grain to supplement on-farm feeding programs. This means that while some crops might be grazed or cut for hay, any lower-quality grain can also be consumed locally outside of the intensive industries, further reducing an already lower availability due to drought conditions.

3.3 Supply – Grain Production

Australian grain production is dominated by wheat and barley (Table 2), with a unique aspect of that production being the prevalence of high-quality milling and malt varieties, respectively, rather than varieties tailored to the quality and functionality needed for animal feed ingredients. The combined quantity of canola and oats production is less than half that of average barley production levels. Various other grains are produced, depending on regional and seasonal adaptation. The major grain production state is WA, followed by NSW, SA, VIC, and QLD (a small quantity is produced in TAS). Winter grain crops make up 93% of annual production – with WA and SA accounting for 57%. Summer grain production is small and largely restricted to QLD and NSW.

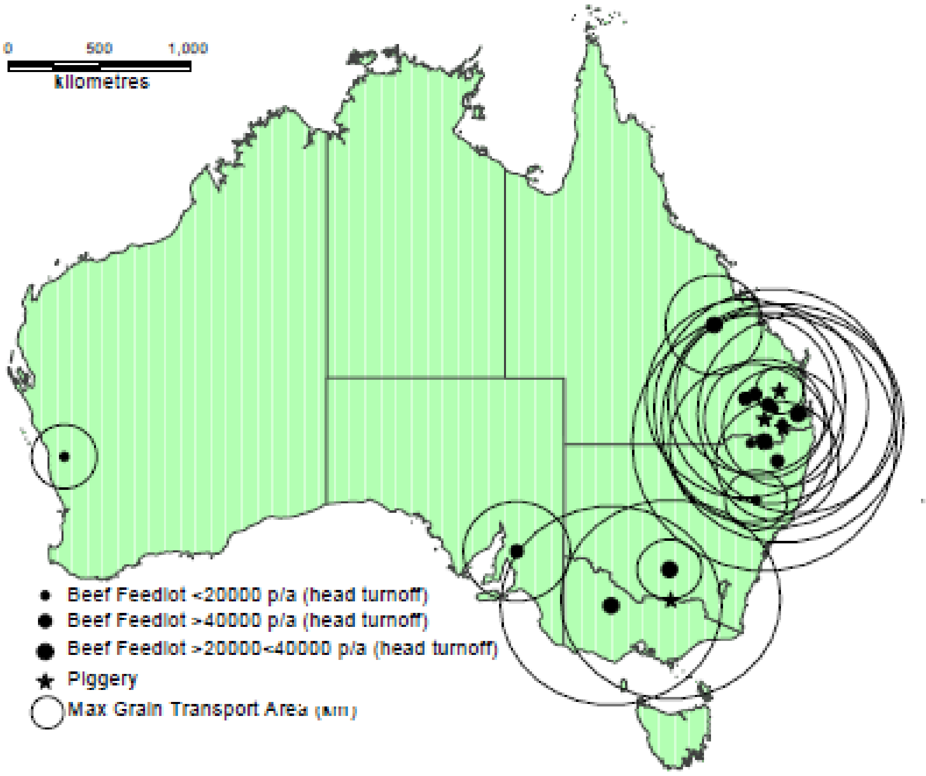
Table 2. Australian grain production - 5-year average to 2018/19 (kt)

Grain type	QLD	NSW	VIC	SA	WA	TAS	TOTAL	
Wheat [W]	994	5,975	2,949	4,283	8,966	48	**23,214**	**54%**
Barley [W]	269	1,833	1,755	2,012	3,850	23	**9,741**	**23%**
Canola [W]	0.9	849	543	304	1,641	3	**3,340**	**8%**
Sorghum [S]	1,047	455	1	0.2	3		**1,506**	**3.5%**
Oats [W]	26	320	237	109	678	6	**1,376**	**3%**
Cottonseed [S A]	392	733					**1,125**	**2.6%**
Chickpeas [W]	476	401	36	23	7		**943**	**2.2%**
Lupins [W]	0.02	65	38	69	555	0.3	**728**	**1.7%**
Corn (maize) [S]	149	204	57	0.3	10	1	**421**	**1.0%**
Lentils [W]	0.2	4	137	249	4		**394**	**0.9%**
Field peas [W]		60	62	114	39	0.04	**276**	**0.6%**
Soybeans [S]	10	28	0.8				**38**	**0.1%**
Sunflower [S]	6	15	0.1	0.03	2		**23**	**0.1%**
TOTAL	**3,369**	**10,940**	**5,817**	**7,163**	**15,756**	**81**	**43,126**	
	8%	**25%**	**13%**	**17%**	**37%**	**0.2%**		

[W] Winter production system; [S] Summer production system; [A] Cottonseed 5-year average to 2017/18
Source ABARES

Freight costs play heavily in the usage equation for domestic grain users. This was highlighted by MLA (2001) with an analysis of average transport distances (Figure 3). It provided a useful insight into the generally accepted areas and distances feed grains can be transported at affordable cost. The distance of the feed grain source for intensive livestock usage influenced:

- location of feed grain required;
- price relativities of all ingredients in the ration mix;
- importance of the feed grain to the ration mix;
- nutritional characteristics of the feed grain relative to the landed cost; and
- transport cost per tonne per kilometre



Source MLA (2001)

Figure 3. Indicative maximum grain transport distance for Australian beef feedlots and

Generally, average grain production (winter or summer) in QLD and NSW is enough to match most domestic consumption requirements, noting there will be price fluctuations in response to the actual level of supply for specific qualities. The response to decreasing supplies and increasing prices differs across the intensive animal industries, depending on a number of factors such as profitability, ability to substitute rations, capital intensity and the proportional cost of feed in the production system (Table 3).

Table 3. Characteristics of each of the key feed grain users and their response to supply restrictions.

	Characterised by	Response to pricing/supply restriction
Chicken meat	• Higher feed conversion efficiency • Primarily focused on domestic market • Grain makes more than 60% of the ration • Limited ability for ration substitution • Plateauing production after 30yrs of growth.	• Potentially the least likely to reduce grain use with higher costs • Potential for some cost recovery from wholesale and retail market sale prices • Production has been moving closer to reliable grain sources • Importation more likely as can use pelleting and closer to port zones
Egg Production	• Domestic consumption continues to grow • Primarily focused on domestic market • Less feed efficient • Grain makes more than 60% of the ration and increased free-range production further increasing grain use • Limited ability for ration substitution	• Potential for significant cost recovery from consumer • Unlikely to change grain usage on price or supply fluctuations • Longer term contracts and hedging now common • Importation more likely as can use pelleting and closer to port zones
Pork	• Limited ability for ration substitution • Primarily focused on domestic market • Currently oversupply of meat and significant international competition	• Limited to no ability to pass on costs due to pork imports • Limited ability to reduce usage • Response is reduced production and further industry exits
Dairy	• Grain is a smaller component of total feed costs • Grain usage has been increasing in the dairy industry (from 0.95t/cow/year in 2007 to 1.3t/cow/year in 2017, although drought can often affect the other components of the rations	• Limited ability to pass on costs • Reduction in grain component of diet • Smaller players are exiting; however, the larger operations are usually using more grain per cow
Sheep	• Grain use by lamb feedlots, supplementary feeding of lambs and ewes and drought feeding • Increased lamb prices driving demand for finished lamb • Decreasing live export	• Some cost recovery possible in the domestic market • Supplemental feeding reduced/stops
Beef feedlots	• Single-largest user of feed grains, however there is diversity in use patterns from opportunistic feeders through to premium beef finishers for export contracts • 50-85% of ration and up to 80% of total costs • Some capacity for substitution of ration components	• Limited ability to pass on costs • Alternative feedstuffs being investigated and utilised • Reduced opportunistic feeding on and reduced numbers in feedlots

4 Imports into Australia

4.1 Import Regulatory Process

The Department of Agriculture (DA) manages the regulatory aspects of Australian agricultural imports and exports under the auspices of the Biosecurity Act 2015. The intent is to keep the biosecurity risk low while balancing the need to protect Australia from pests and diseases whilst maintaining free international trade.

The Biosecurity Act applies to Australia, and its external territories including Norfolk Island, Christmas Island, and the Cocos (Keeling) Islands.

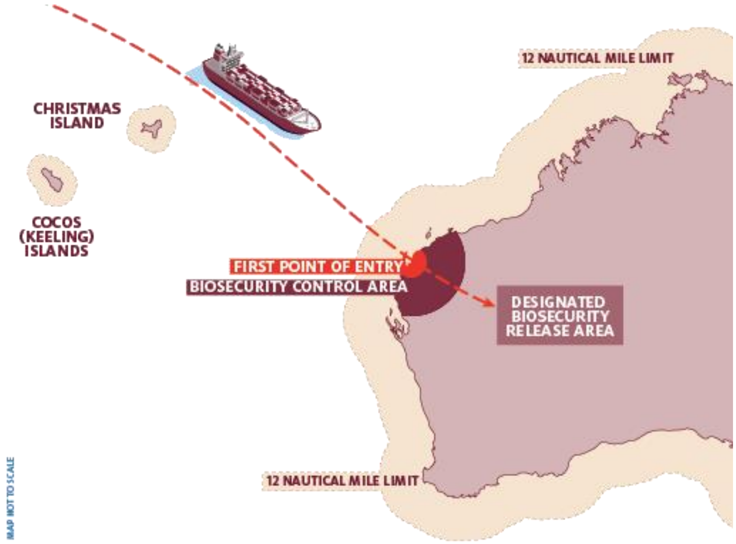


Figure 4 Jurisdiction of Biosecurity Act 2015

Goods imported to Australia are subject to biosecurity control as soon as they enter Australian airspace or territorial waters, which generally extend 12 nautical miles from the coast (see Figure 4).

Under the Sanitary and Phytosanitary Measures Agreement, World Trade Organization members are entitled to maintain a level of protection they consider appropriate to protect life and health within their territory. This is called an Appropriate Level of Protection (ALOP).

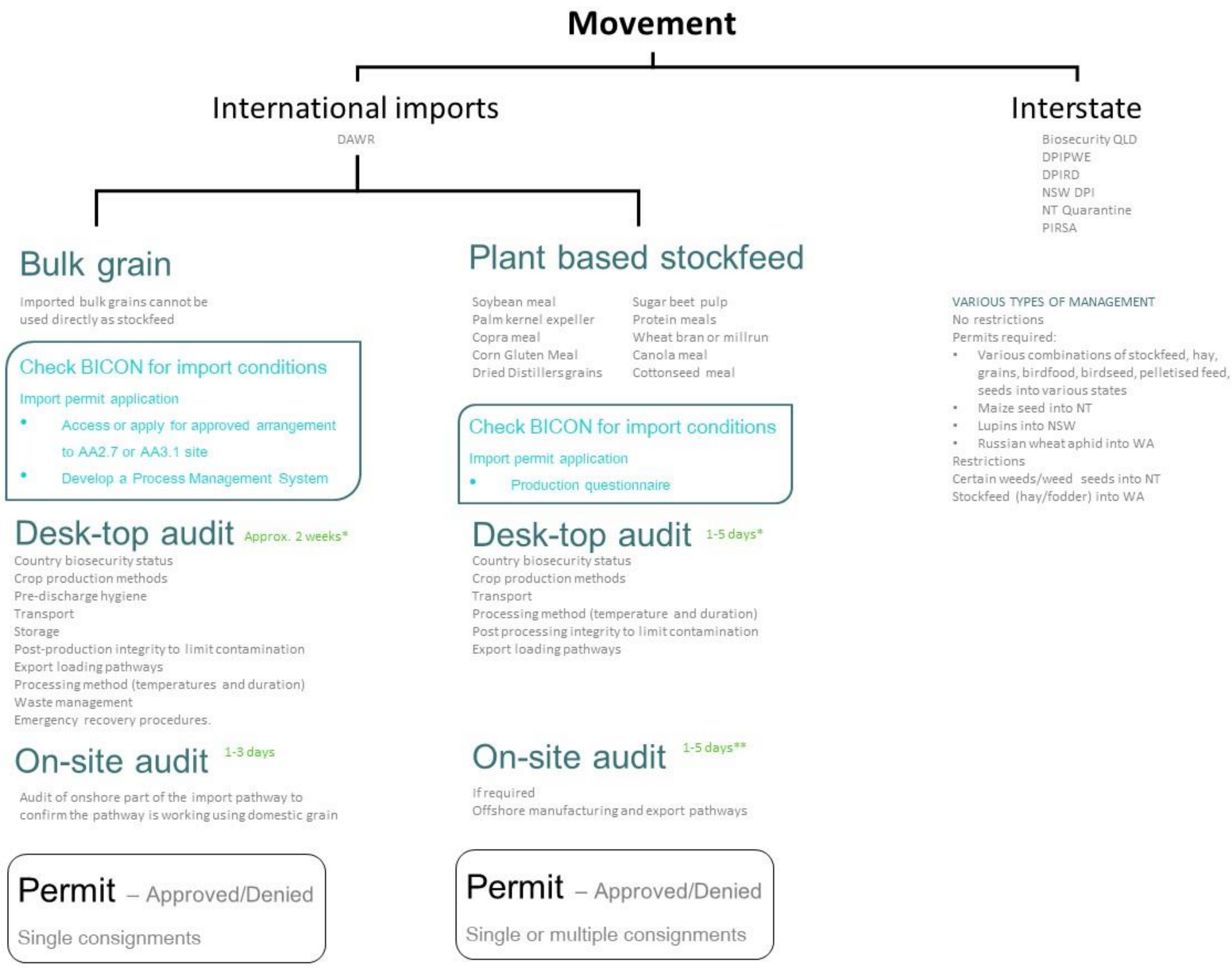
Australia's ALOP is expressed as providing a high level of sanitary and phytosanitary protection aimed at reducing risk to a very low level, but not to zero (DA).

4.2 Bulk grain or plant-based stockfeed

An Import Risk Analysis (IRA) is undertaken to determine whether any sanitary and phytosanitary measures are required to be applied to an import in order to achieve Australia's ALOP (DAWR, 2016). These apply to the importation of bulk grain and plant-based stockfeed and supplements. Outside of DA's direct import remit is the management of interstate movement of bulk grain, which falls to state government agencies.

The international import requirements are summarised in Figure 5. DA have published an infographic that also summaries the process (Appendix 11.1). A common focus associated with importation is to limit the exposure of agricultural production regions to biosecurity risks. This has been achieved by conducting any required treatment or processing before the product is moved into agricultural production areas in places close to ports, urban and coastal regions of Australia. A consequence of that focus drives a fundamental management difference between importation of bulk grain compared to a plant-based stockfeed product. When it arrives in Australia bulk grain will generally be unprocessed and accordingly is a living or viable organism, along with any pests or pathogens. This therefore means risks both pre and post devitalisation treatment have to be managed. To date, plant-based stockfeed has generally been the result of some form of processing that renders the plant material unviable (and any pests or pathogens) so the focus is more on conveyance contamination between the origin of the processed plant-based stockfeed and its ultimate end use location in Australia.

A good example, highlighting the compliance differences between bulk grain and plant-based stockfeed, comes from the importation of soybean meal. For the three years leading to 2017/18 the average quantity of soybean meal imported into Australia was 769,000 tonnes (ABARES, 2017) and this was essentially all from Argentina (UN COMTrade, 2019). This volume has been reached after steady annual increases of around 200,000 tonnes over 20 years. It is suggested that a key component of the increase has been the relative ease of post-processing supply chain management for contaminants of a by-product from a highly industrial process (i.e. soybean oil extraction). By way of comparison, based on USD PSD data only small quantities of bulk wheat, an average of 1180 tonnes were imported for the three years to 2016/17, with larger quantities only imported in years of drought (e.g. 2002/03 and 2018/19). For the same period, an average of 23,913 tonnes processed wheat in the form of flour was imported.



Adapted by Colere Group from Department of Agriculture, Australian Interstate Quarantine and state departments sources

Figure 5. Summary of management pathways for grain and stockfeed movements based on publicly available information (as at August 2019)

A consequence of the 2018 drought conditions and the approval of wheat imports from Canada has provided a blueprint as such with respect to the DA importation requirements for bulk grain. The key steps are illustrated in Figure 6, with the full list of permit conditions listed under Appendix 11.2. The first broad step was the assessment of the potential importation country's biosecurity status with respect to Australian diseases or pests of quarantine. This was based on suitable reference documentation. In the case of wheat from Canada, that was provided by the Canadian Food Inspection Authority in relation to freedom from disease pathogens of Australian concern. The result was that imports were restricted to certain regional areas of Canada which were free from diseases of concern. Once a suitable production region was identified, that could theoretically be used to source the wheat, focus moved to how the physical risks would be managed and certified through the supply chain.

The final area of activity relates to when the grain arrives in Australia, including inspection, movement to approved arrangement sites and the processing and treatments to devitalise the grain and manage any pathogen risks. For bulk grain DA states, "*issuing permits for single consignments (vessels) allows the department to make appropriate adjustments to any future permits".*

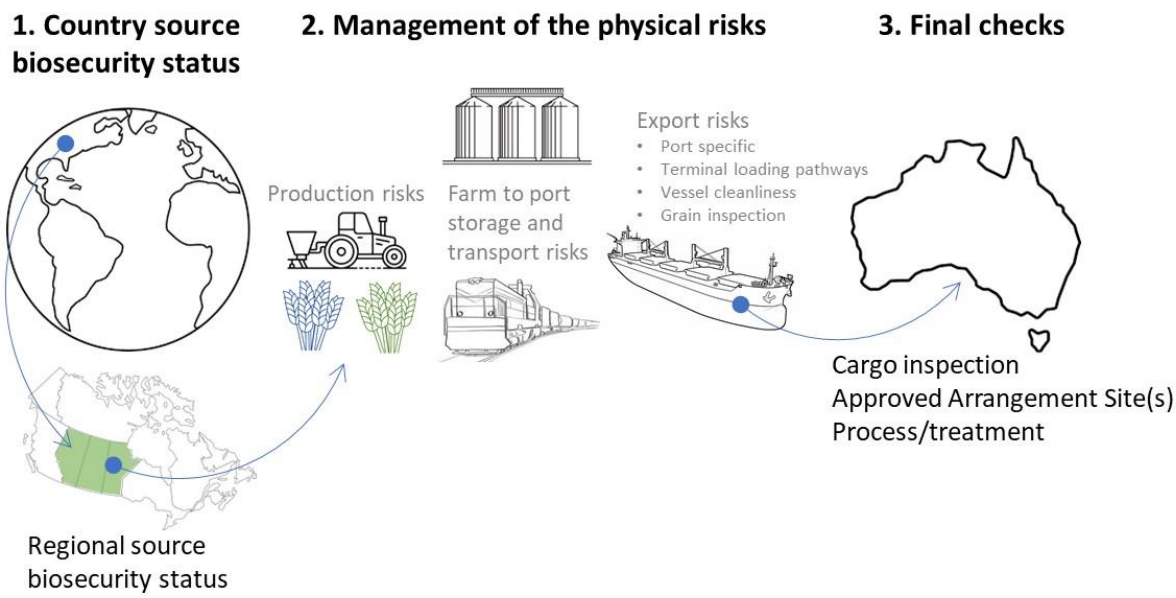


Figure 6. Key steps to import bulk grain into Australia based on publicly available DA information (as at August 2019)

The charges associated with an import permit are detailed in DA's Charging Guidelines (DAWR 2017a). In sum, there are charges linked to the lodgement and assessment of a permit application, approved arrangement application and annual fees, and cargo inspection. Costs associated with the permit and approved arrangement assessments extend to audit time-based charges as required.

4.3 Current Import Activity

As reported online by DA, as of 26 August 2019, the department had received 14 applications to import bulk grain from the USA and Canada. The applications covered canola, wheat, corn, and sorghum. Six permits have been issued for imports of bulk wheat from Canada. The other applications were in varying stages of assessment.

A similar story has emerged in relation to plant-based stockfeed, pet food, fertiliser, baits and bioremediation BICON permit assessment timeframes.

As reported online by DA on 2 August 2019, the recent drought in NSW and QLD, spanning the 2018 and 2019 calendar years, has resulted in a significant increase in the number of permit applications for plant-based stock feed. Additional resources have been brought on to assist in the assessments of plant-based stockfeed permit applications, and resources have also been diverted from other commodity assessments to assist. As a result, the assessment time frames for permit assessments for plant-based stockfeed, pet food, fertiliser and bioremediation products has increased. The number of permits under assessment and approximate minimum assessment times are:

- Over 200 permits under assessment
- Over 60 audits underway
- Minimum six weeks for permit assessments

4.4 Historical Import Activity

The available quantity of grain in NSW and QLD has been closely tied to the frequency of online DA memorandums relating to the import of grain from 2000 (Figure 7). The details of memorandums can be found in Appendix 11.3.

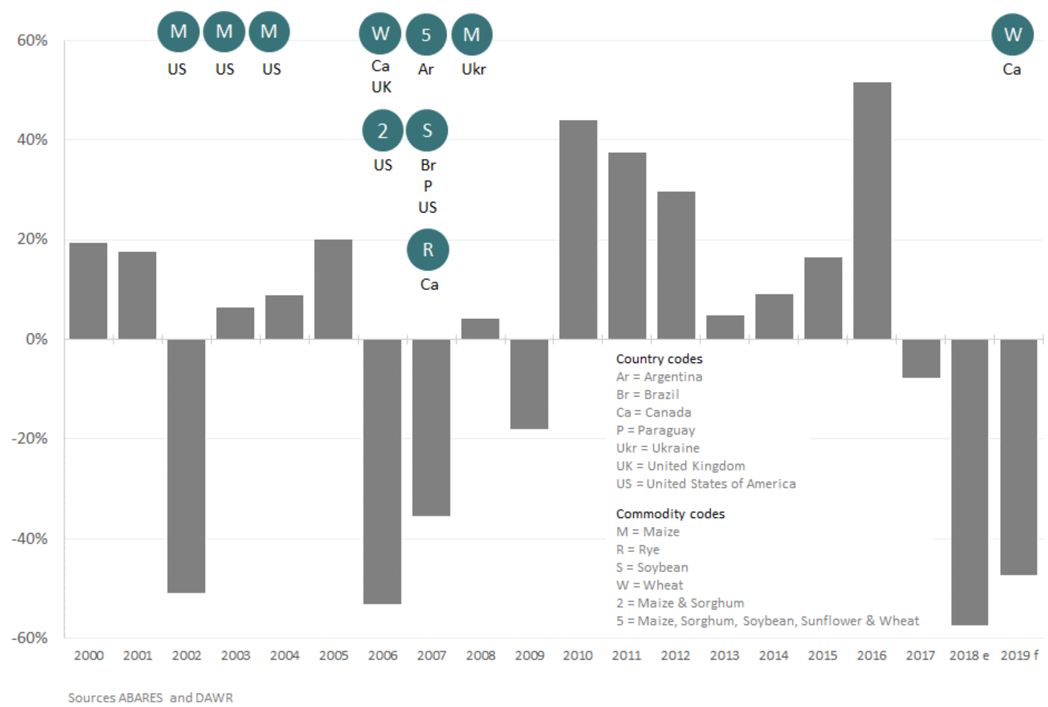


Figure 7 Relationship between combined NSW/QLD winter and summer grain production as a percentage of 20-year average and Department of Agriculture Biosecurity Advice memorandums

Several import pathways were approved for a range of grain types and origins following the low production years of 2006 and 2007. DA has reported online that during that period “canola was imported from Canada[*], soybean from Brazil and sunflower from Argentina". Based on ABARES reports the quantities associated with those imports were 57.3kt, 10.4kt and 25.2kt respectively for the three grain types (ABARES, 2017).

Following the low 2002 production year a total of 430,431 tonnes of grain was imported from four different countries (Canada, Denmark, UK, and US) covering feed wheat, maize, millet, rye, and soybeans (MLA, 2003). The Imported Grains Operations Response group, established in October 2002, aimed to assist in the coordination of operational processes for imported grain during this period. Previously, the Import Grain Task Force played a similar role when 440,506 tonnes of grain (barley, maize, rye, and sorghum) was imported from Canada, Finland and US between 1994 to 1995 (MLA, 2003). The common treatment requirements considered adequate to manage biosecurity risks during these two import periods were:

(1) Steam treatment of grain at the point of entry; with the option to then move this product to any destination for inland usage.
(2) Cracking of grain in metropolitan/port areas and subsequent movement to metropolitan and rural end users on a case-by-case basis. This was subsequently further refined to require pelletising following hammer milling as an approved import process.

4.5 Possible grain supply options analysis

The pest status of selected grain and meal source countries are listed in Table 4. Thirty-two grain and meal exporters were identified from USDA PSD data based on their five-year average export volumes from 2014/15 (excluding Australia). A minimum selection threshold of 100,000 tonnes was used for non-wheat exports while one-million tonnes threshold was used for wheat. Some countries were multiple exporters across both grains and meals, while others were only linked to a single product. Using a combination of resources[†]: DA, PHA, CABI Invasive Species Compendium and Plantwise Knowledge Bank, and WOAH, the major exporters were logged for the presence of a selected set of Australian quarantine pests of concern. The pests of concern are grouped as headline threats nominated by DA (2019a) and those related specifically to corn, sorghum and wheat (DA, 2019b). It should be noted that the EU was listed as a single exporting entity but from a pest presence perspective, individual member countries were assessed, but reported at an aggregate EU level using the term *restricted distribution*, meaning it was only found in selected countries. The complete exporter pest status matrix can be found in Appendix 11.4.

From the list of 32 major exporters, and based on the available and reviewed information, only Norway posed no apparent risk for the selected set of 20 Australian pests of quarantine concern. Belgium had a similar rating but due to exports being aggregated at the EU level, it was not possible to determine whether Belgium exported any grains or meals over the selection thresholds to be considered a major exporter. This highlights the challenge to identify potential sources of grain or

[*] It was noted by the authors that DAWR reported canola imports from Canada but no reference was made to this pathway in Department of Agriculture Biosecurity Advice memorandums available online from 2000.
[†] DA - www.agriculture.gov.au; PHA - www.planthealthaustralia.com.au; Invasive Species Compendium - www.cabi.org/isc/; Plantwise Knowledge Bank - www.plantwise.org/knowledgebank/; World Organisation for Animal Health - www.oie.int

meal import without any biosecurity risk. For example, all major wheat exporters have at least one of the six pests nominated by DA (2019b).

Table 4. Pest status of selected potential grain and meal source countries (highlighted in bold are Source/Grain combination previously approved by DA see Appendix 11.1 for more details)

	Grain and meal export levels												Biosecurity pest status				
	5-year export average from 2014/15 (1000 MT)												A = absent, R.D. = restricted distribution				
	ME (non-wheat) >100,000 tonnes												R.D. = restricted distribution				
	ME (wheat) > 1MMT												Blank = present				
	Grains							*Meals*									
Source	Barley	Corn	Oats	Sorghum	Soybean	Sunflower	Wheat	*Copra*	*Palm kernels*	*Rapeseed*	*Soybean*	*Sunflower*	FMD[1]	Exotic[2]	Corn related	Sorghum related	Wheat related
Argentina	ME	**ME**		**ME**	**ME**	**ME**	**ME**				ME	ME	A		A		
Bolivia											ME		A		A		
Brazil		ME			**ME**						ME		A		A		
Cambodia		ME													A		A
Canada	ME	ME	ME		ME		**ME**			ME	ME		A		A	A	
China					ME	ME					ME						
EU	ME	ME	ME		ME	ME	ME			ME	ME	ME	A	R.D.	R.D.	R.D.	R.D.
India	ME	ME			ME		ME			ME	ME						
Indonesia		ME						ME	ME				A				A
Kazakhstan	ME					ME	ME						A		A	A	
Laos		ME														A	A
Malaysia									ME				A		A	A	A
Mexico		ME					ME						A		A		
Moldova		ME				ME							A		A	A	
Myanmur		ME															A
Nigeria		ME															
Norway											ME		A	A	A	A	A
Paraguay		ME			**ME**						ME		A		A	A	
Philippines								ME					A				A
Russia	ME	ME			ME	ME	ME			ME	ME	ME			A	A	
Serbia		ME				ME							A		A	A	A
South Africa		ME													A		
Tanzania		ME													A		
Thailand		ME															A
Turkey							ME						A		A		
Uganda		ME													A		
Ukraine	ME	ME		ME	ME		ME			ME	ME	ME	A		A	A	
UAE										ME					A	A	A
USA	ME	**ME**		**ME**	**ME**		ME				ME		A		A		
Uruguay					ME										A		A
Vietnam		ME															A
Zambia		ME													A		A

Notes
FMD[1] is Foot and Mouth Disease
Exotic[2] is Infectious Bursal Disease, Newcastle Disease and Khapra Beetle

As a consequence, and to limit the biosecurity risk, the wheat recently permitted for import from Canada to Australia was restricted to spring types (to minimise the risk of Cephalosporium stripe linked with winter types) and that the wheat had to originate from specific provinces (wheat could not be sourced from British Columbia or Ontario, as dwarf bunt of wheat has been reported in these two provinces). In the above table, as highlighted in bold, are source and grain combinations that have been approved by DA (Table 4). Some of these allowed grain from any part of that country (e.g. maize, sorghum, soybean, sunflower, and wheat from Argentina; maize, sorghum and sunflower from Ukraine) while others had restrictions (e.g. soybean from the Brazilian province of Paraná; soybean from the US states of North Dakota and South Dakota, Kansas and Nebraska; wheat from the Odessa region of Ukraine). It is suggested therefore that the DA's case-by-case risk assessment approach for pest and pathogen does provide some flexibility, provided evidence can be demonstrated to how an identified risk might be managed.

5 Existing and emerging devitalisation methods for feed grain

The goal of grain or stockfeed treatment (from the perspective of this review) is to achieve two key targets: devitalise the grain or product (germination as close to zero as possible) and ensure there remain no viable weed seeds, pathogens or insects after the treatment. This section investigates a range of products and processes that have been, or could be, utilised to manage the risk stemming from the importation of contaminated grain.

An important factor in the consideration of most products and processes is that their effectiveness is the result of a combination of rate and exposure time to the treatment. The most benign treatments (such as temperature or atmospheric control) can be effective against seed vitality, insects and pathogens when applied over an extended period. The following analysis considers the individual merits of each product and process; with consideration of combinations in the Discussion (Section 8).

We draw your attention to the fact that the full range of available grain protectants (chemical insecticides) is not being considered in this review, as these products are known to neither have the broad activity spectrum required (predominantly due to insect resistance) nor be totally effective on grain that is already infested with insects.

DAWR (2017b) have approved biosecurity risk treatments with specific references for stored product pests, plant pathogens and plant material – seeds (See Appendix 11.5). The approved treatments include autoclave; ethylene oxide fumigation; methyl bromide fumigation; gamma irradiation; heat; cold; and physical removal/destruction.

5.1 Fumigants

Fumigation with gases is an important and widely used technology for the control of insects and other organisms. Because fumigants are selected based on their uniquely toxic characteristics, ease of application and rapid removal from commodities without leaving residues, fumigants can often provide effective, economical control where other forms of pest control are not feasible (i.e. eliminating insects from grains where direct pesticide applications are not permitted). Although many chemical compounds possess a high enough vapour pressure and toxicity to act as fumigants, very few can be used for this purpose because they are often corrosive to metals, dissolve plastics, are destructive to plant tissues, or leave unacceptable residues in the treated product (Lindgren et al 1954; Bond, 1984; Heaps, 2006).

The ideal fumigant would be inexpensive, easily detected by human senses, able to diffuse and rapidly penetrate the grain, highly toxic to the spectrum of target insects, insoluble in water, non-explosive, non-flammable, non-persistent, and stable in the gaseous state (will not condense to a liquid). In a departure from the traditional use of fumigants, it would also be able to devitalise the product. Unfortunately, no one fumigant has all the above properties.

The lethal insecticidal effects of a fumigant are governed to a great extent by the total uptake of fumigant during the time of exposure. Gas exchange via the tracheal systems of insect larvae, pupae and adults is a dynamic process, whereas the gaseous uptake by eggs takes place through microscopic openings and is therefore slower. This means that a fumigant's concentration will generally need to be adjusted upward or applied a longer period to have similar effects on eggs as those on adults (Will, 2009). Generally, the lower the temperature, the lower the respiration rate of the organism, which tends to make the pest less susceptible to the fumigant. Fumigation at lower temperatures requires a higher dosage rate and longer exposure periods than fumigation at higher temperatures, however the extent of these adjustments differs between products (Heaps, 2006).

Dose calculation: The fumigant dose must be calculated by multiplying the dose rate by the volume of the enclosure. The formula is:

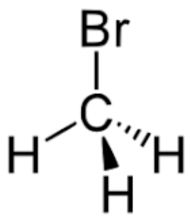
Dose (g) = Enclosure Volume (m^3) x Dose Rate Concentration (g/m^3)

Total usage of fumigant: Because the control of the target organism relies on a combination of dose and time, the total amount of product used per tonne relates to the amount of product required to keep the required dose rate concentration throughout the period.

Fumigants vary greatly in their mode of action. Some kill rapidly while others kill slowly. In sublethal dosages, some fumigants may have a paralysing effect on the pest while others will not allow the pest to recover. Commodities vary in their sorptive capacity of fumigants and in the effort required to aerate the commodities after fumigation.

There is a limited number of registered fumigants, and therefore limited choice for users. While none of the compounds in the following section fulfils the requirements of an ideal fumigant, the individual attributes of each make them amenable for use in combination with other risk management processes or approaches.

5.1.1 Methyl bromide



Methyl bromide is a colourless, non-flammable, non-explosive gas that is generally odourless, except at high levels. Chloropicrin is therefore added occasionally as a warning gas. Methyl bromide is toxic to all living organisms, although in a dose-dependent fashion. Its generic toxicity is probably based on its ability to methylate nucleic acids, fats and proteins. Its effects on higher organisms are primarily neurological.

Methyl bromide is not as toxic to most insect species as are some other commonly used fumigants. Nevertheless, other properties make methyl bromide an effective and versatile fumigant. The most important of these is its ability to penetrate quickly and deeply into sorptive materials at normal atmospheric pressure. Also, at the end of a treatment, the vapours dissipate rapidly and make possible the safe handling of bulk commodities. Another important property is the fact that many living plants are tolerant to methyl bromide in insecticidal treatment levels.

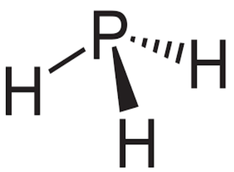
Methyl bromide has been used in areas such as a seed fumigation because of its ability to penetrate pallets of bags. Under certain circumstances (rates and temperatures) it does reduce viability. Also, germination may be delayed, and the vitality of young plants impaired. These negative effects are directly related to abnormally high temperature, dosage of fumigant, length of exposure, and moisture and oil contents of the seed.

The primary use of methyl bromide in the past has been as a soil fumigant to control fungi, nematodes, and weeds; in space fumigation of food commodities (e.g., grains); and in storage facilities (such as mills, warehouses, vaults, ships, and freight cars) to control insects and rodents.

Since 1 January 2005, all uses of methyl bromide, other than for certified Quarantine and Pre-Shipment, approved feedstock applications, or approved under critical use exemptions, have been prohibited in Australia under the Ozone Protection and Synthetic Greenhouse Gas Management Act 1989 (DEE, 2019). While methyl bromide is still effectively being used for both importation (container fumigation) and export (where specific countries such as India require its usage), it is unlikely that special dispensation would be available for the size and scope of activities required for bulk grain importation.

Pros	Cons
Effective against all insects and at all life stages	Being phased out for all uses under the Montreal Protocol as a significant ozone depletory agent.
No known resistance in insects or pathogens	Three times heavier than air and requires pushing through grain
Systems currently in place for use and the product is well understood	Highly toxic to humans with no antidote and undetectable at toxic levels
Excellent at penetrating materials	Limited effect on grain or weed seed germination
Role: While methyl bromide is an excellent fumigant (aside from grain devitalisation), it is not suitable due to the legalities of its usage. Small amounts are expected to be used for the importation of product in shipping containers, however even this is being phased out.	

5.1.2 Phosphine



Phosphine (IUPAC name: phosphane) is a colourless, flammable, toxic gas. Pure phosphine is odourless, but the technical grade product has a highly unpleasant garlic or rotting fish-like odour due to the presence of substituted phosphine and diphosphane (P_2H_4). With traces of P_2H_4 present, phosphine is spontaneously flammable in air. To manage its flammability, phosphine gas is diluted with carbon dioxide, nitrogen or air. Phosphine is used as a gas or formulated as a metal phosphide (aluminium or magnesium), which releases phosphine when interacting with moisture. With the phasing out of methyl bromide in signatory countries under the Montreal Protocol, phosphine is the only widely used, cost-effective, rapidly acting fumigant that does not leave residues on the stored product.

Phosphine is highly toxic to all forms of animal life. Poisoning can result from ingestion or inhalation; however, the gas is not absorbed through the skin. Phosphine ranks as one of the most toxic fumigants of stored product insects. It is a slow-acting poison that is effective at very low concentrations provided exposure time is long enough. The toxicity to insects declines at temperatures below 5°C, so that longer exposure times are required for it to exert its effect. Increasing the dosage in such cases can lead to narcotic effects on insects, resulting in reduced mortality. Phosphine has an inhibitory effect on insect respiration, but only in the presence of oxygen. The action of phosphine is potentiated by carbon dioxide and the exposure time can be reduced when both gases are present. Insect eggs and pupae are generally more tolerant to phosphine, which can be managed to a certain extent by longer exposure time.

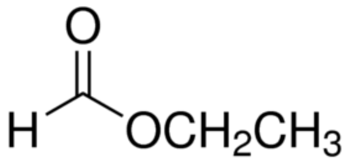
Because of its high volatility, phosphine requires gas-tight structures capable of maintaining an internal pressure of 500 Pa over the time of the treatment. To avoid resistance build-up, the treatment must be aimed at complete control of the pests. To control pests at all life stages and prevent insect resistance, phosphine gas concentration needs to reach 300 parts per million (ppm) for seven days (when grain is stored above 25°C) or 200ppm for 10 days (between 15–25°C); although there have been reports globally of various species tolerating levels up to 700ppm. Insect activity is slower at cooler grain temperatures, thus requiring longer exposure to the gas to receive a lethal dose.

Pests with high levels of resistance toward phosphine have become common in Asia, Australia and Brazil, which is of great concern, given the paucity of alternative fumigants. Phosphine remains the single most relied-upon fumigant to control stored grain pests in Australian grain production systems, but continued misuse is resulting in poor insect control and the development of resistance in key pest species.

Under normal fumigation conditions, phosphine does not affect seed germination.

Pros	**Cons**
Effective against most insect species at all life stages	Significant levels of tolerance and resistance found worldwide in specific storage insect populations such as Khapra beetle, Rusty Red Grain Beetle and Flat Grain Beetle.
Well understood in terms of use, residues and limitations	No effect on pathogens or seed germination at normal rates
	Corrosive to electrical equipment
Cost effective	Widely used in Australia with a level of reliance on continued usage in the grains industry
Role: The ubiquitous nature of phosphine use (and inherent insect resistance build-up) and lack of activity on pathogens and seed germination suggests it should not be used in importation activities, even in combinations.	

5.1.3 Ethyl formate



Ethyl formate is an ester formed when ethanol (an alcohol) reacts with formic acid (a carboxylic acid). Ethyl formate has the characteristic smell of rum and is also partially responsible for the flavour in many foods. Ethyl formate occurs naturally in soil, water, vegetation and a range of raw and processed foods. In insect cells, ethyl formate increases cytochrome c oxidase activity, decreases the expression level of acetylcholine esterase and changes phospholipid production patterns, thereby affecting membrane biosynthesis (Kim et al, 2017).

Linde has developed VAPORMATE, which contains ethyl formate as the active ingredient (16.7% by weight, 11% by volume) in liquid carbon dioxide. When dispensed, the liquid carbon dioxide reduces flammability and acts as a vehicle to deliver the gaseous ethyl formate to the target pests.

It is registered for use in cereal grains and oilseeds to control lesser grain borer, four beetle, psocids, storage moths, saw-toothed grain beetle, and flat grain beetle at all life stages, as well as the rice weevil in egg, larvae and adult life stages.

Pros	Cons
Effective against all key insects.	High sorption and heaviness means it is not ideal for large grain masses.
Cost effective.	Little to no effect on grain and weed seed germination.
Widely used and understood.	Little effect on pathogens at registered rates.
Little to no withholding period when used as a rapid knock down.	Highly flammable
Role: Ethyl formate, while useful as an insecticidal knockdown fumigant, is unlikely to be useful in the importation of grain as it is complicated in its use (flammability and difficulty in application).	

5.1.4 Carbonyl sulphide

Carbonyl sulphide (COS) is a colourless gas with a sulphide-like odour. It decomposes slowly in water and more rapidly in the presence of base. It is relatively soluble in water and it slowly decomposes by hydrolysis into hydrogen sulphide. For a simple molecule, COS has relatively few applications in research and manufacturing.

Despite its structural similarity to carbon dioxide (CO_2), COS is highly flammable and can reignite after being extinguished, making the safe commercial use challenging. However, it has still been deemed of interest due to its low mammalian toxicity and high insecticidal efficacy (Ren et al, 2008).

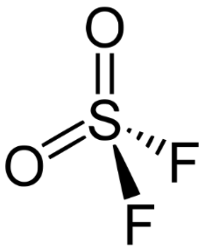
Like phosphine, fumigation time tends to be more important than dosage to ensure insect kill (Obenland et al, 1998). Efficacy is also sensitive to temperature and is generally lower on insect eggs compared to other life stages (requiring higher rates or exposure times). While Ct (concentration-by-time product) for COS is much higher than for other common fumigants (2000 ghm^{-3}) the higher Ct is achievable in practice because of lower sorption for COS than for methyl bromide onto structures and commodities (Desmarchelier, 1994; Ren et al, 1996). Unfortunately, fumigations with COS need to be significantly longer that those with methyl bromide but will be shorter to achieve the same level of kill than with phosphine, carbon dioxide or low oxygen (nitrogen) (Weller and Morton, 2001).

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) lodged patent applications on carbonyl sulphide in 1993 (Banks et al, 2001).

In 2005 BOC Gases (now Linde) obtained a global licence from CSIRO to produce and sell both ethanedinitrile (EDN) and COS as fumigants. But while both products were given approved actives certification by TGA, only EDN progressed to APVMA registration. The review team understands that the difficulty in sourcing a manufacturer for COS as well as the ongoing dominance of the much cheaper phosphine eventually forced the shelving of the product.

Pros	Cons
Effective against key insect pests	Highly flammable
Lower mammalian toxicity than most fumigants	Known to not be as effective against the eggs of some grain storage insects
Low reactivity and therefore doesn't degrade products or cause odours	Negligible effect on pathogens and seeds
Non-corrosive	Not registered for use on grain in Australia
Role: Unlikely to be of value for grain importation due to high costs and limited spectrum, even if it was made available for use in Australia or the grain source countries.	

5.1.5 Sulphuryl fluoride

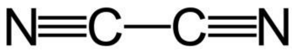


Sulphuryl fluoride is an insecticide and rodenticide that was first registered in the US in 1959. Sulphuryl fluoride is an odourless, colourless and non-flammable gas. It is non-corrosive and does not react with materials to produce odours or residues.

Sulphuryl fluoride is generally very toxic to all postembryonic stages of insects, but less effective on the eggs of many species. Sulphuryl fluoride breaks down to fluoride and sulphate inside the insect's body. Fluoride, the primary toxin, interferes with the metabolism of stored fats and carbohydrates that insects need to maintain satisfactory energy levels (disrupts glycolysis and the citric acid cycle). The insect is then forced to use protein and amino acids as an alternative source of energy, thus stopping development and eventually causing death. Mortality may not occur for several days.

Pros	Cons
Effective against key insect pests	SF is a significant greenhouse gas (reportedly 4000X worse than CO_2). This will likely mean compulsory scrubbing in the future.
Non-flammable and non-corrosive	Known not to be effective against the eggs and pupae of some grain storage insects
Low reactivity and therefore doesn't degrade products or cause odours	Three times heavier than air and requires pushing through grain
	Negligible effect on pathogens and seeds
Role: Even in combination with a physical devitalising process, sulphuryl fluoride is unlikely to be used due to cost and effectiveness in the roles required.	

5.1.6 Ethanedinitrile



Ethanedinitrile (EDN), also known as cyanogen, is a cyanide derivative. It is a colourless, flammable and toxic gas at room temperature and atmospheric pressure, with a characteristic almond-like odour. Commercially sold by Draslovka Services Pty Limited Australia, EDN FUMIGAS was developed by CSIRO as a replacement for the ozone-depleting methyl bromide. EDN is not a new molecule; it was discovered in 1815 but was not manufactured on a large scale until the late 19th century.

EDN enters the organism through inhalation and reacts with moisture (biological system), producing hydrogen cyanide and a cyanate ion. Cyanide targets cytochrome c oxidase (an enzyme in the mito-chondrial respiratory chain) and prevents affected tissues from using oxygen. This results in a reduction in oxygen capable of causing tissue damage throughout the body, with the most vulner-able tissues being those with high oxygen demands. The inhibition of oxygen use by cells causes oxygen tensions to rise in peripheral tissues, resulting in a decrease in the unloading gradient for oxyhaemoglobin and death of the target organisms.

EDN doesn’t accumulate in humans, animals, plants, or as a residue in the soil. While the half-life of EDN in air is 100-150 days, it will only last few minutes to days in soil and water, depending upon pH and temperature. In grain, this effectively means no MRL issues.

EDN was commercially developed as a pre-planting soil fumigant, showing promising activity against several key pests, including plant-parasitic nematodes, a variety of weeds and soilborne pathogens. It has chemical properties similar to those of methyl bromide, and its potential to move readily through the soil profile make it ideal for soil fumigation purposes. In the soil it breaks down to ammonia and nitrates, which are released into the environment or consumed by the plants. EDN has also been globally used to control insect pests and pathogens in timber and logs.

EDN was comprehensively evaluated in the MLA funded projects FLOT.124 and B.FLT.0127. At the time there was hope that EDN may provide the ideal option for managing the pest, germination and pathogen trifecta. Unfortunately, the trials undertaken by CSIRO, highlighted several critical shortcomings, namely:

- Hard coated weed seed species proved tolerant at even the highest doses.
- Smaller grains (wheat and barley) had reduced devitalisation rates, particularly barley.
- Low moisture reduces efficacy of devitalisation.
- At temperatures below 20°C devitalisation efficacy was unsatisfactory.

The trials recommended a treatment rate of 6000 mg h/L of EDN over five days, or approximately 2.5kg per tonne of grain. This was based on maize that had been pre-screened/graded for weed seeds and held in a sealed silo. Potentially further work is now needed as to the effective dosage rates and treatment times, as other grain types are considered for importation, since the focus of the CSIRO research was on maize as it was the most likely import candidate at that point in time. This was principally because it was the most available commodity at that time and it was easy to screen out the small hard coated weed seeds that were known to be difficult to devitalise.

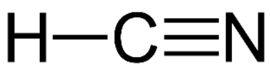
BOC currently holds an Australian registration for EDN (licensed to Draslovka) under the name Fumigas, for use as a fumigant in soil and timber. Further timber registrations are in progress in New Zealand, Malaysia, Israel, India, Russia, USA, EU, Turkey, South Africa, and Egypt.

There is no registration for treatment or use for devitalisation of grain or the management of pests and pathogens in grain. APVMA were supportive of the efficacy and the residue data generated by CSIRO, MLA study. However, Linde, as the previous registrant, removed this particular use from the EDN label a few years ago due to the lack of demand for devitalisation of grains.

Draslovka Services are open to commercialising EDN for devitalisation and have identified the path-way required (registration through APVMA followed by approval by Biosecurity Australia, as it is related to control of exotic weeds and pathogens). Draslovka have calculated a dose rate of 115 g/m3 based on the Ct (115 g x 120 hours = 13,800 ghm^{-3}). Based on this rate (115 gm^{-3}) and an estimated cost of the product of $15/kg, the cost of treating maize would be between $2 and $4/tonne, excluding handling and capital costs (Kade McConville, Draslovka; personal communication).

Pros	**Cons**
Effective against all key pest insects	Likely need for 2.5-3kg per tonne of grain
Devitalises maize without need for physical treatments.	Less effective at lower temperatures
Little to no residue issues	Not effective against hard-seeded weeds at the recommended rates
EDN can be measured and monitored while in use	Requires holding in a sealed silo for 5 days
	Not currently registered or on approved treatment list
Role: EDN is the most promising fumigant option for use in a grain importation process. While it has several limitations, these could be overcome with careful sourcing and physical screening. Industry support is required to support registration (APVMA) and addition to the Approved Treatment list.	

5.1.7 Hydrogen cyanide



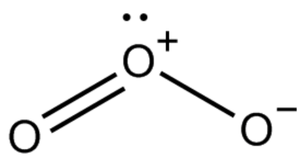
Hydrogen cyanide (HCN) is a colourless, flammable liquid with a boiling point of 26°C. Before the introduction of methyl bromide, HCN was the leading fumigant since the 1880s. HCN was also the first fumigant to which insects developed tolerance, leading to increasing rates and finally, the demise and replacement of the product by the supposedly safer alternatives methyl bromide and phosphine. HCN also caused issues to many food products due its high solubility (discolouring fruit) (Heaps, 2006). Because of the high degree of sorption at atmospheric pressure, HCN does not penetrate well through the bulk of some commodities (Navarro, 2006).

Rambeau et al (2001) found significant differences in the tolerance levels of different insect species to HCN and noted the high sorption rates as being a source of difficulty in the practical application of the fumigant. A recent study, undertaken by the manufacturer (Aulicky et al, 2015), suggested that while tolerance to HCN did build up in grain storage insects, the levels of tolerance were still controllable when the product was used at the recommended rates.

Despite some of its management challenges, HCN is being reconsidered around the world as a resistance breaker for phosphine or replacement for methyl bromide. Registered as BLUEFUME™ in many regions by Draslovka, it is currently used mainly for the treatment of flour mills and empty structures to control stored-product insects. The commercial effectiveness of HCN lies in the opportunity for rapid one-time fumigation with a short exposure and broad-spectrum insect efficacy.

Pros	**Cons**
Effective against all insects at all life stages with no known resistance in Australia	HCN has no detrimental effects on seed germination and has in fact been shown to enhance it
Fumigation times of as little as 48 hours	Does not control key pathogens
HCN vapours are lighter than air (ventilation and aeration is easier)	Highly soluble and highly absorptive, thus creating some issues at varying moisture
Role: HCN may play a potential role in insect control during the importation process but would need to be combined with other processes and or products to manage weed seeds, devitalisation and pathogen loading. As a rapid treatment for all insect species and life stages HCN has scope for use at both source and importation point.	

5.1.8 Ozone



Ozone is a pale blue gas with a distinctively pungent smell. It is an allotrope (alternative physical state) of oxygen that is much less stable than the diatomic allotrope O_2. A known sterilant, ozone has been used as both an insect and pathogen control agent in food commodities. It is readily generated from atmospheric oxygen and is safe to the environment when used for fumigation.

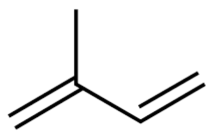
Being highly unstable, it breaks down to molecular oxygen quickly. Because of its high reactivity, it is corrosive towards most metals (Mason et al, 1999). Its decomposition to diatomic oxygen is rapid, with a short half-life of about 20–50 min in the atmosphere and 1–10 min in water. Ozone therefore does not penetrate wet commodities such as fruits and vegetables as well as methyl bromide (Leesch et al, 2003), in part because it reacts rapidly with any free moisture that is present. The free moisture acting as an O_3 sink, prevents further penetration. Ozone is a powerful oxidising agent that reacts with a wide range of materials, including dust in the air, natural products, such as rubber, and synthetic compounds, such as plastics.

Research around ozone as a potential quarantine treatment for controlling stored product has produced mixed results. Ozone does have fumigation potential for dry products, although it does not easily penetrate some grains due to waxy coatings. Some trials suggested that rates of 400ppm were required to get adequate levels of control in products (Hollingsworth and Armstrong, 2005) a difficult proposition given its unstable nature. Any use for insect control may require highly specialised equipment (Armstrong et al, 2014).

Gaseous ozone has been shown to be very effective in inactivating fungi associated with grain. Kells et al (2001) found 50ppm of ozone for 3 days resulted in 63% reduction of the contamination level of the fungus *Aspergillus parasiticus* on the kernel surface of maize.

Pros	Cons
Effective on all insects and pathogens when adequate concentration and exposure reached	Not currently registered as a grain fumigant or treatment
Generally safe use and well understood for commercial use	Reduced activity in lower temperatures (below 20C for pathogens)
	Little effect on seed germination except at extreme exposure levels
Role: While potentially interesting due to its non-toxicity, ozone does not seem to be suited to the types of uses required in grain importation.	

5.1.9 Isoprene



Isoprene has recently been identified as a potential fumigant and is undergoing patent review. It is currently unknown if the active will be developed into a product and registered.

Isoprene is an extremely flammable liquid and vapour. It can easily form explosive peroxides and can polymerise in an uncontrolled reaction on heating or when coming in contact with many materials, resulting in fires, explosions and container rupture.

Even though isoprene is the major endogenous hydrocarbon exhaled in human breath, according to EU classification criteria, isoprene may cause cancer; it is suspected of causing genetic defects and is harmful to aquatic life, with long lasting effects. Additionally, the classification provided by companies to ECHA in REACH registrations identifies that this substance is toxic to aquatic life with long lasting effects.

Isoprene and isoprene analogues have been nominated as potential fumigants in a recent patent application (WO2018141020A1).

Pros	Cons
Likely to be effective against a wide range of insects and some pathogens	Not currently registered as a grain fumigant or treatment
As a common and easily manufactured product, it is likely to be relatively affordable	The risk profile suggested in the literature would make isoprene a difficult product to use due to likely restrictions and safely measures required
Role: Not enough is currently known about the abilities and limitations of isoprene to provide further analysis of its place in grain treatment.	

5.1.10 Combining fumigants with carbon dioxide for synergism or improved activity

Synergists have been commonly utilised in pesticides to improve efficacy or break resistance. Synergism is defined by the combination of two compounds (either one toxic compound and a non-toxic synergist or two toxic compounds) resulting in a combined toxicity that produces a significantly greater mortality to the target pest than can be obtained using each of the compounds or toxicants individually or the simple arithmetic sum of their toxicities when combined. For example, piperonyl butoxide is commonly added to pyrethrum and pyrethroids to significantly enhance both the “knock-down” and mortality effects against target pests compared with using pyrethrum or a pyrethroid alone.

Carbon dioxide enhances both the penetration and distribution of some fumigants, e.g., phosphine and ethyl formate, through the substrate being fumigated (Ren et al, 1994). Carbon dioxide by itself is toxic to insects at adequate concentration and exposure times, and it is a basic component of modified atmosphere fumigation (Bond, 1984). Carbon dioxide can also be used to the reduce the flammability of some fumigants allowing a reduced safety burden (Ryan and Shore, 2010).

There are still knowledge gaps in how CO_2 might be useful in improving the efficacy or handling or decreasing the cost of using various other fumigants.

5.2 Modified Atmosphere

Modified atmosphere fumigation has been in use arguably for hundreds of years with various methods utilised to reduce oxygen content in storage or increase CO_2 concentration to the point of toxicity. While early methods took advantage of the respiring of moist grain (hermetic storage), nitrogen or carbon dioxide have been utilised in modern times to effectively displace and reduce oxygen concentration to very low levels, even though pests are generally killed by the higher carbon dioxide concentrations than by asphyxiation. This alternative is usually more expensive than the use of phosphine and it has low penetration, thus requiring prolonged exposure to be effective.

CO_2 is a non-flammable, colourless, odourless gas that is approximately 1.5 times heavier than air. Food grade CO_2 comes as a liquid in pressurised cylinders, which goes into its gaseous form when released from the cylinder. Treatment with CO_2 involves displacing the air inside a gas-tight silo with a concentration level of CO_2 high enough to be toxic to grain pests. This requires a gas-tight seal, measured by a half-life pressure-test of no less than five minutes. CO_2 must be retained at a minimum concentration of 35% for 15 days to achieve a complete kill of the main grain pests at all life stages.

The amount of CO_2 required to reach a concentration of 35% for 15 days is one 30-Kg (size G) cylinder per 15 tonnes of storage capacity, plus one extra cylinder. The basic process consists of opening the storage's top lid to let oxygen out as CO_2 is introduced. The gas is released into the bottom of the silo via a high-pressure tube no longer than two metres. One kilogram of liquid CO_2 will produce approximately half a cubic metre of gas. Each cylinder could take three hours to dispense. In cooler conditions this process will take longer as the gas will tend to freeze if released from the bottle too quickly. This method of fumigation is therefore not recommended when temperatures are below 15°C. Also, at temperatures below 20°C, CO_2 is less effective, because insects are less active, and hence the CO_2 concentration must be maintained for an extended period.

Even in a silo that meets the five-minute half-life pressure test, an initial CO_2 concentration of 80% or more is required to retain an atmosphere of 35% for the full 15 days, because the CO2 is absorbed by the grain, thus reducing the atmospheric concentration over time. The key is to maintain the CO_2 concentration above 35 per cent for 15 consecutive days, which will require suitable electronic instruments or a gas tube detector kit for monitoring. The silo must be checked the day after fumigation and may need further purging to remove oxygen that has diffused from the grain.

Recently significant R&D has been undertaken to investigate the use of nitrogen in a modified atmosphere grain management system. To achieve effective insect pest control in stored grain, the aim is to use 99% nitrogen gas to purge oxygen levels in the storage container from 21% to below

1%. Nitrogen gas (99%) is delivered into the base of the silo with the aim of completing at least two air changes to reduce oxygen levels measured in the head-space at the top of the silo to less than 1%. Nitrogen storage will also maintain the quality of canola and pulses by inhibiting the respiration process that causes oxidation, which leads to seed deterioration, increased free fatty acids and loss of colour.

Capital costs of the 30 to 60 m^3/ hour nitrogen generators range from $50,000 to $75,000 from China, or approx. $95,000 for Australian built generators. Diesel and electricity operating costs for the generators range from $0.70 to $1.00 / tonne.

Pros	Cons
Effective against insects	Treatment time is typically 15 days or more
	Requires adequate supply of food-grade carbon dioxide or nitrogen gas
	Not ideal below 20°C
Role: The various types of controlled atmosphere approaches are unlikely to suit the timelines and costs of grain importation and devitalisation.	

5.3 Heat

Heat treatment is generally based on maintaining the commodity at a predetermined temperature for a specified time. Heat treatments are designed to kill plant pests without destroying or appreciably devaluing the infested commodity (through potential modification of the proteins and starches). The following heat treatments are in use: Hot water immersion (hydrothermal treatment), steam treatments, vapour heat and forced hot air treatment, and forced hot air treatment alone.

Steam treatments rely on the fact that steam at 100°C will destroy most pathogenic microorganisms, vegetative or growing, after a short exposure to steam at this temperature. Some more recalcitrant spores, however, will require steam at temperatures of 120°C under pressure (in an autoclave).

Vapour heat and forced hot air treatments use heated air to warm the product to temperatures that are lethal to target pests and pathogens. Generally, the two treatments differ from each other only in the relative humidity of the air in the treatment chamber; higher humidity levels may preserve quality but decrease shelf life of the resulting treated product.

5.3.1 Infrared treatment: irtech

The Australia-based company ***irtech*** has developed an IR-based technology (GRAIN EDGE™) to pasteurise, devitalise or micronise (gelatinise starch to increase digestibility) grain. They claim that their patented technology uses around 40 KW over a residence time of 60 seconds to achieve a temperature of 105°C (between a third and quarter of the power requirements of older heat-based technologies. Furthermore, the process reduces rather than adds moisture to the grain (unlike steam flaking) potentially having less effect on shelf life. Irtech currently markets various model sizes, mostly focused on a small 35t/day unit (marketed for A$150K) for use by small feedlots and dairies as an alternative to the larger scale steam flaking processes.

The company suggests that the 105°C treatment of cereal (based on a specific set of factors such as retention time, wavelength and frequency) would be suitable to comply with importation requirements around devitalisation, disinfestation and sterilisation. Using a series of their largest units (rated at 50t/hr) a plant would be able to treat grain directly as it is being unloaded from ship. The concept is being explored for importation of grain for the animal industries during periods of high demand and low supply, but also more regularly for the direct importation of whole soy as part of the current 750Kt of annual importation requirements.

Pros	Cons
Effective against all living organisms	Throughput and cost per tonne
Can be dosed to achieve various outcomes, e.g. disinfestation without devitalisation, pasteurisation or micronisation.	Requirement for a specialist plant to be built at port
Duration of treatment in the one-minute range with scale possible through a 50t/hr unit.	Currently not on the list of approved processes- questions around effectiveness require further enquiry
Efficient way to generate heat compared to steam flaking.	Unknown effect on quality and shelf life.
No residues	
Role: The Grainedge technology has potential for the grain import role in its ability to provide all the treatment requirements in a single pass. See Recommendations for suggestions on a path forward in the assessment of Grainedge.	

5.4 Cold

Sustained cold temperatures have been employed for many years for insect control. When specified temperatures and time periods are adhered to rigorously, certain insect infestations can be eliminated. Treatments may be conducted in warehouses, refrigerated compartments of transporting vessels, containers cooled by the ship's refrigeration system, or by individually refrigerated containers.

In the northern growing regions of Europe and the Americas, the use of cold aeration is a primary reason why other insect management is rarely needed, by dropping the grain temperature to under 5°C (and holding for an extended period) all grain storage pests are eliminated.

Pros	Cons
Effective against all insect species at all life stage given time at sufficiently low temperatures	Little to no effect on most of the relevant weed seeds and pathogens
	Slow (4+ weeks dependent on temperature)
Role: The use of low temperature storage may have a role within the supply chain as a recognised method for managing insects; e.g. grain from North America or northern Europe may be accepted as insect-free if it has been stored at below 5°C for more than 5 weeks.	

5.5 Irradiation

Irradiation reduces the risk of introduction of undesirable pests by achieving certain responses, known as "endpoints," in the targeted pests. These endpoints include the inability of insects to emerge or fly, inactivation or devitalization (seeds may germinate, but seedlings do not grow, or tubers, bulbs, or cuttings do not sprout), increased mortality, and sterility (inability to reproduce). As opposed to chemical treatments, the presence of living insects can be expected days after the irradiation treatment, depending on the targeted endpoint. This requires new inspection standards and checkpoints for risk management, given that there are no clear markers for treatment efficacy.

Control of microorganisms is obtained at higher dosages, at which extensive hydroxyl radical formation leads to chemical modifications of their DNA, leading to strand breakage and thus impairment of DNA replication.

The ionizing radiation utilised can have three different origins: electrons generated from machine sources, with energies levels up to 10 MeV (eBeam); radioactive isotopes (gamma rays from cobalt-60 or cesium-137; 1.33 and 0.66 MeV, respectively); X-rays (with energy levels up to 7.5 MeV).

The dosage used is generally for phytosanitary purposes, i.e., the target are pests but not microorganisms.

The 1980 Joint Expert Committee on the Wholesomeness of Irradiated Food concluded that 'irradiation of any food commodity up to an overall dose of 10 KGy presents no toxicological problems' (WHO, 1981). This was adopted in 1983 as the Codex General Standard for Irradiated Foods. The applications of irradiation for food requiring doses less than 10 KGy include the elimination of vegetative bacterial pathogens from foods such as meat, poultry, fish and fresh fruits and vegetables; the inhibition of sprouting in potatoes and other tubers; the disinfection of grains and dried fruits such as dates and figs; extension of the shelf-life of refrigerated foods; and the treatment of certain foods (Department of Agriculture, 2014). The beneficial results of food irradiation include the improvement of the hygienic quality of certain foods and the reduction of post-harvest losses. In comparison to thermally sterilised foods, the extent of chemical change in radiation-sterilised foods is relatively small and uniform.

Food irradiation has a perception and image problem, although countries are increasingly adopting irradiation for phytosanitary purposes.

Pros	Cons
Effective against all pests, pathogens and seed germination.	Market perception
No residues	Speed and scale of current facilities
	Cost per tonne
Role: While the single pass treatment offered by irradiation is attractive, the size and scale of operation required for grain importation is unlikely to be viable.	

5.6 Microwaves

Microwaves have been considered for use in grain for the management of insects since the early 1970's (Watters 1976). Microwave heating is based on the transformation of alternating electromagnetic field energy into thermal energy by affecting polar molecules of material. While technically a heat treatment, focused microwaves will differentially heat areas with higher moisture, meaning that the insects may be heated at a faster rate than the product they infest because of their relatively high water content, an ideal approach for targeting insects and eggs within a dry grain media. The use of microwave technology in a continuous process is also possible (as opposed to most heat type treatments which need batching to reach the required temperatures).

While several research groups have intermittently assessed the potential of microwave technology for stored product treatment over the last 30 years (Yadav et al 2014) the energy requirements and time required to achieve the desired results have never been able to reach a commercial benchmark. In addition, issues with the non-uniform heating through larger samples have made reliability of the disinfestation questionable (Vadivambal et al 2010, Wang and Tang 2001).

Microwaves offer a similar, if more focused approach to heat treatment for sterilisation of the grain (and any potential weed seeds contained within). Researchers have shown that the weed seed bank in the field can be significantly reduced using microwave treatment of the soil (Khan and Brodie, 2018). A 2.5-minute microwave treatment has been used to devitalise bird seed as an alternative to heat treatment in an oven (Blythman and Sansom, 2019).

Experiments using microwave treatment to eliminate seedborne pathogens in grain were inconclusive, with some pathogens still able to be isolated from the treated material, despite treatments at a level sufficient to kill the seeds themselves (Gaurilčikienė et al, 2013, Hussein et al 2015).

The currently available technologies being used to produce microwaves do not lend themselves to the scale of activities within the scope of this review. The use of microwaves at an acceptably effective level to devitalise grain and weed seeds as well as sterilise the product is likely to require a time and energy combination that would render it too slow and expensive. However, the use of large-scale microwave process is increasing, recent improvements in the design of high-powered microwave ovens, reduced equipment manufacturing cost and trends in electrical energy costs offer a significant potential for developing new and improved industrial microwave processes (Warchalewski et al 2011).

Microwave technology should continue to be monitored as a potential option for treatment of grain.

Pros	**Cons**
Potentially effective against all insects and pathogens	Large energy requirement or holding time with current technology.
Role: The energy requirements and speed of treatment are unlikely to make microwave technology a viable option for the scale of treatments required.	

5.7 Nonthermal Plasma

Atmosphere Cold Plasma (ACP) is generated by electrical discharge at atmospheric pressure and consists of UV photons, neutral or excited atoms and molecules, negative and positive ions, free radicals and free electrons. Cold plasma is a novel nonthermal food processing technology that uses energetic, reactive gases to inactivate contaminating microbes on meats, poultry, fruits, and vegetables. The mode of action is due to UV light and reactive chemical products of the cold plasma ionization process causing damage to proteins and nucleic acids, as well as lesions in cellular membranes (Laroussi and Leipold, 2004; Scholtz et al, 2015). As a non-thermal process, ACP causes minimal or no thermal damage to the food product treated (Niemira, 2012).

Various cold plasma systems that operate at atmospheric pressures or in low pressure treatment chambers are under development. Reductions of greater than 5 logs can be obtained for common pathogens found in food. Effective treatment times can range from 120 seconds to as little as 3 seconds, depending on the food treated and the processing conditions.

Key limitations for cold plasma are the relatively early state of technology development, the variety and complexity of the necessary equipment, and the largely unexplored impacts of cold plasma treatment on the sensory and nutritional qualities of treated foods. Also, the antimicrobial modes of action for various cold plasma systems vary depending on the type of cold plasma generated.

Application of atmospheric and low-pressure cold plasma for decontamination of cereal grains has been reported both for inactivation of indigenous microbial communities of grains (Selcuk et al, 2008; Filatova et al, 2013; Brasoveanu et al, 2015; Kordas et al, 2015; Zahoranova et al, 2016) and for artificially contaminated cereal grains and seeds.

Pros	Cons
Potentially effective against a wide range of pathogens with the ability to penetrate grain	Unknown effects on quality of product after treatment (potential breakdown)
Fast treatment may be possible	Size and scale
Role: A watching brief should be kept on this technology as it continues to evolve for use in other food uses. While the current, commercially available technologies are too small or slow to be viable, the sector is being advanced rapidly.	

5.8 Other Physical Treatments

5.8.1 Grading

Seed size and the weight are used as the basis of the grading process. The basic processes used for grading are aspiration, scalping and grading.

Aspiration of the seeds refers to the process in which light and chaffy seeds are removed from the bulk grain. This can be done by blowing the seeds with an air blower, which deals with light dust and straw present in the grain.

Scalping refers to the process in which particles larger than the seed are screened out and the seeds separated into a vessel.

Grading refers to the actual process of separating seeds by size and quality using a sieve (grain screens) or grading table.

The most common equipment used for seed cleaning is the air screen cleaner. The screen cleaners work like a blower but with four levels used to screen seeds of four different sizes and separate them. The aperture size is specified for each crop in order to filter or screen better and the sizes can be changed if required.

Gravity grading is the most efficient method to clean seed for planting or for delivery of clean grain. Gravity grading achieves quantitative weed seed removal and gets rid of chaff, dirt and other non-seed contaminants, seed from other crops (volunteers), as well as frost-affected and insect-damaged grain, seed that is damaged, shrivelled or unviable is also removed. Grading typically removes about 10% of every load.

Pros	Cons
Potentially effective against a wide range of weed seeds and pathogens associated with the grain dust.	Loss of product volume
	In seed contamination or infestation is unlikely to be removed.
	Grading relies on a size differential between the weed seed and grain so not always possible to separate
Role: Grading is potentially a cost-effective approach for a range of known weed seeds and diseases whereby the amounts of contamination are significantly reduced; possibly to then make the ensuing treatments more effective, faster or less expensive.	

5.8.2 Hammer milling/rolling

Hammer milling and rolling can be used to physically destroy seed, including the feed grain and weed seeds. To deal with pests and pathogens these processes are usually applied in combination with steam pelletising. No whole grain or other seeds should be present in the hammer-milled product.

In theory, the milling and/or rolling of grain should devitalise it completely, and this is usually the case for grain such as maize, however with smaller grains such as wheat and barley, some seeds can potentially survive the process with their germ intact. In addition, these processes are often not totally effective for weed seeds that are significantly smaller than the main grains, thus requiring additional grading. Generally milling/rolling processes have been paired with steam/heat treatments when used for importation of grains.

Pros	Cons
Reliable and known processes when combined with steam/heat that will be effective on all pests, pathogens and seed germination.	Cost per tonne
	Finished product is not ideal for all uses and may have a shelf life limitation.
	Requires dedicated plant at port.
Role: The combination of milling and steam/heat will be the fallback treatment for importation of grain. It is reliable and well understood to manage the risk factors involved.	

5.8.3 Steam flaking

Steam flaking uses moisture, heat and pressure to rupture the starch granules, rendering them more digestible. The physical destruction of the grain and the heat can be used to deal with weed seeds, pests and diseases. Grain for steam flaking is first tempered and then passed through a steam chest (typically at 95–110°C), before being flaked between two rotating corrugated rollers.

Steam flaking has become standard treatment for much of the feedlot industry due to the ability of the process to denature the kafirin protein complexes in sorghum that typically limit the starch availability. The cooking of the grains are also known to increase the attractiveness to even shy feeders, increasing feed intake.

While the process potentially covers the pest, pathogen and seed germination factors, there are several major limitations to steam flaking. The whole process requires significant energy to generate the required steam, drive the augers and for the rolling of the grain. Steam may be generated using gas (LPG, natural or butane gas), with electricity used for the other processes. The throughput of these plants, combined with the capital costs, mean that they are only utilised by large operations and even then, they need to run around the clock for the value proposition to work.

Steam flaking grain increases moisture content by 4 to 8%, resulting in a finished product that must be used within two days to minimise heating and spoilage.

The process of steam flaking should take all product to a temperature of 95-100°C for a period long enough to be effective against pathogens. However commercial units are not designed to be that accurate and may not heat evenly or for long enough (as this is not a commercial requirement) potentially allowing the survival of some pathogens.

Pros	Cons
Effective on pests and germination (total effectiveness on pathogens of commercial steam flaking is not known)	Poor shelf life of steam flaking
Known and understood process accepted by parts of the industry	Product unsuitable for some sectors
	Throughput and cost per tonne Requirement for a specialist plant to be built at port
Role: Steam flaking is unlikely to play a future role in grain importation unless it becomes part of a process whereby grain is securely delivered to the end-user site and managed up until, and through the process in a way that eliminates the risk of external contact.	

6 Treatment of plant-based stockfeed

Plant-based stockfeed, often an industrial by-product, is an alternative to bulk grain for importation. From a biosecurity perspective these by-products offer an advantage over bulk grain, as through the processing (e.g. crushing, heating or chemical treatment) devitalisation has already occurred. Consequently, the quarantine focus on imported plant-based stockfeed into Australia is more on the pathways of post-production and whether pest and pathogen contamination has occurred more broadly than impacting specific plant industries in Australia as outlined in Table 4. Examples listed by DA include Foot and Mouth Disease, Infectious Bursal Disease and Newcastle Disease. Pests of concern like Khapra Beetle are important considerations regardless of the product to be imported (bulk grain or plant-based stockfeed) as the presence of this pest in Australia can restrict export options based on country-specific phytosanitary tolerances.

Table 5 Processing summary of some plant-based stockfeed

Product	Description	Typical processing steps
Copra cake/meal[1]	A coconut by-product of either mechanical (cake) or solvent extract oil (meal) processes. But the terms cake and meal can be used interchangeably.	Common preparation is for dried copra to be ground, flaked and cooked until moisture is brought down to 3%. The oil is then extracted by either mechanical or solvent processes. A cake (mechanical) will have around 7% residual oil compared with meal (solvent extraction) generally less than 3.5% oil.
Distiller's dried grains with solubles[2]	Traditionally, a by-product of the brewing process, the more common source of DDGS now is as a by-product of dry-milled ethanol production	Screened Hammered milled – fine to medium grind meal Mixed with water to form mash Cooked Fermentation Separate liquid and solids Wet solids dried into DDGS
Soybean meal[3]	A by-product from the manufacturing of soybean oil.	Cleaned Cracked and dehulled Heat tempered + rolled into flakes Mixed with solvent to extract oil Desolventising toasting (moisture and heat) to product meal
Palm kernel expeller meal[4]	A by-product from the manufacturing of palm kernel oil that can be either mechanical or solvent extraction.	Range from traditional hand process to industrial. The latter utilises mechanical and/or solvent extraction techniques. Common to all processes is an initial boiling or steam-sterilising preparation.

[1] Heuzé et al (2015) Copra meal and coconut by-products. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. From www.feedipedia.org downloaded 20/8/2019
[2] Kalscheur et al (2008) Ethanol Coproducts for Ruminant Livestock Diets, SDSU Extension Fact Sheets. Paper 146.
[3] Johnson and Smith (2004) Soybean processing, Soybean InfoCenter, From www.soybean.org downloaded 25/6/2019
[4] Heuzé et al (2016) Palm kernel meal. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. From www.feedipedia.org downloaded 20/8/2019

7 Supply Chain Considerations

7.1 Approved Arrangement Site

Currently, imported bulk grain or plant-based stockfeed needs to be handled through an Approved Arrangement Site(s). DA (2019c) define such a site as:

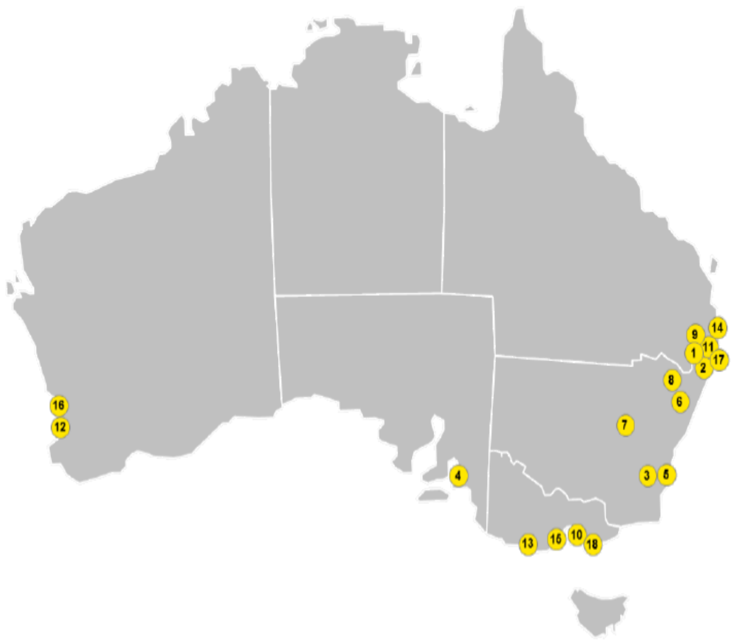
> *Approved arrangements, previously Quarantine Approved Premises and Compliance Agreements, are voluntary arrangements entered into with the Department of Agriculture. These arrangements allow operators to manage biosecurity risks and/or perform the documentary assessment of goods in accordance with departmental requirements, using their own sites, facilities, equipment and people, and without constant supervision by the department and with occasional compliance monitoring or auditing.*

The import permits of bulk wheat from Canada (Appendix 11) references two approved arrangement site classes – 2.7 (Grain storage) and 3.1 (Grain Processing). As of 2 July 2019, DA listed five class 2.7 sites and five 3.1 sites. The location of all but one Class 3.1 site (Queensland) were in NSW (see Appendix 11.6). Additionally, there are 95 Bulk stockfeed/fertiliser (Class 2.3) and 7 Seed cleaning (Class 4.4) approved arrangement sites. Most bulk stockfeed and fertiliser sites are located in either Vic or WA (50%) with the balance spread evenly across QLD, NSW, SA and TAS.

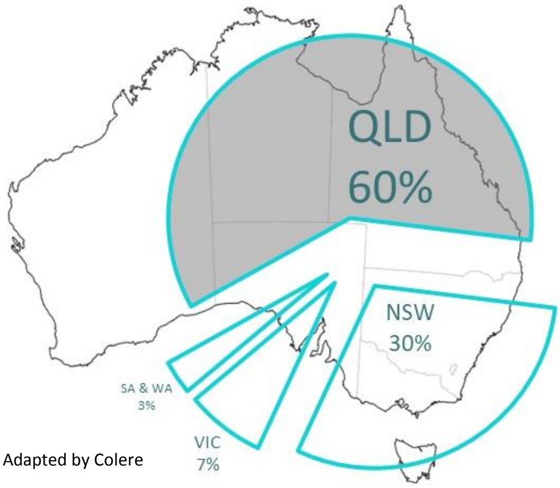
7.2 Proximity of animal industries and ports

A key dynamic that impacts the consideration of bulk grain or plant-based stockfeed importation is the relative distance between the animal industries using these products and port facilities where imports would first be received into Australia. There are examples from various sectors that clearly illustrate the concentration of these animal industries in QLD, NSW and VIC, with some increasing levels of production in SA.

In its 2017 State of the Industry Report, MLA stated that 18 of the top-100 Australian food and drink companies were red meat and processing companies (MLA, 2017b). Of these, 15 were located in VIC, NSW and QLD (the others were in SA (1) and WA (2)). The report noted *"an even larger percentage of smaller processing facilities located in regional communities that are not shown on the map"*. Source www.mla.com.au

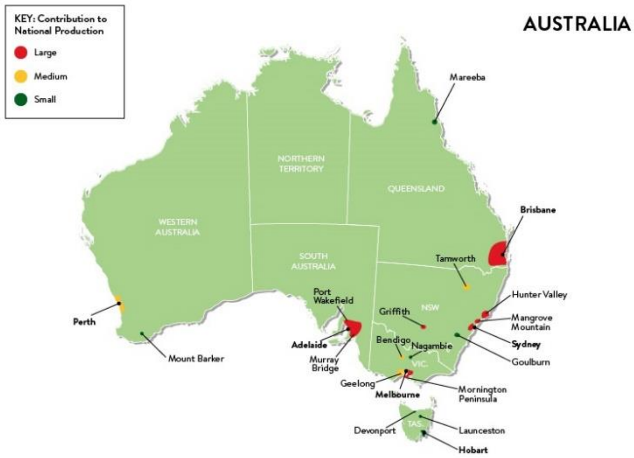


As reported by the Australian Lot Feeder's Association, there are approximately 400 accredited beef cattle feedlots in Australia. Qld is the largest state in terms of cattle numbers on feed, with approximately 60%, followed by NSW with 30%, Victoria with 7% and the remainder shared between SA and WA. Feedlots are generally located in areas which have a ready access to grain, cattle and water. At any one time, up to 5% of Australia's cattle population can be located in feedlots, with grain-fed beef representing 30-40% of total beef production in Australia.
Source www.feedlots.com.au

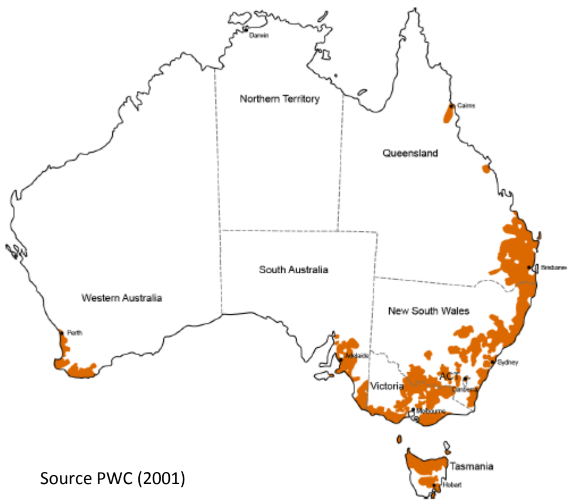


Adapted by Colere

Poultry processing plants have historically developed close to markets and labour sources, with many of the largest operations within 100km of a capital city. This ensures distribution and transport costs are kept down and labour and other services are available. However, over the past ten years there has been regional growth in locations around Griffith and Tamworth in NSW and regional SA.
Source www.chicken.org.au

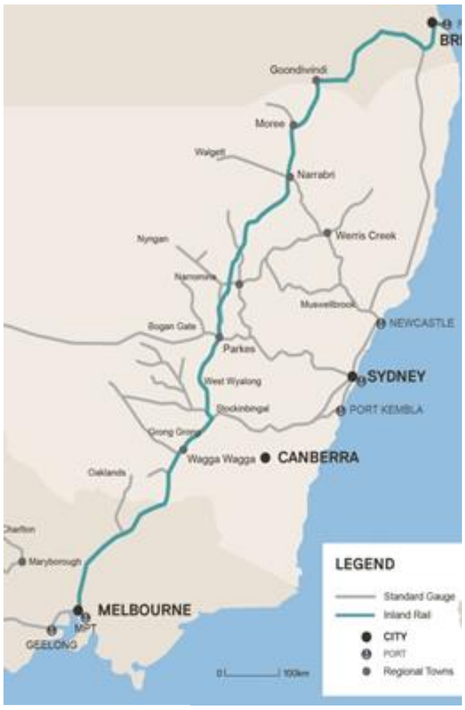


Dairy Australia reports that 81% of milk production is from VIC, NSW and QLD – with an estimated 22% from the Murray Region of Northern VIC and Southern NSW.
Source www.dairy.com.au



Source PWC (2001)

The ACCC reported in their 2017/18 bulk grain ports monitoring report that there were 26 active port terminals (ACCC, 2018). In QLD and NSW there were four each, five in both VIC and WA, and eight in SA. The standard flow path for these terminals is bulk export. Following the 2018 drought many ports on the eastern seaboard reversed that standard flow path to import grain from both interstate and internationally. Feedback from terminal operators was that while cargo discharge was efficient, but not comparable to bulk loading rates, their infrastructure was largely restrictive to managing a single flow path at any given time. Industry suggested at least 900,000 tonnes of grain was trans-shipped from ports in WA and SA to ports along the eastern seaboard. It is more difficult to ascertain how that grain then reached its destination – by road or rail. However, as noted in the AGIC (2019) Domestic Supply Chain Opportunities session, the completion of the inland rail infrastructure will connect Brisbane and Melbourne, passing through many of the areas where animal industries consuming grain are located.



Source AGIC (2019)

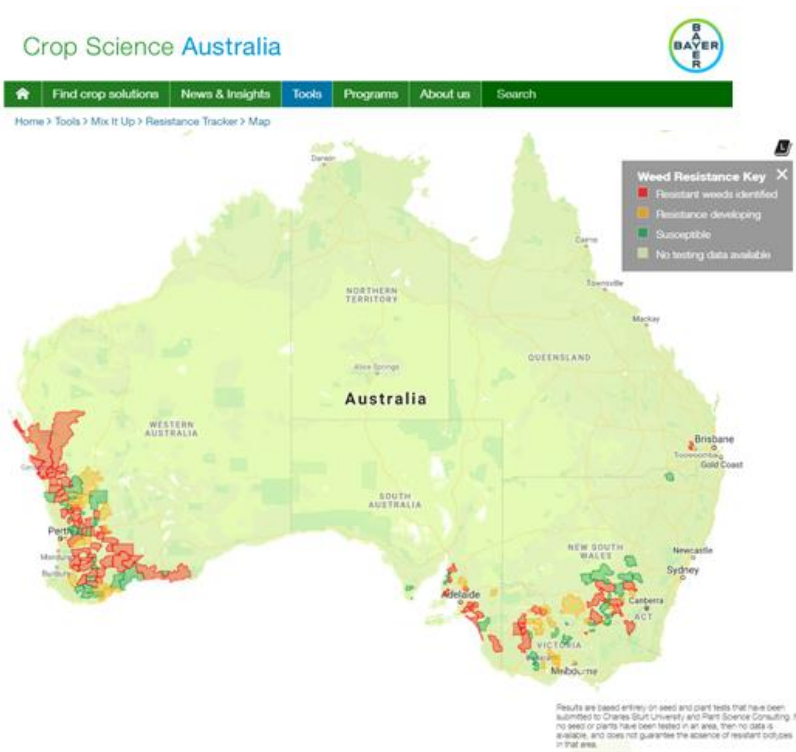
7.3 Interstate quarantine

Australian Interstate Quarantine states that "Pests, diseases and weeds can spread from one part of Australia to another through the movement of plants or plant products; animals or animal products; soil; agricultural machinery and recreational equipment" (AIQ, 2019). Such risks were noted by the SA government in relation to hay movements from WA (Whetstone, 2019)

> "Green snail is currently regulated under the South Australian Plant Quarantine Standard and currently consignments of hay may only enter the state from Western Australia if they meet stringent conditions to mitigate the risk posed", said Minister Whetstone.,
>
> "I cannot emphasise enough the importance of protecting South Australia from the significant impact a pest such as green snail could have on local horticultural and broad acre farming industries if the species were to become established here", said Minister Whetstone

A report by ABC Rural in late 2018 outlined the shortage of hay and included the following image of "prime movers laden with hay from WA passing through Port Augusta (ABC Rural, 2018). While the movement of hay was critical to the survival of those industries in need, the image does illustrate a potential biosecurity risk stemming from the movement of 'open' consignments.

To put in context the potential impact of open movements between states, the distribution of resistant wild radish to herbicide group I chemicals (e.g. 2,4-D Amine and MCPA) in 2017 is shown in (Bayer, 2019). It is important to note that the map is "based entirely on seed and plant tests that were submitted to Charles Sturt University and Plant Science Consulting. If no seed or plants have been tested in an area, then no data is available and there is no guarantee that resistant biotypes are absent in that area" (Bayer, 2019). Notwithstanding the representativeness of the data, the example of the resistant wild radish map highlights the potential for the resistance to spread between production areas.



8 Discussion

The DA's current approach to review each application on its merits is good from the point of view that it allows for novel and different approaches as long as they achieve the required outcomes of reducing biosecurity risks to a very low level, but not to zero. The DA's disclosure of the permit conditions for the 2019 importation of wheat from Canada was helpful to this review in providing a current reference point. That documentation builds on previously released information following previous periods of bulk grain importation (1994-1995; 2002-2003; and 2006-2007) noting that increasing volumes of certain plant-based stockfeed (e.g. soybean meal) have been imported for over 20 years. A potential negative aspect of the case-by-case application process is the time it takes to receive an answer. As illustrated, the number of applications peaks in the period prior to and following a low-level grain harvest (particularly from NSW and QLD). Leveraging the information available from prior decisions can be used to offset potential delays (e.g. a DA Import Risk Analysis for specific bulk grain/plant-based stockfeed and source combination). Introducing a new or untested bulk grain/plant-based stockfeed source option has the potential to further delay an application assessment timeframe. Releasing information on why applications were not approved (e.g. China and South Africa were referenced in DAWR (2006) but no final decision appears online) is worth consideration.

Managing Risk

The desktop review found that key to a successful importation of bulk-grain or plant-based stockfeed was to demonstrate both effective devitalisation and management of transit risks. Since most plant-based stockfeed undergo multiple stages of processing (e.g. crushing, chemical treatment, heating) assessment risks are largely focused on the likelihood of post-processing contamination. The significantly greater challenge with bulk grain is managing the transit movement from where devitalisation has occurred to its destination. In the case of the 2019 wheat imports, this meant moving the wheat in sealed containers from the approved 'grain storage' site where it was initially received after vessel discharge to the approved 'grain processing' site. An additional consideration for bulk grain to be used by animal industries is that both plant and animal biosecurity risks will be assessed in any permit application.

A matrix of potential sources of bulk grain or plant-based stockfeed, based on consistent exportable levels and biosecurity risks, showed a limited number of countries free of all current DA concerns. Overlaying that matrix with published DA Biosecurity Advice memorandums for grain-related imports from 2000 illustrated the flexible risk management approach taken by DA, whereby whole countries were not excluded, if defined lower-risk pathways could be identified (e.g. soybean from the Brazilian province of Paraná; maize from the northern states the US states; wheat from the Odessa region of Ukraine; and more recently 'spring' wheat imports from the Canadian provinces of Alberta, Manitoba and Saskatchewan). To create the matrix, published DA pests and pathogens of biosecurity risks were used. It was noted in assembling those risks that PHA also publishes an expansive list of high-priority pests of grains and pulses. For simplicity, in making assessments a single reference list of biosecurity risk pests and pathogens for bulk grain and plant-based stockfeed would be useful.

Processes and treatments

There is a strong case for adding more options to the approved treatment list of fumigants, with some formerly approved fumigants no longer being available due to their toxicity profile (e.g. ethylene oxide). The commercial development and registration of fumigants has mostly targeted products for the disinfestation of insects (and to a lesser extent eradication of pathogens). As such, most fumigants do not have the ability to damage plant material and devitalise grain (and other seeds), as this would reduce their market potential in many food areas. Only one of the fumigants investigated (EDN) has the (likely) ability to fit the needs of grain importation as a stand-alone treatment. However, EDN is not currently registered for use in grain nor its use listed as an approved treatment for grain importation. EDN also requires a treatment time of at least five days (at suitable temperatures and moisture levels), which is likely to create logistical complications at port. Support from the intensive livestock industries is likely still needed to make EDN an option in the future, as the commercial imperative for the manufacturer is not strong.

Table 6. Comparative effectiveness of devitalisation treatments

Treatment	Grain sterilisation	Weed seed sterilisation	Insect disinfestation	Pathogen sterilisation	Cost/t	Effect on quality
Methyl bromide	X	★★	★★★	★★	$1.00-2.00	X
Phosphine	X	X	★★	X	$0.30-2.00	X
Ethyl formate	X	X	★★★	X	$1.50-2.50	X
Carbonyl sulphide	X	X	★★★	X	?	X
Sulphuryl fluoride	X	X	★★	X	$2.50-4.00	X
Ethanedinitrile	★★★	★★	★★★	★★	$2.00-4.00	X
Hydrogen cyanide	X	X	★★★	X	$0.50-1.50	X
Ozone	X	X	★★	★★		X
Isoprene	X	X	★★	★★	?	?
Modified atmosphere	X	X	★★★	X	<$1.00	X
Heat	★★★	★★★	★★★	★★★	>$10.00	negative
Grainedge	★★★	★★★	★★★	★★★	?	?
Cold	X	X	★★★	X	<$1.00	X
Irradiation	★★★	★★★	★★★	★★★	?	X
Microwaves	★	★	★★★	★★	?	negative
Nonthermal plasma	★★	★★	★★	★★★	?	?

X = no effect; ★= minimal effect; ★★ = significant effect; ★★★ = excellent (99.99%); ★★ or ? = unclear status

The cost, shelf life and throughput issues of at-port milling and heat treatment were proven in the mid 1990s to not suit an industry needing sporadic imports of large volumes in short periods of time. The scale alone required to match the logistical needs of ship outturns using steam flaking, pelleting or direct heat treatments made for a capital expenditure that was difficult to justify even when grain price differentials were very high, due to the sporadic and short usage periods. Two factors have changed since this time: namely new technology in the form or infrared heat treatment (which may offer significantly improved throughput and lower costs), and the growth in the annual importation of processed soy. A model recommended for investigation hinges on a port-based “Grainedge” plant that is used to treat imported soy for use in the intensive industries but can alternatively then be utilised when whole feed grain is required.

Future risk

The focus of this report has been importation of bulk grain or plant-based stockfeed from sources other than Australia. As has been widely documented, large quantities of both bulk grain and plant-based stockfeed (e.g. hay) have been trans-shipped from WA and SA by sea and road transport during 2019, respectively. While it is not the intention of the report to highlight gaps (and cause increased scrutiny and possible heightened bureaucratic hurdles), these trans-shipments ‘within’ an Australian context do have a level of biosecurity risk. The example provided related to the unintentional spread of herbicide-tolerant wild radish. Other formally recognised biosecurity risks related to lupin anthracnose (NSWDPI, 2019) and Russian wheat aphid (DPIRD, 2019). The Russian wheat aphid restrictions expands the scope of pests and pathogens to movement of machinery and equipment from one location to another (AV, 2017). A final comment on trans-shipment is the direction in which they might occur. A state like WA may have a greater number of biosecurity risks to manage given its natural isolation (e.g. deserts and prevailing wind direction) relative to NSW, which has common land boundaries with QLD, VIC and SA.

9 Conclusions and recommendations

While the title of this report is a review of grain devitalisation (for importation), the report demonstrates that the successful importation of bulk grain and plant-based stockfeed for the intensive animal industries is a process of risk management. Management of the complicated intersection of best-practice disinfestation, eradication and sterilisation of grain pests, pathogens and grain and weed seeds, respectively; and acceptable risk, in terms of protecting our own plant and animal production industries. As such, both the importing and production industries should expect to see this intersection move over time, responding to new risks, new processes and technologies, and the ability to measure and manage both.

Predictions of increased drought prevalence and intensity due to climate change suggest that drought events (and their resulting influence on grain pricing) are likely to increase in frequency. Likewise, with increasing international demand for meat protein, local production of beef, pork and chicken meat and eggs will continue to grow and demand for feed grain will follow this trend. This means that there are likely to be more frequent situations where the differential between the local cost per unit of digestible energy (in grain, fodder or feed stuff form) justifies the cost of importation (with all the additional costs). This acknowledges that the threshold for importing grain for animal industries, due to the inability to substitute or scale activities, will always be higher than for specialist grain for processing (production of gluten, starch or other food ingredient needs).

Where the differential between the local cost per unit of digestible energy (in grain, fodder or feed stuff form) justifies the cost of importation (with all the additional costs), the pathways for future importation need to be easier and faster to deploy. To match the demands of the intensive animal industries in these periods the much-discussed option is for a facility that can be utilised for the (within quarantine) treatment of whole grain on import at a peak capacity of 8-10,000t per day. The commercial case for an operation of this type (to be utilised sporadically for a few months each decade) has previously never made sense, and the technologies and processes being envisaged reduced the logistical likelihood even further. The new options discussed in the body of this report suggest a need for this opportunity to be revisited, especially if the same facility could be utilised for other more regular activities (i.e. importation of whole soy), or if the combined importation and treatment cost increased the number and frequency of periods where the differential made importation viable.

The review team have also surmised that there may be a potential for an individual operator to commission a steam flaking plant that can utilise a combination of carefully selected grain sources, sealed shipping containers and improved plant hygiene standards to import whole grain. Any new investor in a feedlot would be well served by considering a design that incorporates the ability to upgrade to this level. This should be explored by MLA and key stakeholders.

Recommendations

The review team have developed a set of recommendations that have the potential to improve clarity, transparency and increase the opportunities for the intensive animal industries to respond to supply and price pressures in the future:

1. The number and complexity of grain import application assessments to be undertaken by the Department of Agriculture is always likely to cause capacity difficulties (due to the sporadic and intensity of need). **A process whereby permit applications are regularly submitted by MLA on a theoretical basis, would provide a level of departmental and industry understanding and experience that would improve the quality of applications (by industry) and timeliness of assessment (by the department) in the event of the next drought event.**

2. The sporadic need for the lodging of grain import applications results in little history and experience by those applying. **To facilitate a faster learning curve, the Department of Agriculture is encouraged to publish both approved and unapproved permit applications (together with their feedback) as soon as decisions are made.**

3. The different lists of pests, pathogen and weeds that pose a risk to Australian agriculture from different sources (DA, PHA and CABI), appears to be causing confusion or conflict. **The DA is recommended to publish a single list of pests and pathogens of concern in relation to bulk grain and plant-based stockfeed to help industry assess the likelihood of an application achieving DA requirements thus improving processing efficiency.**

4. Ethanedinitrile (EDN) has potential use in the treatment of maize for importation, however it is not currently registered or available for that role. Draslovka Services (the commercial agent for EDN) are open to commercialising FUMIGAS for devitalisation of grain in Australia. However, they recognise the infrequent nature of this potential use and are therefore requesting support in their registration application. **MLA (together with ALFA, Chicken Meat Federation, Australian Egg Corporation and Australian Pork Limited) should consider supporting the registration of EDN. This would include:**
    a. Commissioning a brief business case to be developed in partnership with Draslovka, the bulk handlers, importers and users to identify the technical details and gather additional data to support approval.
    b. Work with Draslovka to apply for a minor-use permit supported by the industries.
    c. Support an application to Biosecurity Australia and discussions with the federal Department of Agriculture for inclusion on the “approved treatments” list.

5. The infrared irradiation-based heat treatment being commercialised by IRtech has the potential to address all specific importation requirements around devitalisation, disinfestation and sterilisation while also offering a potential value add-to the grain in the form of improved digestibility. For this technology to progress in the grain importation space, there are several prescribed trials required to confirm its efficacy and allow it to be added to the “approved treatments” list.
    a. **MLA (together with ALFA, Chicken Meat Federation, Australian Egg Corporation and Australian Pork Limited) should consider supporting IRtech in an ARC-Linkage (or similar proposal) that would fund a research provider to undertake this work.**
    b. **Chicken Meat Federation, Australian Egg Corporation and Australian Pork Limited should consider partnering with IRtech to evaluate the potential for importation of whole soy (utilising this process) and the comparative advantages in cost and nutrition in chicken and pig rations.**

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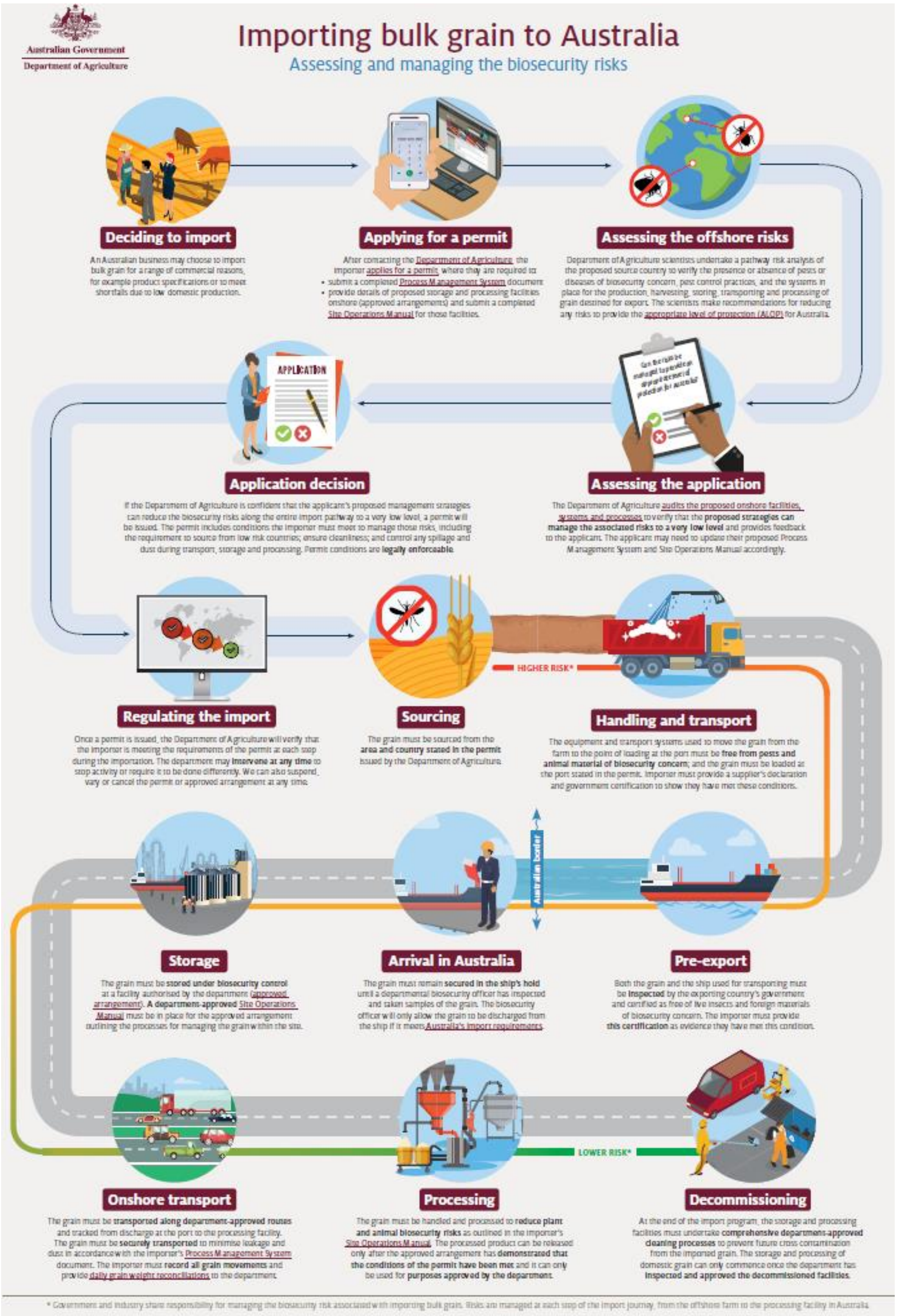
11 Appendix

11.1 Department of Agriculture – Importing grain into Australia (August 2019)



11.2 Conditions for importing bulk wheat from Canada

Downloaded 6 August 2018 from http://www.agriculture.gov.au/import/goods/plant-products/importing-bulk-grain/canadian-bulk-wheat-import-conditions

Please note: The department handles personal information in accordance with its privacy policy and obligations. The below table includes details of the import conditions imposed under the permits we issue for bulk wheat from Canada

Conditions we have imposed

This table sets out the conditions that are imposed by the permits, how each condition addresses specific biosecurity risks and the information that must be supplied to demonstrate and provide assurance that the condition is met.

The conditions were assessed as reducing the level of biosecurity risk to an acceptable level of protection, the ALOP (a high level of protection aimed at reducing biosecurity risks to a very low level, but not to zero).

	Permit condition	How permit condition addresses the risk	Assurance provided
1	This permit only allows for the importation of a single consignment of wheat from Canada on a specified vessel for discharge in **Port Kembla.**	Issuing permits for single vessels enables an assessment of the risks associated with the vessel including from previous cargoes. Nominating Port of Discharge reduces the risk of inadvertent discharge of grain at ports without a suitable AA storage facility.	Cargo history provided by shipping line. Ports of discharge are stipulated in the approved Process Management System (PMS). Issuing permits for single consignments (vessels) allows the department to make appropriate adjustments to any future permits.
2	The importer must provide evidence that the consignment of wheat was produced in Canada and that Canada is free of *Alternaria triticina, Magnaporthe oryzae Triticum* pathotype*, Puccinia graminis* f. sp. *tritici* strain Ug 99and *Tilletia indica*. To demonstrate compliance with this requirement the importer must present the following on a **Phytosanitary certificate**: i. The country of origin as Canada ii. The additional declaration: "*Alternaria triticina*, *Magnaporthe oryzae Triticum*pathotype, *Puc*	Pest free areas are areas where a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained by a National Plant Protection Authority (ISPM 4). In this instance, these pests are considered to be absent from Canada.	The Canadian Food Inspection Authority (CFIA) regulates phytosanitary standards in accordance with the *Plant Protection Act*. This includes the issuing of phytosanitary certification. A phytosanitary certificate is a government to government document dealing with plant health issued in accordance with ISPM 7 and 12 provided from CFIA. The department's plant biosecurity risk assessment determined that these pests of concern were not present in Canada. The CFIA has confirmed this status during a visit by a

	Permit condition	How permit condition addresses the risk	Assurance provided
	cinia graminis f. sp. *tritici* strain Ug 99and *Tilletia indica* are not present in Canada”		department delegation to Canada in February 2019. CFIA will inform the department if this status changes in Canada.
3	The importer must provide evidence that the consignment of wheat was produced in Alberta, Manitoba and/or Saskatchewan and that these provinces have been surveyed and found free of *Tilletia controversa*. To demonstrate compliance with this requirement the importer must present the following on a **Phytosanitary certificate**: The additional declaration: “The consignment was produced in <insert name of province(s)> that has/have been surveyed and found free of Tilletia controversa.”	Pest free areas are areas where a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained by a National Plant Protection Authority (ISPM 4). In this instance, this pest is considered to be present in Canada but absent from Alberta, Manitoba and Saskatchewan.	The CFIA regulates phytosanitary standards in accordance with the *Plant Protection Act*. This includes the issuing of phytosanitary certification. A phytosanitary certificate is a government to government document dealing with plant health issued in accordance with ISPM 7 and 12 provided from CFIA. The department’s plant biosecurity risk assessment determined that this pest is present in Canada but absent from Alberta, Manitoba and Saskatchewan. CFIA has confirmed this status during a visit by a department delegation to Canada in February 2019. CFIA will inform the department if this status changes in Canada.
4	The importer must provide evidence that the consignment of wheat has been certified by the Canadian Grain Commission (CGC) as spring wheat. To demonstrate compliance with this requirement the importer must present the following on a **CGC certificate**: One of the following wheat grades: Canada Western Red Spring (CWRS), Canada Western Hard White Spring (CWHWS), Canada Western Soft White Spring (CWSWS), Canada Prairie Spring White (CPSW), Canada Prairie Spring Red (CPSR).	This condition restricts the importation to spring wheats. Spring wheats are not considered hosts of Cephalosporium stripe, a quarantine pest to Australia.	The CGC regulates grain quality standards in accordance with the *Canada Grain Act*. This includes providing grain certification based on the Official Grain Grading Guide. The department’s plant biosecurity risk assessment determined that *Cephalosporium* stripe is present in Canada primarily on winter wheat. Spring wheat has been assessed as a lower risk for *Cephalosporium* stripe due to biological, and environmental factors during the growing season.
5	The importer must provide evidence that the consignment of	This condition restricts the importation to wheat produced	The source provider of the grain in Canada is licenced by the CGC.

	Permit condition	How permit condition addresses the risk	Assurance provided
	wheat was grown, harvested, stored and transported in a way that manages risks associated with contamination of grain exports with material of animal origin. To demonstrate compliance with this requirement, the importer must present the following on a **Supplier's declaration**: i. The grain has been sourced from broad-acre cultivation systems using mechanical production methods; and ii. The grain is sourced from farms that have not used off-farm or commercial organic fertilisers containing material of animal origin; and iii. The grain, if stored in grain bags (on the ground under covers) on farm or bunkers at grain terminals, was a temporary, short-term measure pending transfer to permanent storage off ground; and iv. A statement that the grain elevators and transport units (e.g. trucks and rail cars) were inspected for cleanliness and found free of residues of all previous cargoes and extraneous contaminants including animal material prior to being filled with grain intended for export to Australia.	in broad-acre farming systems that do not use off-farm or commercial organic fertilisers, do not store grain in temporary storages, and are transported within units or elevators that are free of animal material. These restrictions reduce the likelihood of exposure to animal material including excreta that may harbour animal pathogens.	The CGC regulates grain quality standards in accordance with the *Canada Grain Act* which includes licencing grain dealers, primary, terminal and process elevator operators. A third-party certifier will verify that the rail wagons are clean and free from previous residues. This third-party certifier must be accredited service provider of the CGC. The source provider also has ISO 22000:2005 (Food safety management system) accreditation for all of their primary elevators in the Canadian Prairies. The SOPs and HACCP prerequisite programs that underpin this accreditation manage the risk of contamination at the point of grain receipt, during storage and dispatch. The department's biosecurity risk assessment determined that these types of production, storage and transport methods would lower the risks of exposure to animal pathogens of concern to Australia to an acceptable level.
6	**Pre-export** The importer must provide evidence that the export flow path (i.e. equipment and conveyance systems used to handle grain) at the terminal elevator was inspected prior to loading and found free from residues of all previous cargoes	This condition limits risk of contamination at the terminal elevator from residues (grain, stockfeed, insect pests, residues, soil, animal material or other contaminants).	The export grain terminal in Canada is licenced by the CGC. The CGC regulates grain quality standards in accordance with the *Canada Grain Act* which includes licencing grain dealers, primary, terminal and process elevator operators. CGC officers are present at the Port and oversee the inspections.

	Permit condition	How permit condition addresses the risk	Assurance provided
	and other extraneous contaminants. To demonstrate compliance with this requirement the importer must present the following on a Supplier's declaration: "The export flow path at the terminal elevator was inspected prior to loading and found to be free of residues of all previous cargoes and other extraneous contaminants".		The export grain terminal is CGC HACCP certified, which means that the company has a quality management system that meets the grain safety requirements of the national Food Safety and Identity Quality Management System Preserved Standard. The terminal have procedures to manage cleanliness of the export flow path. The procedures are applied before and after loading a vessel. The department's biosecurity risk assessments determined that controls for cleanliness at the terminal elevator would lower the risks of exposure to plant pests and diseases and animal pathogens of concern to Australia to an acceptable level.
7	The importer must provide evidence that the empty holds of the shipping vessel were inspected by the CFIA and found free of live insects and extraneous materials that pose a phytosanitary or sanitary risk. To demonstrate compliance with this requirement the importer must present the following on a CFIA ship inspection approval for loading certificate Evidence that each hold carrying grain was approved by the CFIA for loading.	This condition limits risk of contamination within the ship's hold from residues of previous cargoes (grain, stockfeed, insect pests, residues, soil, animal material or other contaminants).	The CFIA regulates phytosanitary standards in accordance with the *Plant Protection Act*. This includes verification of the phytosanitary status of ships' holds prior to loading. The CFIA inspection of ship's holds is performed in accordance with directive PI-008: Inspecting Ships that Carry Grain and Grain Products for Export. This directive allows for a tolerance of less than 3 insects excluding khapra beetle. The department imposes a nil tolerance for all insects in ships exporting grain to Australia. The department's biosecurity risk assessments determined that ships' hold cleanliness would lower the risks of exposure to plant pests and diseases and animal pathogens of concern to Australia to an acceptable level.
8	The importer must provide evidence that the consignment of wheat was sampled and inspected by the National Plant	This condition limits the likelihood that bulk grain consignments from Canada are contaminated with stored grain	The CFIA regulates phytosanitary standards in accordance with the *Plant Protection Act*. This

	Permit condition	How permit condition addresses the risk	Assurance provided
	Protection Organisation (NPPO) and found free of stored grain pests that are quarantine pests for Australia. To demonstrate compliance with this requirement the importer must present the following on a Phytosanitary certificate The additional declaration: "Representative samples from the consignment for export to Australia have been drawn and visually inspected in accordance with official procedures and determined to be free from all species of Trogoderma and free from infestation by stored product pests of quarantine concern for Australia".	pests of quarantine concern for Australia.	includes the issuing of phytosanitary certification. A phytosanitary certificate is a government to government document dealing with plant health issued in accordance with ISPM 7 and 12 provided from CFIA. The department's plant biosecurity risk assessment determined that there are several species of stored grain pests that could be present in bulk grain sourced from Canada, and that phytosanitary measures would be required to reduce the potential risks to an acceptable level.
9	The importer must provide evidence that the consignment of wheat was officially sampled and graded by the CGC during the course of loading and found to contain: 1. No vertebrate animal material (excluding rodent excreta). 2. No more than 0.01% of rodent excreta. 3. No more than 1% of other foreign material (other foreign material means Total Foreign Material, as defined in the Canadian grading table for wheat, excluding vertebrate animal material). To demonstrate compliance with this requirement the importer must present the following on a CGC Certificate: "The grain described in this certificate was sampled and graded during the course of loading and found to contain no vertebrate animal material (excluding rodent excreta), no	This condition limits the likelihood that bulk grain consignments from Canada are contaminated with animal material that may harbour animal pathogens or other foreign material that may harbour weed seed, soil or other residues of biosecurity concern.	The CGC regulates grain quality standards in accordance with the *Canada Grain Act*. This includes providing grain certification based on the Official Grain Grading Guide. The department's biosecurity risk assessment determined that freedom from foreign material would lower the risks of exposure to plant pests and diseases and animal pathogens of concern to Australia to an acceptable level.

	Permit condition	How permit condition addresses the risk	Assurance provided
	more than 0.01% rodent excreta and no more than 1% of other foreign material.”		
10	The consignment of wheat must be loaded for export at the Port of Vancouver. To demonstrate compliance with this requirement the importer must present the following on a Bill of Lading: The port of loading as Vancouver.	This condition limits the likelihood of exposure to *Tilletia controversa,* a quarantine pest to Australia.	The department’s plant biosecurity risk assessment determined that shipping wheat from the Port of Vancouver would lower the risks of exposure to *Tilletia controversa,* a quarantine pest to Australia. This disease is present in Canada but has a restricted distribution in Southern British Colombia and southern Ontario. Import and domestic movement restrictions exist to prevent spread into non-regulated areas of Canada, including preventing grain from these regions from being exported from the Port of Vancouver.
11	**On arrival in Australia** Prior to discharge at the first port, the importer must present the consignment of wheat for inspection by a biosecurity officer. The wheat must remain secured in the ship’s hold until completion of inspection and provision of biosecurity directions by a biosecurity officer.	This condition is in place to verify that the consignment is free from visible pests and diseases of quarantine concern to Australia.	Instructional material to support this activity is available. An information session was held in April 2019 outlining the roles and responsibilities for officers inspecting bulk grain.
12	Following discharge from the ship, the importer must move the wheat directly to the Approved Arrangement site(s) for storage.	This condition is in place to manage the biosecurity risks associated with the storage and handling of bulk grain following discharge from the ship at Port Kembla.	Approved arrangements are voluntary arrangements that operators enter into with the department. These arrangements allow operators to manage biosecurity risks of goods in accordance with departmental requirements, using their own premises, facilities, equipment and people, and without constant supervision by the department and with occasional compliance monitoring or auditing. AA 2.7 sites are used for the storage and handling of bulk

	Permit condition	How permit condition addresses the risk	Assurance provided
			imported grain commodities such as maize, wheat, barley and sorghum. Conditions, including an approved site location and a department-approved site operations manual, must be met before approval by the AA delegate. The location of the site has been approved. The Site Operations Manual that outlines operations for the management of biosecurity risk has been approved. The site has been audited and approved. The delegate for the AA has approved the site.
13	The importer must ensure that the discharge and movement of wheat is performed in accordance with the requirements of the PMS document for the Discharge, Storage and Transport of imported grain to the processing facility from the port of discharge. Note: this includes, but is not limited to, ensuring that: • all precautions are taken to minimise spillage during discharge and movement. • spillages during discharge operations are cleaned as they occur. • all equipment and port areas are cleaned on completion of discharge operations. • spillage and material collected during discharge and movement are disposed of as biosecurity waste or re-introduced into the pathway for processing.	This condition is in place to manage the biosecurity risks associated with discharge of grain from the ship's hold and transport of that grain to the AA 2.7.	The PMS is used to describe the processes that an importer proposes to use to manage the importation, movement and processing of imported bulk grain. It must document the end-to-end import pathway, including the discharge of grain from the ship's hold and transport of that grain to AA 2.7 site and detail the parties responsible for actions/activities. It must be audited and approved prior to permit issuance. The PMS has been approved. The pathway described in the PMS has been audited and approved.

	Permit condition	How permit condition addresses the risk	Assurance provided
	• conveyances used to transport grain comply with the department's Conveyance Standards for Imported Bulk Grain. • loaded conveyances are secured and free of grain and grain residues prior to leaving the wharf. • grain is transported directly to the AA site via a department-approved transportation route.		
14	The wheat must be processed at the Class 3.1 Approved Arrangement site(s)	This condition is in place to manage the biosecurity risks associated with processing bulk grain.	Approved arrangements are voluntary arrangements that operators enter into with the department. These arrangements allow operators to manage biosecurity risks of goods in accordance with departmental requirements, using their own premises, facilities, equipment and people, and without constant supervision by the department and with occasional compliance monitoring or auditing. AA 3.1 sites are used for the processing of bulk imported grain commodities such as maize, wheat, barley and sorghum. Conditions, including an approved site location and a department-approved site operations manual, must be met before approval by the AA delegate. The location of the site has been approved by the department. The Site Operations Manual that outlines operations for the management of biosecurity risk has been approved. The site has been audited and approved.

	Permit condition	How permit condition addresses the risk	Assurance provided
			The delegate for AA has approved the site.
15	The importer must ensure that the movement of wheat between Approved Arrangement sites listed on this import permit is performed in accordance with the PMS document for the Discharge, Storage and Transport of imported grain to the processing facility from the port of discharge. Note: The biosecurity industry participant at the sending and receiving Approved Arrangement sites must handle imported wheat in accordance with the Class 2.7 and 3.1 Approved Arrangement conditions.	This condition is in place to manage the biosecurity risks associated movement of grain between AA sites.	The PMS is used to describe the processes that an importer proposes to use to manage the importation, movement and processing of imported bulk grain. It must document the end-to-end import pathway, including the movement of grain between AA sites and detail the parties responsible for actions/activities. It must been audited and approved prior to permit issuance. The PMS has been approved by the department. The pathway described in the PMS has been audited and approved.
16	The wheat must be processed by a method approved by the department. Processing notes: Processed imported wheat is released from biosecurity control when the biosecurity industry participant creates a grain processing record indicating that the conditions of the import permit and the approved arrangement have been met. Processed products released from biosecurity control must only be used for purposes approved by the department.	This condition specifies the processing requirements and end-use limitations for the mitigation of animal pathogen risks associated with bulk grain. These processing conditions are also sufficient to mitigate any plant pest or disease risks.	The PMS is used to describe the processes that an importer proposes to use to manage the importation, movement and processing of imported bulk grain. It must document end-to-end import pathway, including the processing steps used mitigate potential biosecurity risks. It must been audited and approved prior to permit issuance. The department’s biosecurity risk assessment determined that grain must be processed at an AA facility to render the wheat non-viable, and to address any residual risk posed by seed-borne, debris-borne or soil-borne *Cephalosporium gramineum* and contaminant seeds. Only processed goods may be released from biosecurity control. The PMS has been approved by the department.

	Permit condition	How permit condition addresses the risk	Assurance provided
			The pathway described in the PMS has been audited and approved.

11.3 Department of Agriculture Biosecurity Advice memorandums for grain-related imports

Year	Department of Agriculture reference document	Source	Grain type	Highlighted conditions
2000	IMPORT RISK ANALYSIS FOR THE IMPORTATION OF BULK MAIZE (*Zea mays* L.) FROM THE UNITED STATES OF AMERICA REVISED DRAFT	USA	Maize	
2002	PLANT BIOSECURITY POLICY MEMORANDUM 2002/44 IMPORT RISK ANALYSIS – BULK MAIZE (*Zea mays* L.) FROM THE UNITED STATES OF AMERICA	US	Maize	From selected states and clearly defined requirements in Section 7 of IRA
2003	PLANT BIOSECURITY POLICY MEMORANDUM 2003/01 IMPORT RISK ANALYSIS - BULK MAIZE (*Zea mays* L.) FROM THE UNITED STATES OF AMERICA	US	Maize	The conditions include heat sterilisation, prior to exports, to ensure that all seed present (i.e. maize, other crop seed admixtures and weed seeds) are rendered non-viable and all plant pathogens and arthropod pests present in grain are killed. Such treatment denatures protein and as a result would mitigate against any potential quarantine issues associated with genetically modified material.
2006	BIOSECURITY AUSTRALIA POLICY MEMORANDUM 2006/36 IMPORTATION OF GRAIN FOR PROCESSING AT AQIS APPROVED FACILITIES IN METROPOLITAN AREAS	Canada UK	Wheat	From selected sites
		US	Maize and sorghum	From selected states
2007	BIOSECURITY AUSTRALIA POLICY MEMORANDUM 2007/01 ASSESSMENT OF APPLICATIONS TO IMPORT GRAIN	Argentina	Maize Sorghum Soybean Sunflower Wheat	Processing in metropolitan areas.
		Paraguay	Soybean	Processing in metropolitan areas.
	BIOSECURITY AUSTRALIA POLICY MEMORANDUM 2007/03 ASSESSMENT OF APPLICATION TO IMPORT RYE	Canada	Rye	Selected areas for metropolitan processing
	BIOSECURITY AUSTRALIA POLICY MEMORANDUM 2007/10 ASSESSMENT OF APPLICATIONS TO IMPORT SOYBEAN	Brazil	Soybean	Specific province of Paraná
		US	Soybean	States of North Dakota and South Dakota, Kansas and Nebraska
2008	BIOSECURITY AUSTRALIA ADVICE 2008/03 ASSESSMENT OF APPLICATIONS TO IMPORT BULK GRAIN FROM THE UKRAINE	Ukraine	Maize Sorghum Sunflower Wheat (Odessa region only)	Processing at approved facilities in metropolitan areas

11.4 Matrix of potential sources of grain and meal and biosecurity status

	5-year export average from 2014/15 (1000 MT)																															
	Grains							*Meals*					Exotic pests				Wheat						Sorghum				Corn					
Source	Barley	Corn	Oats	Sorghum	Soybean	Sunflower	Wheat	*Copra*	*Palm kernels*	*Rapeseed*	*Soybean*	*Sunflower*	Foot and Mouth Disease	Infectious Bursal Disease	Newcastle Disease	Khapra Beetle	Cephalosporium stripe	Dwarf bunt	Karnal bunt	Leaf blight	Ug99	Wheat blast	Sorghum ergot	Long smut	Downy mildew	Loose kernel smut	Banded leaf and sheath spot	Brown stripe downy mildew	Late Wilt	Philippines downy mildew	Spontaneum downy mildew	Sugarcane downy mildew
Argentina	2,557	24,820		428	7,677	113	10,877				*28,716*	*716*	FMD zone(s)	RPoKtbP				P		P		P			P							
Bolivia											*1,650*		FMD zone(s)	RPoKtbP	R.D.							P			P							
Brazil		28,036			64,311						*15,125*		FMD zone(s)	RPoKtbP					R.D.			P			P							
Cambodia		340														P									P							
Canada	1,696	1,524	1,648		4,583		22,578			*4,321*	*319*		FMD FREE	RPoKtbP	R.D.		P	R.D.														
China					126	370					*1,353*			P	R.D.					P				P	P	P	P			P		P
European Union	7,329	2,484	184		186	486	28,989			*456*	*349*	*319*	FMD FREE	RPoKtbP	R.D.	R.D.	R.D.	R.D.		R.D.				R.D.		R.D.	R.D.		R.D.			
Austria													FMD FREE				P	P														
Belgium													FMD FREE																			
Bulgaria													FMD FREE	Last reported 1998	P			P														
Croatia													FMD FREE	RPoKtbP				P														
France													FMD FREE	RPoKtbP						P												
Germany													FMD FREE	RPoKtbP	P		P	R.D.								P	P					
Greece													FMD FREE					P		P												
Hungary													FMD FREE	RPoKtbP	R.D.			R.D.								P			P			
Italy													FMD FREE				P	P		P				P								
Netherlands													FMD FREE	RPoKtbP			P															
Poland													FMD FREE	Last reported 2003			P	P								P						
Romania													FMD FREE		P			P														
Spain													FMD FREE			P																
Sweden													FMD FREE	Last reported 2000	P		P	P														
United Kingdom													FMD FREE	RPoKtbP	R.D.		P															
India	104	774			221		1,224			*701*	*1,526*			P	R.D.	P	P		P	P			P	P	P	P		P	P	P		P
Indonesia		160						*267*	*4,345*				FMD FREE	RPoKtbP	P										P		P			P		R.D.
Kazakhstan	1,023					223	7,608						FMD zone(s)			P		P														
Laos		270														P											P					
Malaysia									*2,378*				FMD zone(s)	P	P																	
Mexico		1,128					1,098						FMD FREE	RPoKtbP	R.D.		P		R.D.	P					P	P						
Moldova		324				462							FMD zone(s)		Last reported 1993			P														
Myanmur (Burma)		1,320												RPoKtbP	P	P							P					P				
Nigeria		160												RPoKtbP	P	P				P				P	P							P
Norway											*184*		FMD FREE																			
Paraguay		2,246			5,546						*2,541*		FMD FREE*		Last reported 1997							P										
Philippines								*329*					FMD FREE		P										P					P	P	P
Russia	4,645	4,407			577	157	30,714			*207*	*420*	*1,279*		RPoKtbP	P			R.D.		P												
Serbia		2,091				120							FMD FREE	RPoKtbP	P																	
South Africa		1,378													P		P		R.D.						P							
Tanzania		200												RPoKtbP	P	P					P			P	P							
Thailand		360												RPoKtbP									P		P		P	P		P	P	P
Turkey							5,672						FMD zone(s)	Last reported 1996	P	P		R.D.		P				P								
Uganda		190												RPoKtbP	P	P					P			P	P	P						
Ukraine	4,462	21,025		136	2,580		16,156			*126*	*426*	*4,251*	FMD FREE	Last reported 2002				R.D.														
UAE										*155*				RPoKtbP		P																
USA	172	53,835		6,181	53,261		24,685				*11,713*		FMD FREE	RPoKtbP			P	R.D.	R.D.						P							
Uruguay					2,492									RPoKtbP											P							
Vietnam		500												RPoKtbP	P	P							P		P		P					P
Zambia		600												RPoKtbP	P	P									P							
													WOAH	CABI	CABI	DAWR	CABI	CABI	CABI	CABI	CABI	CABI	CABI	CABI	CABI	CABI	PHA	CABI	CABI	CABI	CABI	CABI
													FMD free where vaccination is not practised and FMD free* where vaccinatino is practised	RPoKtbP = Reported present or known to be present	Blanks include "disease not reported" status	Any trade of a good that comes from a known Khapra beetle country must be associated with a phytosanitary certificate	Only reported present or restricted distributions											Only reported present or restricted distributions				
													FMD zone(s) where vaccination is/is not practised	Australia has RPoKtbP distribution																		

11.5 Selected DAWR approved treatments

13.3 Treatments – stored product pests

Table 9 lists and describes the department approved treatments for stored product pests.

Table 9 Department approved treatments for stored product pests

Autoclave	Ethylene oxide fumigation	Methyl bromide fumigation	Gamma irradiation	Heat	Cold	Physical removal and destruction	Other
n/a	n/a	**Khapra beetle** 80g/m^3 for 48 hrs at ≥21˚C at NAP with an end point concentration of 20g/m^3.	n/a	n/a	n/a	n/a	Refer to OSS for advice on treatment options.
n/a	n/a	**Other stored product pests** 32g/m^3 for 24 hrs at ≥21˚C at NAP; **OR** 40g/m^3 for 2 hrs at ≥21˚C under 660mm vacuum. Refer to OSS for treatment options to treat insects in seeds for sowing.	n/a	n/a	-18 ˚C for min 7 days.	n/a	**Phosphine fumigation treatment** 1.0-1.5g/m^3 for 10 days at 15˚C-25˚C; **OR** 1.0-1.5g/m^3 for 7 days at ≥25˚C.

16.4 Treatments

Table 11 lists and describes the department approved treatments for plant pathogens. Note: Verification by a biosecurity plant pathologist is required to determine suitable treatment.

Table 11 Department approved treatments for plant pathogens

Autoclave	Ethylene oxide fumigation	Methyl bromide fumigation	Gamma irradiation	Heat	Cold	Physical removal
121˚C 105kPa (15psi) for 15 min; **OR** 134˚C 205kPa (31psi) for 4 min.	Under vacuum of 50kPa at 1200g/m^3 for 5 hrs at 50˚C; **OR** 1500g/m^3 for 24 hrs at 21˚C.	n/a	For items of plant origin 25kGray (2.5Mrad).	Core temperature 85˚C $\geq$8 hrs.	n/a	n/a

19.3 Treatments for biosecurity risks found in seeds

Table 16 lists and describes the department approved treatments for seeds as per the following key:

1) Treatments for seed contaminated with soil are marked '1' in the table header below.
2) Treatments for seed with insect infestation/s are marked '2' in the table header below.
3) Treatments for seed contaminated with plant pathogens are marked '3' in the table header below.
4) Treatments for seed contaminated with other viable seeds are marked '4' in the table header below.

Note: Some treatments for the contaminant, may affect the viability of the seed.

Table 16 Department approved treatments for seeds

[1,3] Autoclave	[2] Ethylene oxide fumigation	Methyl bromide fumigation	[1,2,3] Gamma irradiation	[1,3] Heat	Cold	[4] Physical removal and destruction
121˚C 105kPa (15psi) for 15 min; **OR** 134˚C 205kPa (31psi) for 4 min.	Under vacuum of 50kPa at 1200g/m^3 for 5 hrs at 50˚C **OR** 1500g/m^3 for 24 hrs at 21˚C.	n/a	25kGray (2.5Mrad)	Core temperature 85˚C $\geq$48 hrs (50% relative humidity); **OR** Core temperature 95˚C $\geq$24hrs (50% relative humidity).	n/a	If appropriate for the type of biosecurity risk and goods. Immediate removal is usually followed by destruction using a department approved method.

11.6 Approved Sites Class 2.7 and 3.1

Approved Site Class	Registered Name	Physical State Location
2.7	Graincorp Operations Ltd	NSW
	Sylvan Australia Pty Ltd	NSW
	Quattro P Re Services Pty Ltd	NSW
	Premier Stockfeeds Pty Ltd	NSW
3.1	Sylvan Australia Pty Ltd	NSW
	Premier Stockfeeds Pty Ltd	NSW
	Shoalhaven Starches Pty Ltd	NSW
	Darwalla Milling Company Pty Ltd	QLD
As at 2 July 2019		

Source www.agriculture.gov.au/import/arrival/arrangements/sites

11.7 Glossary

Ambient temperature	The air temperature of the surrounding area where the fumigation will be conducted.
Buffer zone	The area around the enclosure, outside of which, the concentration levels of sulfuryl fluoride should not exceed the TLV–TWA during ventilation.
Commodity	The item or goods that are being exported or imported.
Concentration	The amount of fumigant present at a certain point in the fumigation enclosure, usually expressed as grams per cubic metre (g/m^3).
Consignment	Refers collectively to the commodity, any packing materials used and the mode of transport such as a shipping container.
Dosage	The cumulative concentration of fumigant in the enclosure over the exposure period. Also referred to as the Concentration by Time Product (CT Product) normally expressed as gram hours per cubic metre.
Dose	The amount of fumigant applied to a fumigation enclosure.
Dose rate	The prescribed concentration of fumigant to be used per unit of volume and the exposure period.
Enclosure	Any gas–tight space intended to contain sufficient concentrations of fumigant for a period of time. Common examples of fumigation enclosures used for QPS fumigations are sealed shipping containers, gas–proof sheets sealed to an impervious floor and purpose–built chambers
Equilibrium	An even distribution of fumigant throughout the enclosure.
Exposure period	The amount of time, in one continuous block, that the consignment must be exposed to sufficient concentration levels of fumigant to be lethal to the targeted pests.
Free air space	Empty space in the enclosure between, above or around a commodity.
Fumigant	A chemical, which at a particular temperature and pressure can exist in a gaseous state in sufficient concentration and for sufficient time to be lethal to insects and other pests
Fumigation sheets	A sheet (or tarpaulin) that is made of material impervious to the fumigant used to create a temporary fumigation enclosure.
ISPM15	International Standards for Phytosanitary Measures No. 15 – Regulation of wood packaging material in International trade
Minimum top-up concentration	The absolute minimum concentration below which levels fumigant concentration must not fall at any time during the exposure period.
Sampling tube	A small diameter tube used to draw a sample of gas/air mixture from within a fumigation enclosure to measure the fumigant concentration.
Pascal (Pa)	The standard international unit for pressure. Standard atmospheric pressure is 101.325 kPa.
Permeability	The rate at which a substance (such as sulfuryl fluoride) passes through a material (such as a fumigation sheet).
Pest	Any animal, plant or other organism that may pose a threat to the community or the natural environment.

Quarantine pest	A pest of potential economic and/or environmental importance to an area where it is not yet present or is present but not widely distributed and is being officially controlled.
Quarantine and Pre–shipment (QPS)	1. Quarantine treatment applications are treatments conducted to prevent the introduction, establishment and or spread of quarantine pests. 2. Pre-shipment treatment applications are treatments conducted prior to export to meet the official requirements of the importing or exporting country.
Record of fumigation	A document that records the relevant information to demonstrate the fumigation complied with requirements.
Relevant authority	The government department, ministry or agency responsible for animal and plant biosecurity in the importing or exporting country.
Risk area	The area around the enclosure to which access is restricted to personnel wearing personal protective equipment.
Sheet fumigation	A process of creating a gas–tight enclosure by covering/enclosing the commodities to be fumigated under a gas–proof sheet.
Shipping container	Standardised transportation units that can be moved from one mode of transport to another without needing to unload the contents.
Sorption/sorptive	A physical and chemical action by which one substance becomes attached to another. De-sorption is the reversal of this process.
Standard concentration	The fumigant concentration below which the fumigation will not be effective unless additional fumigation is added to the enclosure to compensate.
Target of the fumigation	The target of the fumigation may be the commodity, packaging material or both.
Treatment	Application of a set of specified requirements intended to kill pests and diseases that may be associated with a consignment.
Treatment Schedule	The specified treatment requirements (initial dose, minimum exposure period, minimum temperature, minimum end point concentration %).
Threshold Limit Value – Time Weighted Average (TLV–TWA)	TLV–TWA is the maximum concentration of fumigant that a person can be repeatedly exposed to in the workplace without harmful effects. This figure is based on an 8-hour day, 40 hour working week.

11.8 Example record of fumigation

Australian Government
Department of Agriculture and Water Resources

Sulfuryl Fluoride - Record of Fumigation

Job Details			
Job Identification	Customer Name	Start Date of Fumigation	Location
Description of Consignment			
Target of Fumigation		Container Numbers / Consignment Identification	

Fumigation Details			
The consignment complies with the following requirements: Adequate free airspace, no impervious surfaces or wrapping, maximum timber thickness & spacing ☐ Yes ☐ No			
☐ Sheeted Stack Length = ______ ☐ Sheeted Container/s Width = ______ Size: ______ Qty: ______ Height = ______		☐ Un-sheeted Container ☐ Chamber	Volume ☐ m³ or ☐ ft³
Specified Dose Rate ☐ g/m³ or ☐ oz/1000ft³	Exposure Period hrs	Forecast Minimum Temp ☐ °C or ☐ °F	Fumigation Minimum Temp (if heated) ☐ °C or ☐ °F
Calculated Dose ☐ g or ☐ oz	Chloropicrin ☐ N/A % ☐ g or ☐ oz	Actual Dose Applied ☐ g or ☐ oz	Time Dosing Finished

Concentration Readings

Phase	Time of Reading	Dose rate	Monitor Line Readings by Location					Equilibrium Calculation	Top-up Dose
			1:	2:	3:	4:	5:		
Start								%	NA
								%	NA
During		NA						NA	
End								NA	
								NA	NA

Comments

Ventilation			
Time commenced	Date commenced	Final TLV reading ppm	Date & time reading taken
Fumigator in Charge		Government Officer (if supervised)	
Name	Signature	Name	Signature