aegic
Australian Export Grains Innovation Centre

Grain Growers

New opportunities for feed grains in Indonesia's growing livestock industry

Department of Primary Industries and Regional Development
GOVERNMENT OF WESTERN AUSTRALIA

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

AEGIC is an initiative of the Western Australian State Government and Grains Research & Development Corporation

New opportunities for feed grains in Indonesia's growing livestock industry

31 March 2021

Authors

Economics and Market Insights Team, AEGIC

in collaboration with

Policy Team, Grain Growers.

Work completed with a funding grant administered by the Department of Foreign Affairs and Trade

Australian Government
Department of Foreign Affairs and Trade

aegic
Australian Export Grains Innovation Centre

Grain Growers

Department of Primary Industries and Regional Development
GOVERNMENT OF WESTERN AUSTRALIA

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

AEGIC is an initiative of the Western Australian State Government and Australia's Grains Research and Development Corporation

Cover image alexas_fotos: Pixabay

Introduction

The Indonesia-Australia Comprehensive Economic Partnership Agreement (IA-CEPA) includes economic programs to support closer cooperation in the agri-food sectors between Australia and Indonesia. The Grains Partnership is one such program aimed at unlocking value in the food and feed grain sectors.

Rising incomes and changing population demographics are driving increased animal protein consumption (fish, chicken, beef, eggs and dairy) in Indonesia. Per capita meat and fish consumption is set to increase from 52 kg per person in 2019 to 59 kg per person by 2030 and is driving strong increases in Indonesian animal and fish production. By 2030 an extra 8.7 mmt of feed grains and meals will be needed every year to help boost production in order to meet the increased demand for meat and fish (OECD-FAO, 2020). Some of the increased supply of feed grain will be met by increased domestic corn production. A proportion will also come from improved efficiency in feed use together with increased import of high-quality cereals grains and protein meals.

This report provides an overview of Indonesia’s animal production and explores opportunities for smarter use of feed grains to help boost sustainability and profitably. In particular, it focuses on opportunities where Australia, through the Grains Partnership Program, can assist Indonesia increase the efficiency in its feed grain use to ensure the future of the expanding Indonesian animal production industry remains bright. The report contains five sections as described below.

Section 1 describes the changing patterns of animal protein consumption in Indonesia and the factors driving these changes, how animal protein is produced in Indonesia, and the main feed ingredients currently used together with forecast use over the next decade.

This section shows that demographics, income growth and relatively low starting base all indicate that per capita animal protein consumption will grow strongly in Indonesia over the next decade. To keep pace with this consumption growth, animal producers will use increasing amounts of feed ingredients that will be supplied through increase local production, more efficient handling and use and increased imports.

Section 2 provides an overview of animal production trends in Australia, the types of feed grains used and the production volumes available for the Australian domestic and export markets.

This section shows the that Australian feed grains underpin the highly productive Australian animal production industry. Grain production in Australia is increasing with higher volumes expected to be available for export over the next decade, much of this well suited to Indonesian requirements.

Section 3 provides a quantitative analysis of the fit and value in Indonesian feed rations of the most readily available Australian feed ingredients. (wheat, barley, sorghum, lupin and canola meal).

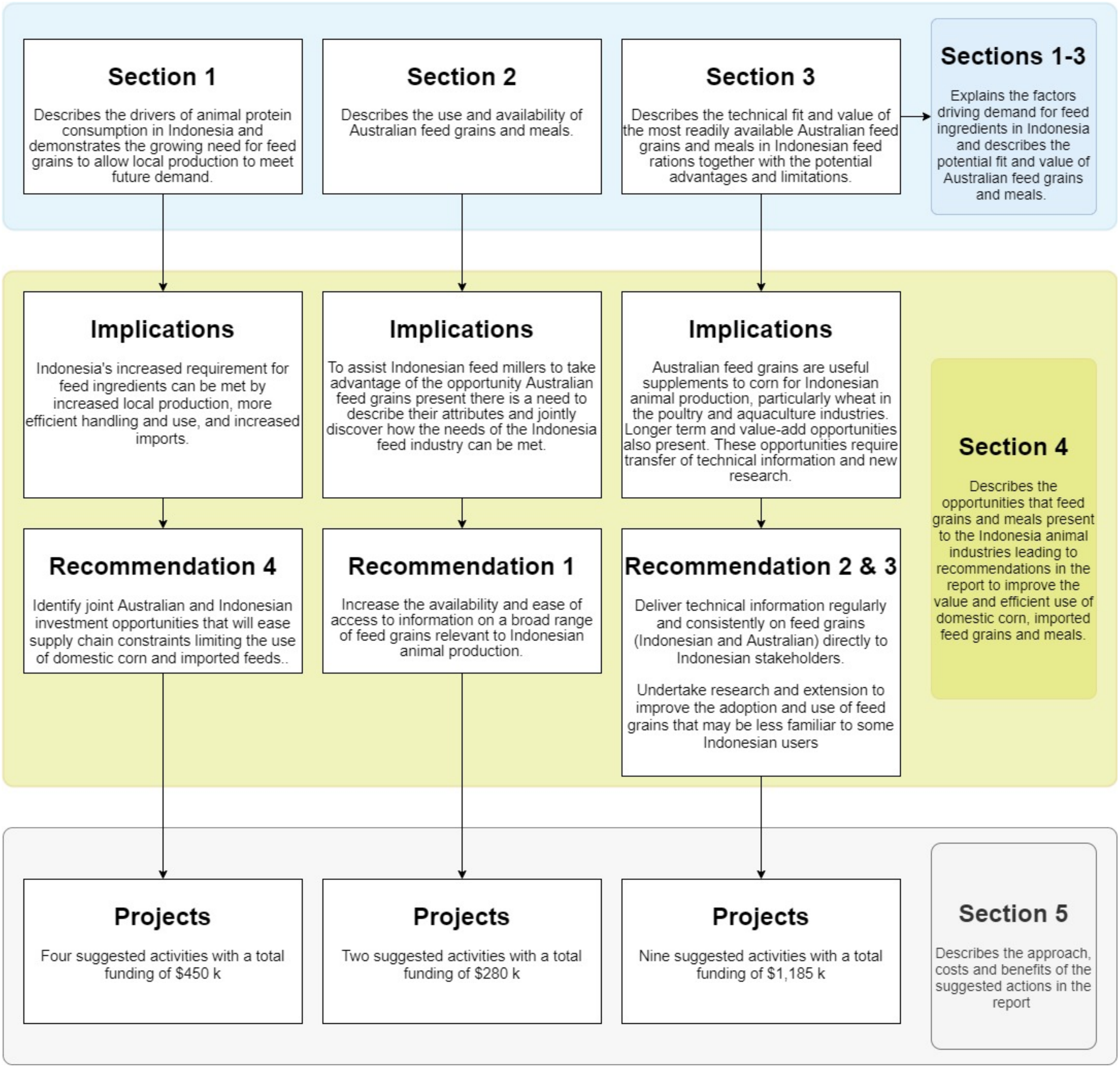
This section shows the circumstances under which these feed ingredients can be most cost effectively used together with their advantages and limitations. The largest and most immediate opportunity is for wheat in poultry diets. Further exchange of technical information and research has the potential to expand the use of canola meal and barley in dairy diets, and lupins and barley in aquaculture.

Section 4 identifies some of the factors currently constraining more efficient use of feed grains in Indonesian animal production and the opportunities to improve use. This section largely reflects discussions with Indonesian and Australian stakeholders in the feed and animal producing industries. Discussions highlight the need for building relationships and increasing the awareness of the opportunities that feed grains present. The potential for research to develop new ways of processing and using feed ingredients and the requirement to support small businesses in feed and animal industry value chains.

Section 5 Lists the costs of proposed actions recommended in the report, their potential impact and anticipated social benefits in Indonesia.

This report was commissioned by the Australian Government Department of Foreign Affairs and Trade to identify how the Australian grains industry could support Indonesia' growing livestock and feed industries.

Overview of the Report Structure



Contents

Key findings

Section 1 - Overview of Indonesia’s livestock sector

Indonesia’s economic development, income growth, population increase, and continued urbanisation point toward sustained growth in demand for animal proteins over the next decade, both in volume and quality. Changes, however, will occur unevenly across income, age, and regional groupings.

- Current per capita consumption of animal proteins in Indonesia is less than most of its neighbours in South East Asia. It is less than half the per capita consumption of Malaysia.

- Annual per capita consumption of meat and fish in Indonesia is forecast to grow a further 13% to reach 59 kg over the next decade. Fish constitutes nearly 80% of consumption, chicken 13% and beef 5%.

- Both chicken and beef consumption are expected to grow the fastest with annual rates of 2.7% to 2.8% respectively, but fish consumption, while growing at a slightly slower rate (1.5%), is expected to see the largest jump in total consumption, because it comprises such a high proportion of the Indonesian diet.

- In 2019, Indonesia produced 10.2 mmt of animal protein making it the largest producer in South East Asia:
  - It is self-sufficient in chicken and egg production.
  - It is self-sufficient in fish production and since 2010, fish from aquaculture has nearly doubled to supplement the slowdown in wild-caught fish.
  - Intensive beef production mostly occurs within feedlots using imported cattle. Half the beef demand is met through imported meat.
  - Indonesia remains the largest dairy producer in South East Asia, however, 75 per cent of the demand for milk and milk products is supplied by imports.

- Indonesia is the second largest user of commercial feed in Asia after China and consumption has grown rapidly. Commercial feed consumption was 11.3 mmt in 2011 and grew to 20.5 mmt in 2019. Most feed (86%) is used for poultry production which used 17.6 mmt in 2019. Aquaculture is the next largest user of commercial feed (8% or 1.6 mmt) followed by beef and dairy (6% or 1.2 mmt)

- Demand growth for commercial feed has been consistent at 7.1% per annum between 2011 and 2020 and is projected to continue to increase at a similar rate beyond 2020.

- Currently, 75 per cent of Indonesian feed ingredients are produced domestically. Corn and agro-industrial by-products (e.g., onggok a by-product of cassava processing) are the main domestic feed sources. As domestic production of feed ingredients grows, the Indonesian industry will need to continue to improve the sophistication of its storage, processing and handling infrastructure.

- OECD-FAO (2020) forecasts that imports of feed ingredients by Indonesia – except for corn – will grow by 20 per cent over the next decade, (i.e., soybean meal, wheat, distillers dried grains with solubles (DDGS) and other grains).

Section 2 - Australia's livestock sector, grain production and use

Australia is a large producer of animal products and feed grains that are used to supply growing domestic and export markets.

- Annual consumption of meat and fish in Australia is about 115kg, most of which is produced domestically. Consumption of chicken and pigmeat has steadily increased while consumption of beef and sheepmeat has declined. In 2019 about 38% of total meat and fish consumption was poultry meat, 22% fish 18% pigmeat while beef and sheepmeat comprised 17%, and 5% of consumption, respectively. Australians also consume over 100kg of fresh dairy products per year.

- Despite declining trends in beef and sheepmeat production, Australia remains a large exporter of beef, and sheepmeat both as chilled meat and live animals. Animal production methods have also changed with a large increase in beef feedlot production over the past 20 years.

- Changing pattern of domestic consumption and animal production methods has seen a 50 per cent rise in Australia feed grain use over the past 20 years particularly for poultry and beef feedlots production. In recent years Australia used about 9 to 10 mmt of feed grains annually. Annual feed grain use is expected to increase by a further 2 to 2.5 mmt over the next decade.

- Australia uses domestically produced wheat, barley and sorghum as the main energy component of commercial feed rations. Imported soybean meal, supplemented by locally produced ingredients such as canola meal and processed lupins are used as the main protein components of feed rations.

- Australia produces about 34 mmt of wheat, barley and sorghum annually and exports about 67% of this (22 mmt) although annual variation in total production and export can be large. About 7.1 mmt of exported wheat, barley and sorghum is used for feed each year, particularly within Asia.

- By 2030 Australia's total grain production is expected to increase by 5.6 mmt annually, 40 per cent of this increase will be used in the domestic feed industry, most of the rest will be available for export.

Section 3 - Feed sources and feed formulation and price sensitivity

Indonesian animal producers have a wide range of local and imported ingredients available to meet their feed needs. The commercial sector utilises least cost ration formulations, to produce rations with optimal nutrition at the lowest cost.

- Poultry production dominates feed grain use and generally require high energy ingredients (mostly corn, but also wheat and cereal by-products) together with protein meals (mostly soybean meal or meat meal).

- Beef feedlot and dairy production uses relatively small amounts of feed grains and mainly rely on agro-industrial by-products to supply the energy components of diets (e.g., onggok).

- Aquaculture uses feed grade wheat flour (aqua flour) supplied by local mills as the predominant cereal in diets, supplying digestible starch as well as providing binding for pellets.

- Australian wheat, barley, sorghum, canola meal and lupins are well suited to nutritional requirements of Indonesian feed systems, but their fit and price competitiveness vary across the different production systems. Wheat in poultry diets shows the largest and most immediate application. In contrast, there is likely to be little immediate requirement for feed grains in the beef production where by-products are currently being used effectively. Table 1 summarises the fit and value of the main Australian feed grains[1]:

- In addition to their value in least cost ration analyses Australian feed grains have other useful properties that complement Indonesian feed ingredients. For example:
    - The low moisture of Australian grain increases its nutrient concentration and lowers risk of mycotoxin contamination.
    - The soluble fibre from barley allows greater dry matter intake in breeding herds fed standard Indonesian diets with high fibre levels.
    - Canola meal may increase yield of key milk components and is a good source of by-pass methionine which is limiting in high yielding dairy feeds.
    - Canola meal and lupin seed meal are both good sources of protein without significant levels of trypsin inhibitor present in soybean meal making these products safe choices for use in aquaculture feeds.

- Opportunities are likely to exist within Indonesia for technical education and training to improve the knowledge and use of lupin seed meal in poultry diets. Further opportunities may exist in cost effective processing of lupin seeds in Indonesia to enhance value for domestic use and export.

- Formulating aquafeeds is an area of continuous innovation as the feed industry keeps pace with this rapidly growing sector in Indonesia. Further research will improve the use of cereal and protein meals in Indonesian aquaculture feeds. For example, some work on improving the protein/gluten content of wheat varieties and flours may allow improved pellet quality and water holding capacity.

- The opportunity for barley in aquaculture feeds appears to be strong despite its higher fibre and current limited use. The use of barley in the shrimp feeds, in particular, is worth investigating further. Some producers are looking at lower cost

[1] The least cost ration analysis conducted in this report is based on the best available information at the time. The relevance of the assumptions used in the analysis will vary over time, geographic location, and production system. Assumptions are detailed in Clarke (2020) and Permana *et al* (2020).

ingredients that are higher in fibre so the trend to the higher NSP ingredients is an opening for barley.

Table 1. Summary of the fit and value of Australian feed grains in Indonesian animal feeds.*

	Poultry	Beef	Dairy	Aquaculture
Wheat	Higher value than corn, and superior to barley and sorghum	Uncompetitive against onggok	Suitable for higher productivity herds and priced above corn.	Valued consistently higher than corn
Barley	Discounted to corn but relative value better within less energy dense formulations	Uncompetitive against onggok, but preferred compared with wheat and sorghum	Priced lower than corn and other grains in early lactation diets but higher in late lactation diets.	Valued consistently higher than corn, particularly in shrimp diets
Sorghum	Closest to corn in nutrient content and value	Uncompetitive against onggok	Suitable for higher productivity herds and priced above corn in late lactation diets.	Valued lower than corn
Canola	Heavily discounted to soybean meal but has a higher value than lupin	Heavily discounted to soybean meal	Heavily discounted to soybean meal with value improving in late lactation diets.	Discounted to soybean meal,
Lupin	Heavily discounted to soybean meal. Processing to remove the hull substantially increases value.	Heavily discounted to soybean meal but has a higher value than canola meal	Heavily discounted to soybean meal with value consistent across lactation diets and higher than canola meal	Discounted to soybean meal. Processing to remove the hull substantially increases value.

* Findings based on price assumptions as at November 2020.

Section 4 - Opportunities for the wider use of feed grains in Indonesia's animal protein industries

Findings described above show that Indonesian consumers will eat more animal protein of higher quality over the next decade. To keep pace with this demand animal producers will increase their use of feed grains and protein meals. Locally produced corn and imported soybean meal will be the mainstay of the Indonesian feed industry, but Indonesia will also need to import alternative feed ingredients to supplement local corn production. These developments in Indonesia's growing animal industries present several new opportunities for feed grains.

Improved storage and distribution of local corn in Indonesia presents opportunities to improve the quality of feed and reduce costs to feed millers. Australian feed grains also present opportunities for feed millers, particularly wheat, barley, sorghum, canola meal and lupin seed. These commonly used feed ingredients can be effectively incorporated into a range of Indonesian feed applications also potentially reducing costs and increasing feed quality.

Australia through the IA-CEPA can assist Indonesia take advantage of these opportunities by building awareness about the potential use of alternative feed grains and targeting investments in infrastructure and research as described below.

Awareness Building

- Australian feed grains are well suited to Indonesian animal production systems and some Indonesian stakeholders can benefit from a greater understanding of their, use and value. Likewise, some Australian stakeholders could benefit from a greater understanding of the needs of the Indonesian feed industry. Furthermore, as Indonesian animal production continues to grow, feed grains will be needed in sectors that are currently unfamiliar with their use. Australian and Indonesian stakeholders could jointly benefit by increasing the availability and access to information on each other's feed grain and livestock industries.

Collaborative Research and Development

- Given the growth in Indonesian demand for animal products, there is a need to continually improve the efficiency and sustainability of animal production systems. The Grains Partnership Program could deliver collaborative research and develop feed grain initiatives to further advance productivity and profitability within the Indonesian feed industry. Indonesia and Australia could jointly initiate:
    - feed trials and extension of case studies demonstrating the effective use of feed grains in Indonesian animal production systems.
    - technical training initiatives and exchange visits between Indonesian and Australian animal producers and feed specialists, including farm visits.

Grains Supply and Value Chains

- Indonesia's archipelagic geography creates unique challenges to the arrangement of supply and value chains. Smallholders and small and medium enterprises (SMEs) spread across the archipelago produce a range of agricultural products on small lots. These independent farmers may have less consistent access to information, and technical advice resulting in greater management and profit risk. For these farmers, a switch from local ingredients to feed grain use presents multiple challenges and consequently, rates of change are slow. The Grains Partnership Program provides opportunity to support these enterprises through innovation in the way technical and price information is provided, accounting for the complex internal supply and value chains. For example:

- innovation in the way information is provided (e.g., mobile phone messaging),
- new initiatives to efficiently aggregate and deliver feed grains to small regional users (e.g., containers),
- appraise the value and suitability of improved phone-based services that provides pricing transparency to Indonesian sellers and buyers of feed grains and a platform for secure transactions.

Infrastructure and Capital

- Indonesia continues to develop its port infrastructure and hubs, including planning for bulk grain receivals, grain storage at port, and streamlined container processing. There is an opportunity for Indonesia and Australia to share expertise in developing and utilising grain handling infrastructure and technologies. Indonesia and Australia could jointly examine the potential for improved infrastructure and capital systems that enable productivity advancements for the animal and feed industries.

Section 5 - Implementing recommendations: approach, cost and benefits

A portfolio of investments is presented for consideration by the Grains Partnership Program (GPP) within IA-CEPA that may contribute to more efficient use of feed grains in Indonesia. The main impacts of these activities are:

- More efficient production and use of local and imported feed grains in Indonesia.
- Better informed Indonesian producers and users of local and imported feed grains.
- Enhanced supply of higher quality local and imported feed grains in Indonesia.

Preliminary costings of the activities listed amount to an expenditure of US$1.91 million over a 5-year period. Estimated costs for each activity are listed in Table 23 of Section 5 - Implementing Recommendations: Approach, Cost and Benefits.

Several of the activities could be on-going, most of the benefits will occur in Indonesia and the impacts of the activities are potentially long-lasting.

Recommendations

Build awareness and support networks

Indonesia and Australia will mutually benefit from building awareness of the complementarity of Indonesian and Australian feed grains, firstly in the large and growing poultry segment, and subsequently in the developing beef and dairy industries.

Recommendation 1

Increase the availability and ease of access to information on a broad range of feed grains relevant to Indonesian animal production. Specifically:

a) Develop a feed grains information portal that delivers:
   i. Technical information and data on a broad range of feed grains, specific to Indonesia, including corn, wheat, barley, sorghum, canola meal and lupins.
   ii. E-Learning training modules on the use of feed grains in Indonesia.
   iii. Historic pricing trends for a range of feed grains that will assist in formulating least cost rations.
   iv. Information that government and business managers can use to inform policy and strategy (e.g., ABARES crop forecasting, TraNSIT, and economic modelling).

b) Develop and extend case studies that demonstrate the effective use of a broad range of feed grains in Indonesia.

Recommendation 2

Deliver technical information regularly and consistently on feed grains (Indonesian and Australian) directly to Indonesian stakeholders (either virtually or face-to-face when health conditions allow) through:

a) Timely delivery of targeted Feed Grain Workshops.
b) Demonstration trials on leading dairy farms and beef feedlots that have a propensity to use feed grains and the capacity to store and process grain.
c) Presentations at local and regional feed conferences.
d) Technical training and exchange programmes between Indonesian and Australian animal producers and feed specialists.
e) On-line media and other information distribution channels (e.g., social media, blogs, newspapers, and magazines).

Collaborative research and development

Indonesia's research and development sector has a longstanding collaborative relationship with Australian researchers, across multiple livestock industries. IA-CEPA provides a framework to jointly realise new opportunities to enhance the use of feed grains in Indonesia, through research as outlined below:

Recommendation 3

Undertake research and extension to improve the adoption and use of feed grains that may be less familiar to some Indonesian users. For example, develop methods and technologies that improve the adoption and use of domestically produced feed grains, complemented by Australian wheat, barley, sorghum and other grains. The methods and technologies may include:

a) Near-Infrared (NIR) calibrations such as those provided by AusScan Online to improve efficiency and safety of feed raw materials (e.g., non-starch polysaccharides (NSPs) and energy analysis in poultry or acidosis indices for ruminants).
b) Application of targeted enzyme packages optimised for different raw materials to maximise energy extraction.
c) Effective and reliable feed grain processing techniques for dairy and feed lot operations, for large and small operators.
d) Feeding trials combining domestic corn with proven but less familiar feeds such as barley, lupins, and cold-pressed canola meal.
e) Cost effective processing of lupin seeds in Indonesia to enhance value for local use and export.

Recommendation 4

Identify joint Australian and Indonesian investment opportunities that will ease supply chain constraints currently limiting the use of domestic corn and imported feeds, and lowers the cost of exporting products. Areas of research where business cases could be presented include (but are not limited to):

a) Novel grain storage and warehousing solutions that enable small holders to safely keep grain, reducing losses and that enable medium to large enterprises to aggregate grain more efficiently.
b) New logistic pathways that increase access to feed grains at viable cost. For example, use Australian modelling technologies to optimally locate grain storage and mills relative to ports and delivery of specialised feed mixes direct to outer islands.
c) Opportunities for developing ‘powerhouse’ export opportunities, for example processed lupin products for re-export to South East Asian aquaculture industries.
d) Using feed grains to achieve consistent supply and quality standards for meat products, required by the high value retail and supermarket sectors.

1. Overview of Indonesia's livestock sector

Animal protein consumption: demographic factors

Demographic trends including those in age and income will drive sustained increases in animal protein consumption.

Meat and fish consumption in Indonesia have doubled from about 26 kg per person in 1995 to 52 kg per person in 2019 (OECD-FAO, 2020). These trends are in line with general global trends for increased animal protein consumption, particularly as incomes rise.

The Indonesian population consume more fish and less chicken than their near neighbours. This is in part driven by archipelagic geography of the country, with its traditional reliance on the abundant fish resources. While there is a proportional shift towards farmed fish (aquaculture) away from the wild catch, the preference for fish, and the low cost of fish remains. Also, being a predominantly Muslim country, the pork consumption is much lower than in most of the rest of South East Asia.

Understanding consumption trends, how they vary across the country and how animal production will respond to demand will be important to understand feed and feed grain requirements over the next 10 years.

Population

Indonesia's population is expanding but at a slowing rate, and in the process, the median age is increasing.

Indonesia's population in 2020 was approximately 273 million, making it the fourth most populous nation in the world (Figure 2). The population was growing at 1.5% per annum up to 2008, though the rate is now slowing. In 2020 the 20-year growth rate was down to 1.3%. and it is expected to fall below 1% per annum by 2046.

By 2050 the Indonesian population is expected to grow to 330 million, an increase of 47 million people (Figure 2).

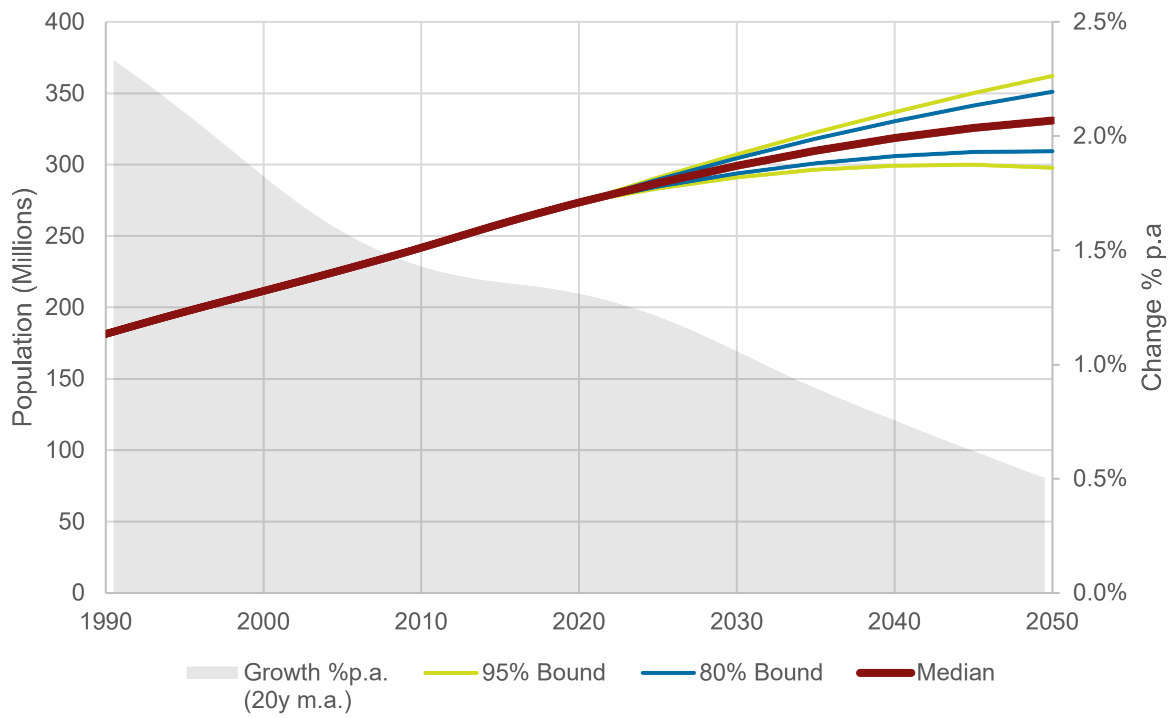


Figure 1: Historic and forecast population of Indonesia (UN, 2020).

Both the total amount and rate of population growth have a strong effect on the Indonesian agricultural and food industry, and consequent government policy. The growing population provides increased demand and growth prospects for food consumption while also focussing the government's policy on food security.

The Indonesian population has a young to middle aged workforce with proportionally fewer dependants.

The slowing population growth rate affects the composition of the population (Figure 3). People within the 20- to 50-year-old age bracket now form the bulk of the working population and have fewer dependants. Compared with other sections of the population, this young to middle aged workforce has a larger proportion of their income available for personal consumption, including the capacity to buy more meat and fish of higher quality.

AEGIC Australian Export Grains Innovation Centre

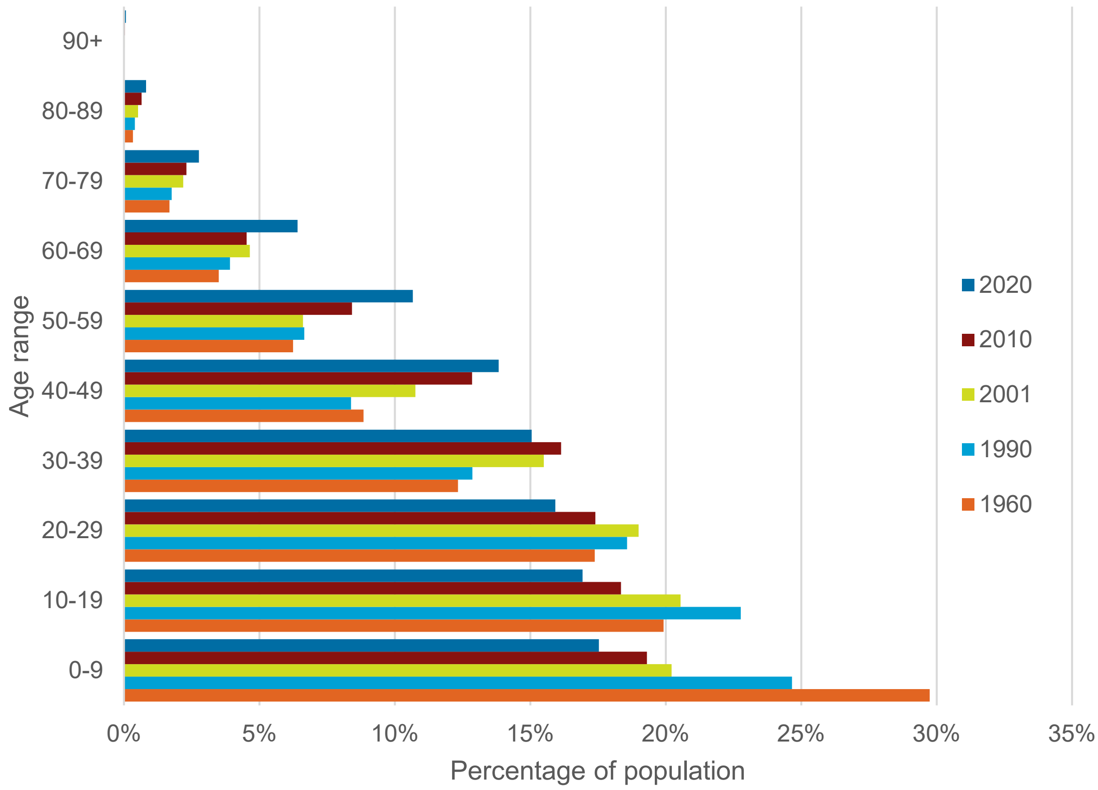


Figure 2:Change in age composition of Indonesia's population since 1960 (UN, 2020).

Income growth and distribution

The population is increasingly wealthy, with over 90% of the population above the poverty line.

Indonesian Gross National Income (GNI[2]) has been increasing at 13.1% pa, from US$122.5b in 2000, to US$1,029b in 2018 (Table 2). The growth has come at the expense of high inflation, with an average rate of 6.4% between 2000 and 2020. As such real incomes have been increasing at a rate of 6.7% pa over the period.

Income distributions have changed, with the share of income held by the highest income earning group increasing by 5% since 2000, while the share held by the lowest income group has decreased by 1.6% in the same period. Across the income groups, real incomes have increased significantly since 2000, with middle, and lower middle-income groups now displaying income well above the cost of living, allowing choices in employment, education, housing and diet. The average annual income within the lowest 20% of income earners is now double the poverty line, which in Indonesia in 2020 is approximately US$380/year.

[2] GNI: World Bank Atlas method, Current USD (World Bank, 2020)

Table 2: Change in income share held by income group from 1984 to 2018 (World Bank, 2020)

Year	GNI (USD Billion)	Income Group				
		Lowest 20%	Second 20%	Third 20%	Fourth 20%	Highest 20%
2000	122.5	8.3%	12.4%	16.3%	21.8%	41.2%
2018	1,029.2	6.7%	10.5%	14.9%	21.7%	46.2%

Effect of urbanisation on consumption

As urbanisation increases there is income growth, with wages in the urban centres 150% of those in rural centres.

Urbanisation is increasing, with more than 50% of the Indonesian population living in urban centres as of 2010 (Figure 4). It is expected that 68% of the population will be living in urban centres by 2050.

Wages in the urban centres are 150 per cent of those in rural centres. Income and economic growth associated with the urbanising population is recognised in many developing countries as having stimulated dietary shifts towards animal sourced foods and resulted in increased demand for animal livestock (Hatab, *et al* 2019).

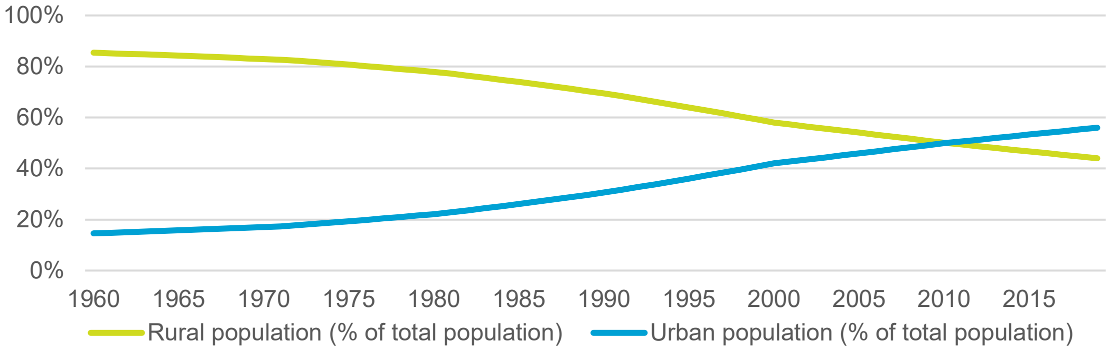


Figure 3: Percentage of rural and urban populations in Indonesia (World Bank, 2020)

The Indonesian rate of urbanisation reflects the urbanising trend on Java – the most populous island – given that in 2020 Java housed over 55% of the Indonesian population. In all the six administrative regions of Java, more than 50% of the population live in urban centres, with over 70% in Yogyakarta, West Java and 100% in Jakarta (Figure 5). In the eastern islands of Indonesia, urbanisation has not yet reached the same level as Java, with over 50% of the population living in rural areas. The populations are much smaller on these islands than Java, though the populations are large relative to Australian populations.

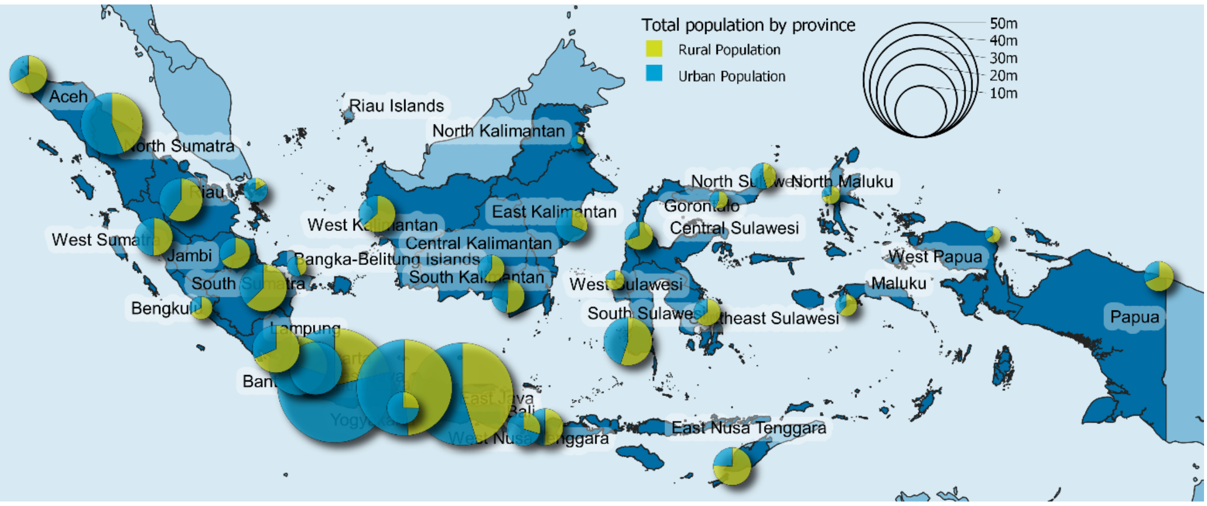


Figure 4: Urban and rural populations by province (BPS 2020)

As incomes rise, urban populations consume more processed food and less home cooked food (Figure 6). This has implications for the way basic ingredients are sold. The food processing and prepared food (restaurant) sectors require basic ingredients that are consistent quality product with certainty of supply, which in turn favours modern commercial scale enterprises that can produce standardised products, and deliver those products (animals, grain) into urban areas at a low cost. The quality requirements of these sectors – that include supermarkets – may be as simple as providing cuts of meat, of a similar size and colour.

At the same income levels, urban consumers spend more on preprepared food than rural consumers.

As incomes increase, monthly expenditure on food also increases, though, preferences for spending on grain, meat or fish change. For instance, the monthly spend on fish and meat increases, particularly in the urban areas (Figure 6). Wealthier groups consume more fish than those in the lower income groups, though the price they pay for fish is higher and differentiated through perceptions of quality. The spend on meat is more closely linked to volume, and in general lower income groups heavily prioritise grains within the diet, with very small expenditure on fish and meats.

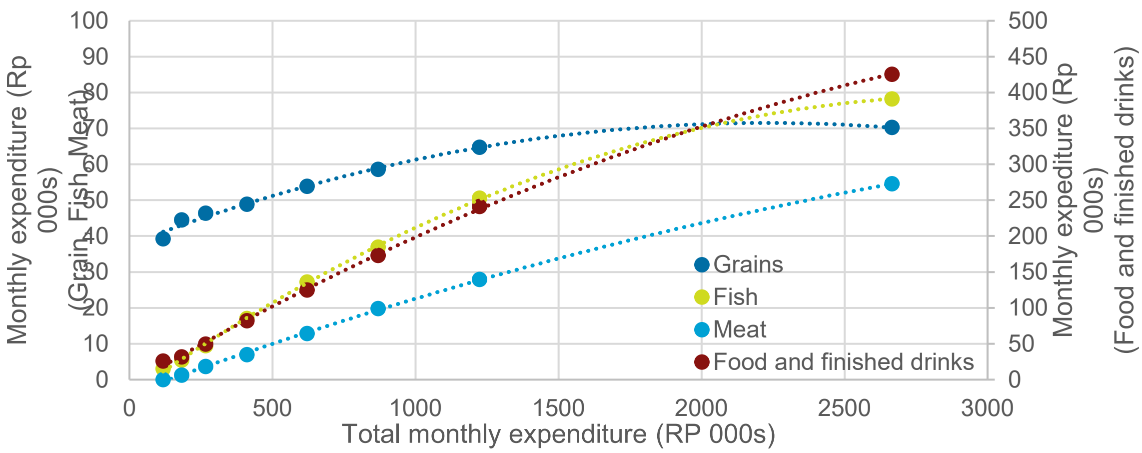


Figure 5: Monthly expenditure on food products within the URBAN population, as a function of total monthly expenditure (BPS 2020)

Indonesian animal protein consumption: 2020 and beyond

Composition of meat and fish consumption

Animal protein consumption in Indonesia is low compared to nearby neighbours.

Compared with many other countries in Asia, the average Indonesian diet for animal protein contains a higher proportion of fish, a slightly lower proportion of poultry and substantially lower proportion of pig meat (Figure 7). Annual per capita meat and fish consumption is forecast to grow a further 13% to reach 59 kg over the next decade but the relative proportion of protein sources will remain the same.

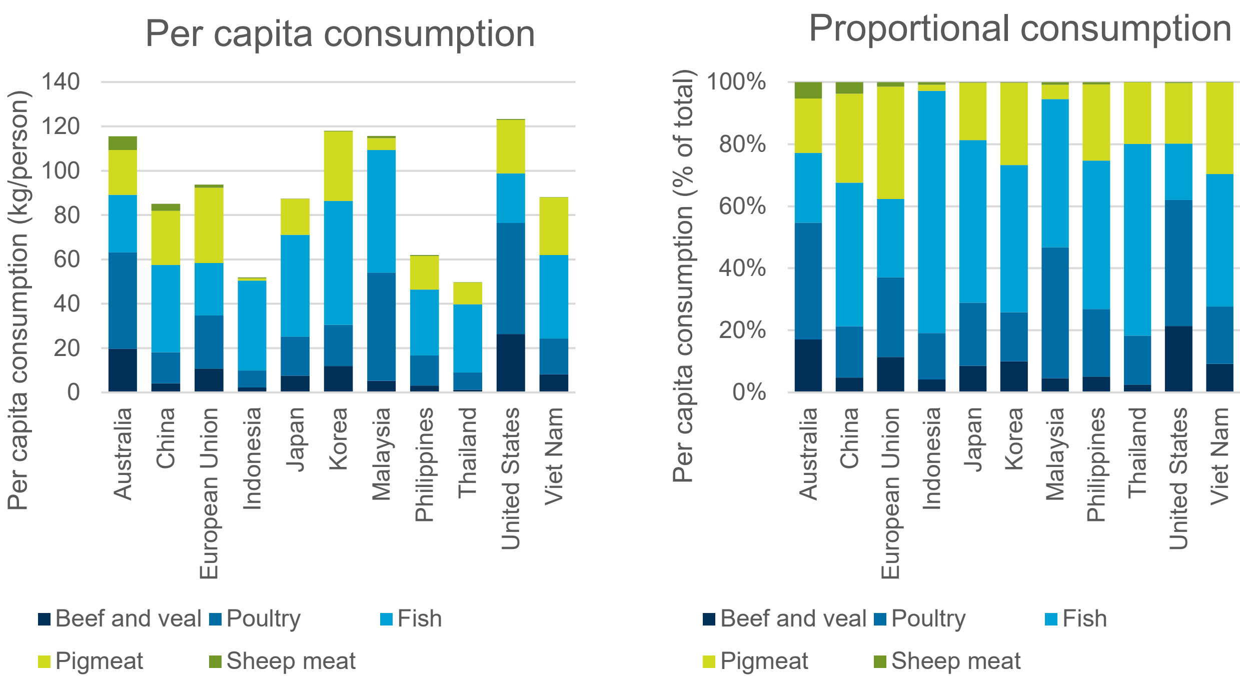


Figure 6. Per capita and proportional consumption of animal protein for diets in selected countries for 2018 (OECD-FAO 2020).

Fish is the dominant animal protein consumed in Indonesia followed by chicken.

Fish consumption by Indonesians has steadily grown over the past 20 years and now constitutes nearly 80% of total animal protein in the diet (see Figure 8). In 2000 Indonesians consumed on average about 20 kg of fish per capita. This increased to over 40 kg per capita by 2019.

Poultry consumption has also increased from a small base over this period and has approximately maintained its position at about 15 per cent of the Indonesian diet. Beef consumption has grown in absolute terms but decreased as a proportion of the diet. Consumption of other meats has decreased in both absolute and relative terms.

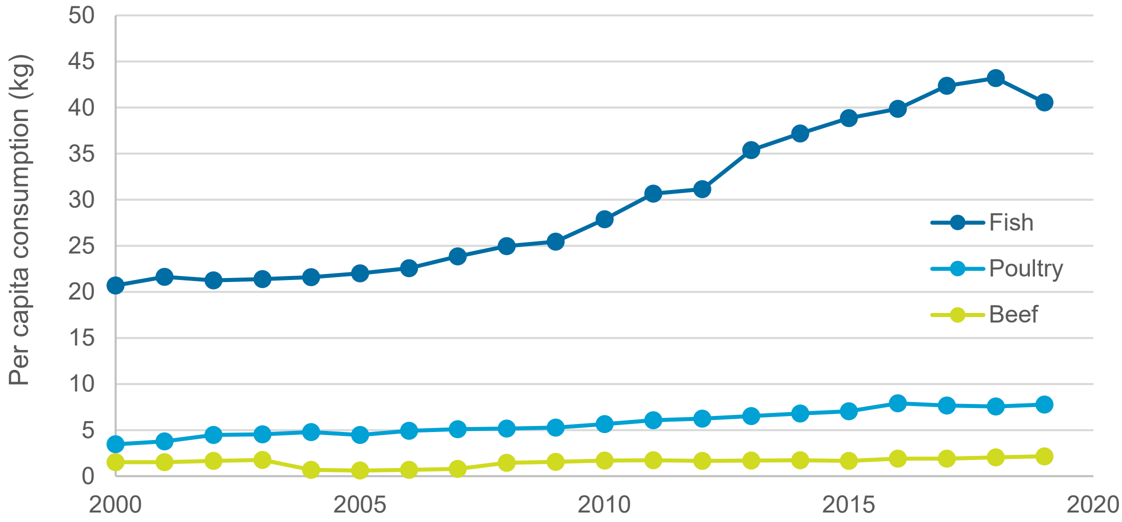


Figure 7. Per capita consumption of poultry, fish and beef in Indonesia. (OECD-FAO 2020)

In addition to rising per capita consumption, population growth will accelerate total Indonesian meat consumption. Both chicken and beef consumption are expected to grow the fastest with annual rates of 2.7% to 2.8% respectively, but fish consumption, while growing at a slightly slower rate (1.5%), is expected to see the largest jump in total consumption, because it occupies such a high proportion of the Indonesian diet (Figure 9).

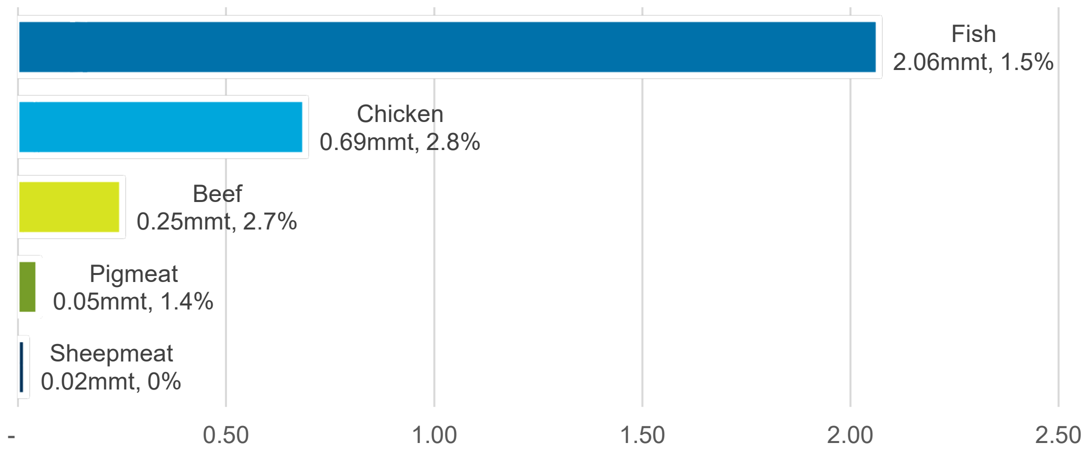


Figure 8: Expected growth in total Indonesian animal protein consumption, excluding eggs and dairy. Difference in average annual consumption for 2015-2019 compared with 2025-2029 compared in mmt and average annual growth (%) over the period. (OECD-FAO 2020)

Regional distribution of fish and shrimp consumption

Fish consumption is higher outside of the major urban areas in Java

In Java, the consumption of fish is under (0.8kg/month) a third of that in less populated and less urbanised islands of Sulawesi and Kalimantan (3.2kg/month) (Figure 10). Fish supply in Java is more constrained, meaning the population in Java consume a greater amount of animal protein in the form of chicken and beef.

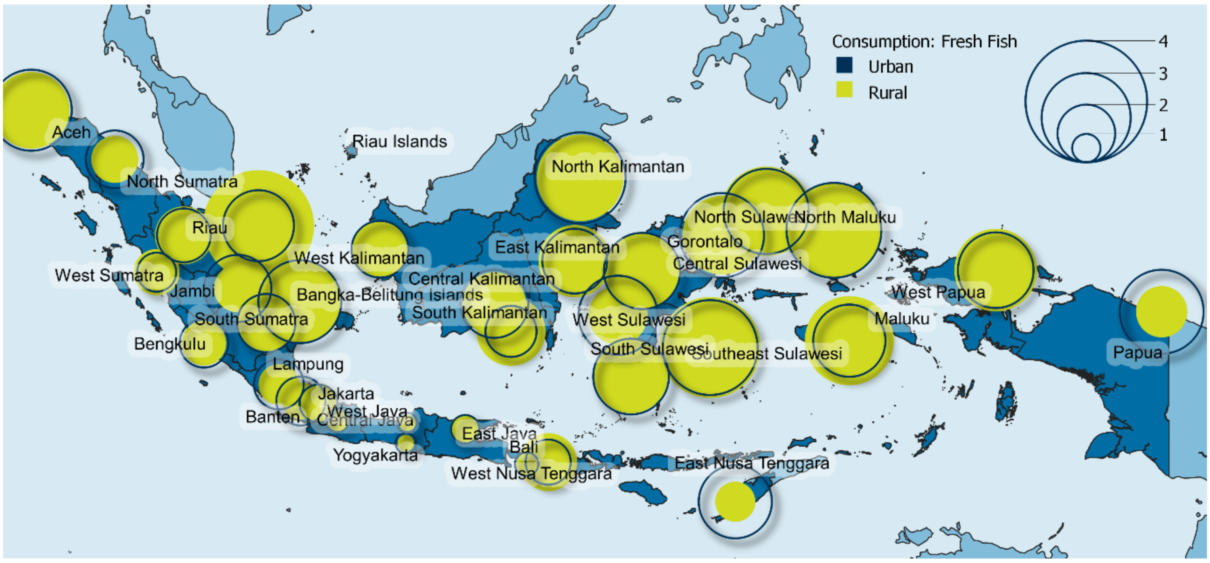


Figure 9: Consumption of fresh fish and shrimp within each province (kg/month) (BPS)

Regional distribution of chicken consumption

Indonesian per capita chicken consumption is well below that of near neighbours.

Indonesians ate about 10.5 kg of chicken per capita in 2020, much less than counterparts in neighbouring countries. For example, Malaysians consumed around 46 kg of chicken per capita (Figure 11).

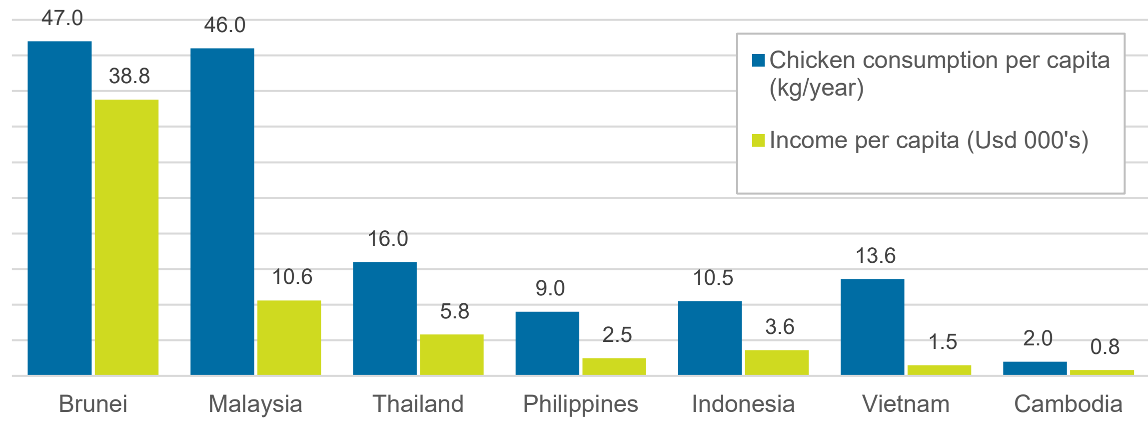


Figure 10: Comparison of chicken consumption and income in Indonesia, with neighbouring countries. (Malindo 2020)

Chicken is consumed across urban and rural locations, though with slightly higher consumption in urban centres.

The volume of chicken consumed in each area of a province is broadly reflective of the urbanisation level within that province (Figure 12). Exceptions occur in the eastern islands and in northern Sumatra, where there is a high rural population though much of the chicken is eaten in the urban centres. Chicken consumption patterns are similar between urban and rural consumers, on the islands of Java, Sumatra and Kalimantan.

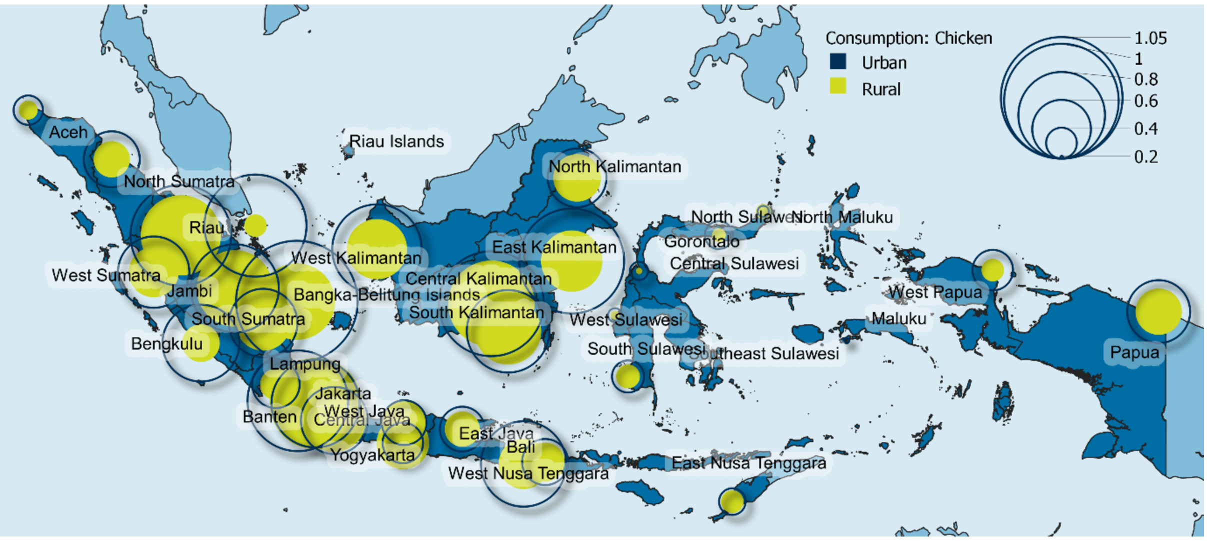


Figure 11: Chicken consumption per capita in each province, showing difference in consumption between urban and rural areas. (kg per week) (BPS 2020)

Regional distribution of beef consumption

Beef is mostly consumed in urban centres, with lesser consumption in rural regions.

Beef is mostly consumed in urban centres, with lesser consumption in rural regions (Figure 13). In the rural areas, cattle produced by small holders have traditionally been used for draught (pulling ploughs and carts) and as a store of wealth. In rural regions, beef is not an everyday component of the diet and is mostly reserved for special occasions. West Papua is the exception to the rule and consume higher quantities in the rural areas. Java and East Kalimantan are the leading consumers of beef, based on quantity per capita. Southern Sumatra is also a consumer of beef, more so than the eastern islands.

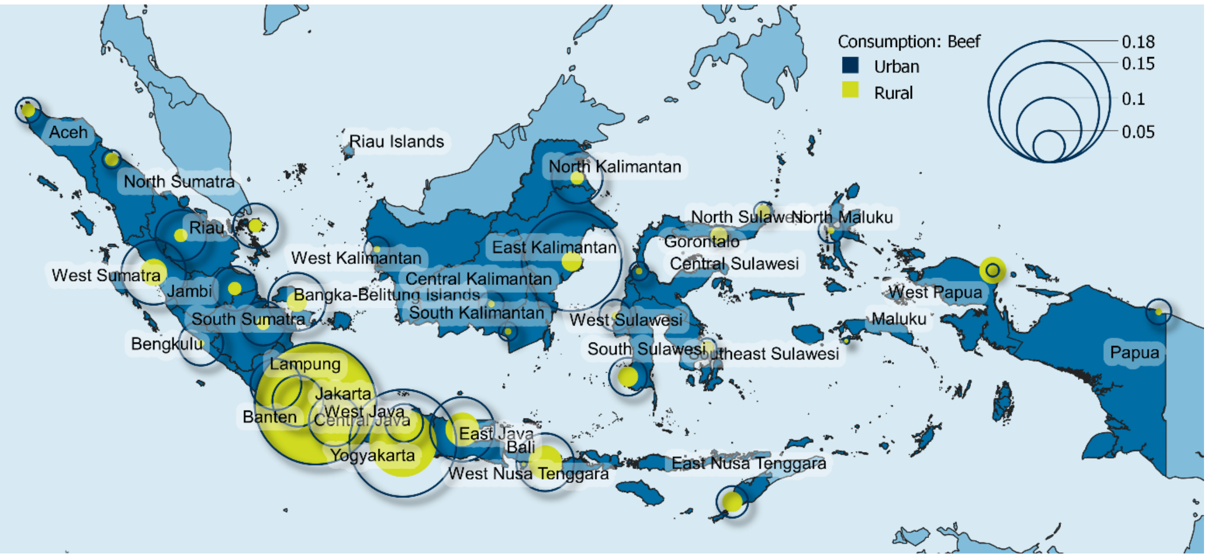


Figure 12: Beef consumption per capita in each province, showing difference in consumption between urban and rural areas (kg per week). NOTE: Difference in scale to Figure 12 (BPS 2020)

Egg and dairy consumption and regional distribution

Egg consumption has nearly doubled in the past 20 years but like fresh dairy, Indonesian per capita consumption remains lower than its more developed regional neighbours.

As with meat consumption, per capita egg consumption in Indonesia has nearly doubled from 3.1 to 5.7 kg per capita over the past 20 years (FAO, 2020). Egg consumption, however, is still relatively low compared with other more developed countries in Asia, being only 30 per cent of the consumption in Malaysia and less than half the consumption in Thailand. Consumption in Indonesia is similar to Vietnam and the Philippines. As incomes continue to grow, per capita egg consumption is expected to grow by over 2 percent per annum to 2030.

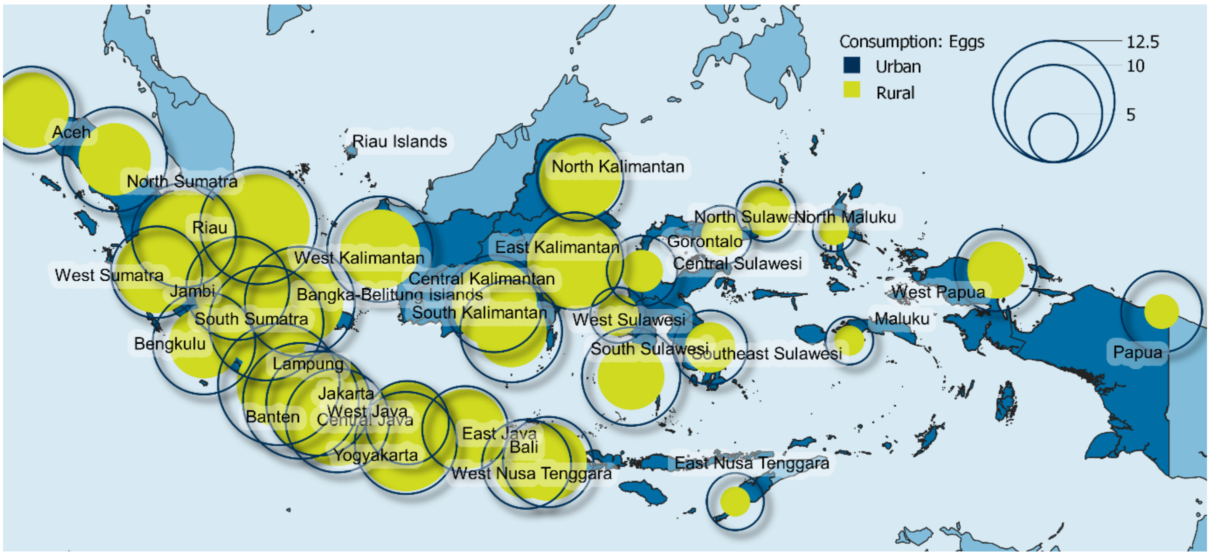


Figure 13: Egg consumption per capita in each province, showing difference in consumption between urban and rural areas. (eggs per month) (BPS 2020).

Fresh dairy products occupy a relatively small proportion of the diets of Indonesians compared with Europe, Australia and the United States. Generally, as incomes rise, in South East Asia, the per capita consumption of fresh dairy products tend not to increase as much as they do for many other countries (Figure 15). Nevertheless, per capita consumption of fresh dairy in Indonesia is low compared to Malaysia and Thailand which have higher per capita GDP that Indonesia suggesting that per capita milk consumption in Indonesia still has room to grow.

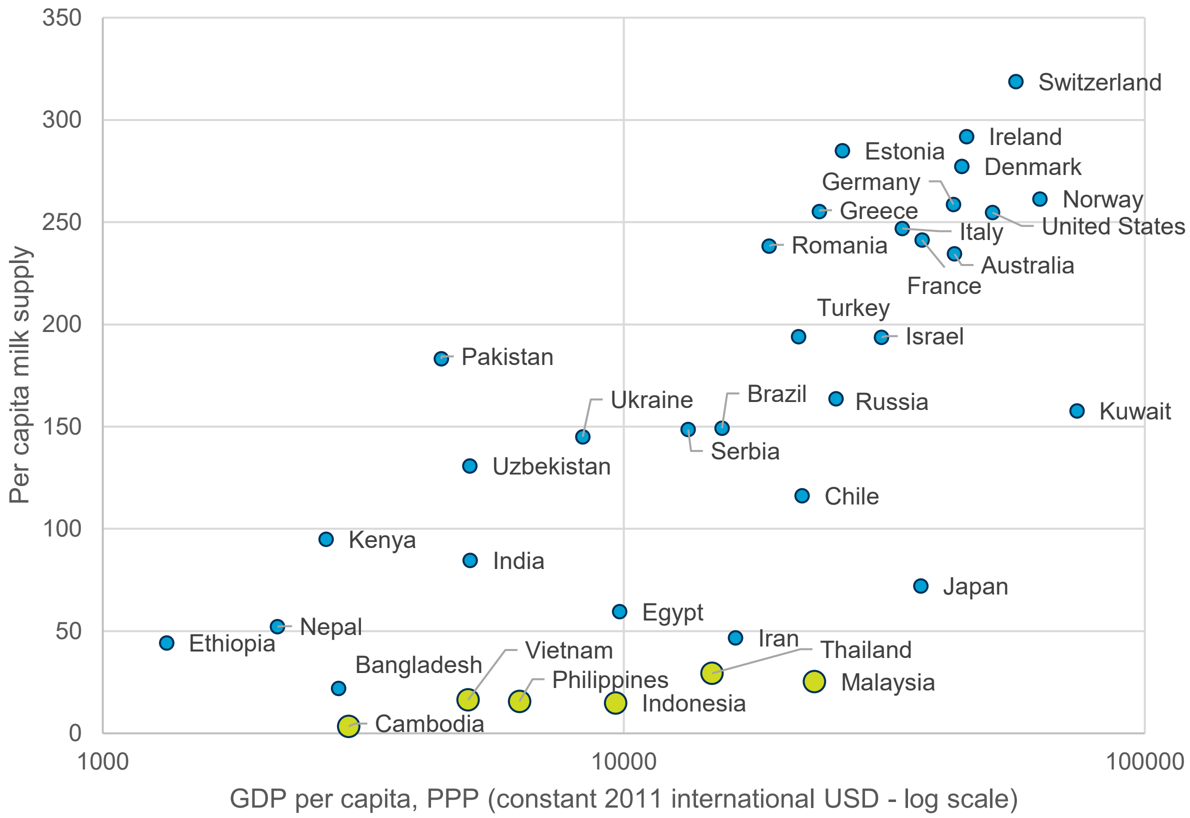


Figure 14 Per capita milk supply versus. GDP per capita (FAO cited by Our World in Data)*

**Average per capita milk supply, measured in kilograms per person per year versus gross domestic product (GDP) per capita, measured in 2011 international-USD. Per capita milk supply represents the average quantity of milk that is available for consumption by consumers; it is the sum of average consumption plus any household or consumption waste.*

Animal production: 2020 and beyond

In 2019, Indonesia produced 10.2 mmt of animal protein making it the largest producer in South East Asia. Vietnam was the second largest producer with a total 9.9 mmt, only slightly lower than that of Indonesia, but more than twice that of the Philippines the next largest producer. For much of the previous decade, however, Vietnam was a larger producer than Indonesia. Higher growth rates in Indonesia have seen it overtake Vietnam in total animal production and it is forecast to remain the largest producer in South East Asia over the next decade (OCED-FAO, 2020).

Fish from aquaculture, poultry and milk constitute the bulk of Indonesia's animal protein production (Figure 16). Together these make up about 90 per cent of the total animal protein that Indonesia has produced annually since 2010. Fish from aquaculture has been the faster growing sector with average annual growth rates of about 10% since 2010. Poultry production has also shown strong growth with annual increases in production averaging close to 5% since 2010. Both fish from aquaculture and poultry are forecast remain the fastest growing production sectors over the next decade (OECD-FAO, 2020).

Beef production in Indonesia is relatively small and has averaged about 0.44 mmt since 2015 - only slightly higher than pigmeat production (0.36 mmt) over the same period. Indonesians consume considerably more beef and veal than pigmeat hence, Indonesia imports about 40 per cent of its total beef and veal consumption.

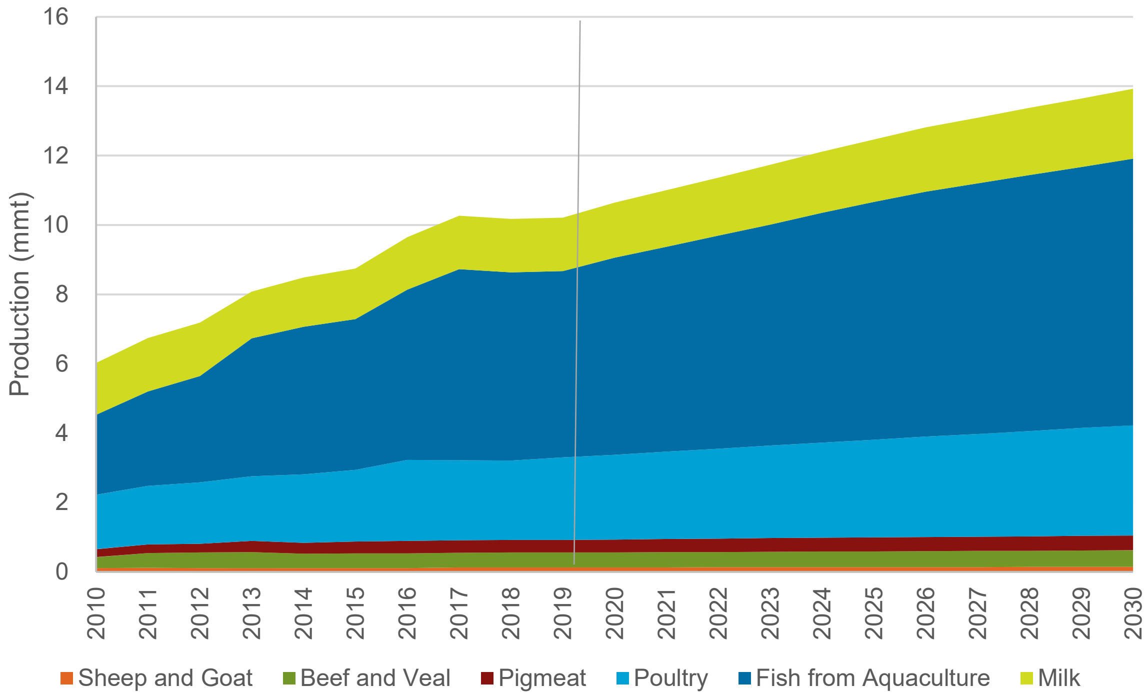


Figure 15. Total, fish from aquaculture, meat and milk production in Indonesia from 2010 to 2019 and forecast production from 2020 to 2030. (OECD-FAO 2020)

Poultry: chicken, native chicken, and duck

Indonesia is South East Asia's largest poultry meat producer with a total production of about 2.4 mmt in 2020. There are about 3.1 billion broilers and 0.26 billion layers (BPS 2020).

Total poultry meat production was approximately 2.4 mmt in 2020 which was 27 per cent of Indonesia's the total meat and aquaculture fish production, making Indonesia the largest producer of poultry meat in South East Asia. Malaysia is the second largest with a production of 2.0 mmt in 2020. Indonesian poultry meat production is growing faster than most of its South East Asian neighbours and is forecast to reach 3.0 mmt by 2030. Indonesia imports only a minor amount of poultry meat.

Chickens raised to produce poultry meat are "broilers", females raised to produce eggs for consumption are termed "layers". A supporting industry to the two, is the breeder industry. Breeders are chickens raised to produced fertilised eggs that when hatched may be broilers, layers or breeders.

Poultry meat is supplied mainly through commercial broiler chicken production (76%), local native chicken (19%), layer meat (3%) and commercial duck farming (2%) (Figure 17). Native chickens or "Ayam Kampung" raised in villages are preferred by many Indonesian consumers, although they continue to lose market share against broilers. Historically, native chickens produced much of Indonesia's egg production. Today, egg production is dominated by intensive layer industries.

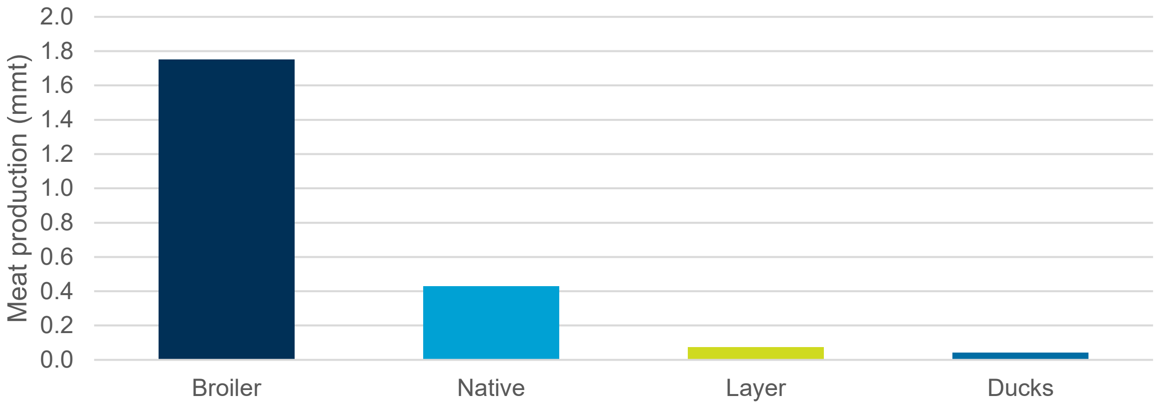


Figure 16. Annual production of poultry meat as commercial broiler, native chickens, layer meat and duck production (five-year average 2015-2019) (OECD-FAO, 2020, USDA, 2020)

Poultry meat and egg production is concentrated in Java, close to large markets.

Broiler and layer production extends across Indonesia (Figure 18). Java is the centre of production supplying about 57% of Indonesia's broilers and 54% of Indonesia's eggs. Broiler production in java is concentrated mostly in west Java, while layer production is concentrated in east Java (Figure 19).

Most of the production on Java is consumed in Java, therefore, a sizable proportion, nearly 50 per cent of broilers and eggs, are produced on other islands, though not in such concentrated production hubs as on Java.

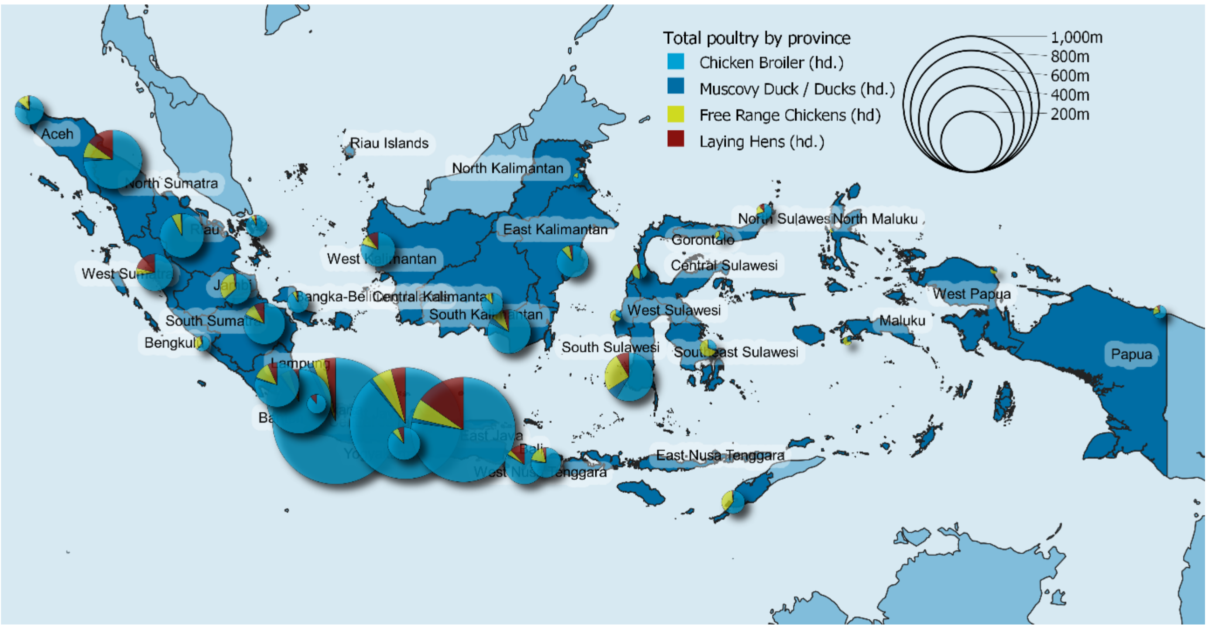


Figure 17: Spatial distribution of poultry production in Indonesia (BPS 2020)

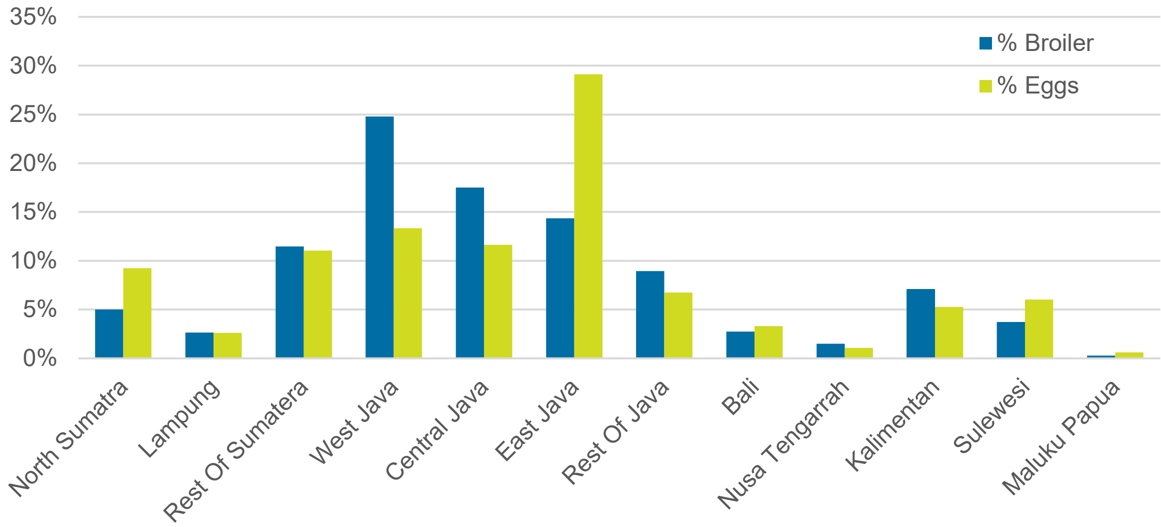


Figure 18: Indonesian production of broiler and eggs by region, 2019 (Based on: Poultry reforms on poultry in Indonesia Ferlito and Respatiadi, 2018)

Structure of the poultry industry

Large feed companies provide substantial support to contracted farms and farmers.

The broiler and layer sectors are increasingly industrialised, vertically integrated with rapidly improving in productivity. Over sixty percent of poultry production is now generated by industrialised farms using closed housing production systems. The remaining 40 per cent of poultry production mainly originates from small-medium enterprises using open housing farming systems.

The main poultry production models in Indonesia include:

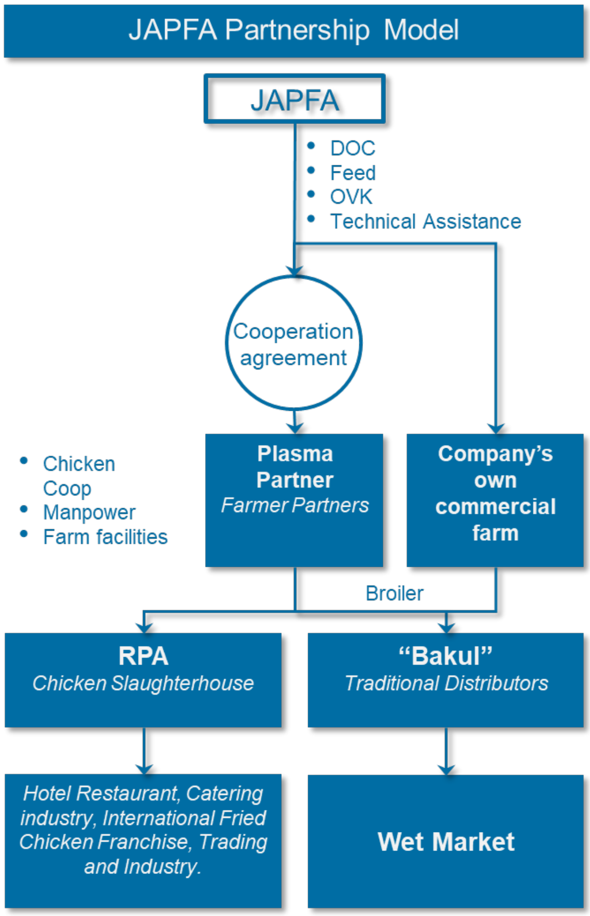
- Company farms wholly owned by vertically integrated companies operating closed housing production systems. JAPFA is a major feed company (see case study example below). They wholly own production farms and supply inputs to contract producers.
- Contractors (sometimes called farmer partners) that supply the vertically integrated companies. Contractors receive day old chickens, animal feed, medicines and technical support from the vertically integrated companies that then purchase the chickens once they have been grown out to the desired weight. (See JAPFA case study example below.
- Independent producers, including small holders that are not aligned to large poultry companies. The independent producers, who are reducing in number, manage their own inputs, which often includes mixing their own feed, although many will also purchase inputs from vertically integrated feed companies.

Case Study: JAPFA Partnership model

JAPFA runs partnership programmes with farmers, where it carries out knowledge transfer to improve their technical skills and raise their farming capabilities in producing healthy and affordable protein. These efforts will ultimately help them become better farmers and improve their economic wellbeing. In 2017, JAPFA established partnerships with more than 9,000 poultry partners in Indonesia.

Starting in 1998 when the financial crisis hit Indonesia, the programme aims to create job opportunities through the development of local farming and raise farmers abilities to increase production efficiency. Under the programme, JAPFA supplies its farmer partners with day old chickens (DOC), medicine, feed, vaccines and chemicals, as well as veterinary service and technical assistance.

Farmer partners receive information about how JAPFA manages the sales and marketing. In situations when broiler market prices are high, the farmers receive the upside accordingly. This partnership programme with small local farmers is in line with JAPFA's goals of sustainable development and poverty reduction.



Source: JAPFA (2018)

Over time consumers will purchase less poultry from wet markets, and more from modern retail chains.

Traditionally Indonesian consumers have preferred to purchase live poultry or poultry products from local markets. Consequently 80-90 per cent of finished poultry are sold live through wet markets. The proportion of chicken meat sold through supermarkets is increasing, though it is still small given prices are generally higher. Post-Covid, there is some expectation of a shift in consumer sentiment away from the wet markets into retail and supermarket value chains.

Duck production is the second largest component of the poultry industry. Indonesia is one of the largest duck producers globally. The raising of ducks in Indonesia consists of traditional (foraging and backyard raising), semi-intensive and intensive farming practices. About 20 per cent of the duck population is in West Java (Ismoyowati, *et al,* 2018). While most ducks are produced for meat, there is also a large duck egg industry. Ducks are typically fed a wide range of materials including dried rice, rice bran, trash fish, snails, food scraps and animal waste. These products are sourced locally within the area in which the ducks are produced.

Poultry productivity and profitability

Feed is the largest component of the operating cost for broiler and layer poultry production.

Input costs for the different types of poultry production reflect the level of industrialisation within that sector (Table 3). Feed is the largest component of the operating cost in broiler and layer enterprises with 60% to 90% of the total feed cost being feed concentrates, which are a combination of grains or manufactured feeds. Feed costs are lower in duck and native chicken production with lower use of concentrates.

Table 3: Revenue and costs within poultry enterprises in Indonesia (Rp 000's) (BPS 2020)

Description	Broiler	Layer	Duck	Native Chicken
A. Revenue (RP 000s)	175,951	209,239	133,990	116,260
Production (%)	100%	100%	100%	100%
Weight Change	99%	8%	24%	77%
Eggs		89%	74%	15%
By-products	1%	1%	1%	8%
Sales of Elderly Livestock		1%	1%	
Day Old Chick/Day Old Duck Production		1%	1%	
B. Production Cost (RP 000s)	127,408	136,385	106,320	68,600
Production Cost (%)	100.00	100.00	100.00	100.00
Wages	10%	17%	30%	41%
Feed	57%	72%	58%	40%
a. Forage Animal Feed	*1%*	*16%*	*4%*	*8%*
b. Manufactured Feed/Concentrate	*52%*	*45%*	*16%*	*5%*
*c. Other Feed**	*4%*	*11%*	*39%*	*27%*
Fuel	1%	1%	1%	1%
Electricity	1%	1%	1%	1%
Water	0%	1%	1%	2%
Health Care (Vaccinations)	2%	2%	1%	2%
Other Expenses	7%	6%	7%	9%
Purchasing Day old chicks	23%		1%	3%
Operating Margin (per 1000 head)	48,544	72,854	27,670	47,660
C. Percentage of Expenditures to Revenue	72%	65%	79%	59%

** (Agricultural waste, household waste, tofu waste, oilcake, palm, bran, salt, etc.)*

Ruminants and pigs

Total ruminant (cattle, sheep, and goats) and pigmeat production was about 0.9 mmt in 2020 which was 10 per cent of Indonesia's the total meat and fish from aquaculture production, making Indonesia the largest ruminant producer (mostly beef and veal) in South East Asia but a relatively small pigmeat producer. Projected growth in the Indonesian ruminant and pigmeat production is modest compared with its South East Asian neighbours and is forecast to reach just over 1 mmt by 2030.

Most beef is produced by small landholders, though production through feed lots is increasing.

Beef and pigs dominate the production of animal protein outside of the poultry and fish sectors, with Indonesia producing 0.41 mmt of beef per annum, and 0.36 mmt of pig meat. In 2020 the cattle population in Indonesia was around 17.1 million head. Around 43% of cattle are located on Java, 23% in the Eastern islands including Sulawesi and the remaining 34% spread throughout Indonesia (Figure 20).

Sheep meat production occurs largely in Western Java, while pigmeat production occurs mostly in north Sumatera and Nusa Tengarra.

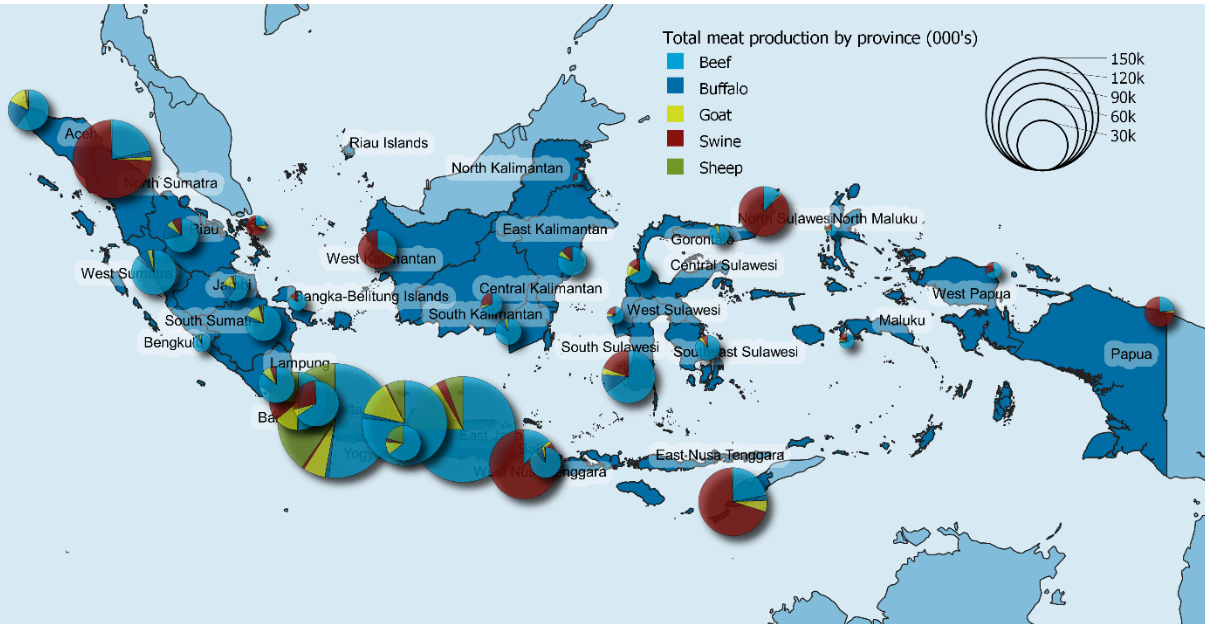


Figure 19: Meat production from ruminants and pigs in Indonesia by province (BPS 2020)

Structure of the beef industry

There are distinct sectors within the cattle industry, differentiated through the company structures, head per operation and in the case of the large feed lotting companies, the type of cattle. These sectors include the large feed lotting industries on Java and Sumatra with the dominant species being Ongoles (*Bos Indicus*), either Brahman or Brahman cross, often imported live from Australia for fattening. Smallholders also use Ongoles across most of Indonesia especially Java, although in eastern Indonesia Bali cattle (*Bos Javanicus*) become more prevalent. Breeds are restricted to regions, sometimes by legislation.

Smallholder cattle producers are distributed throughout Indonesia while feedlot beef production is concentrated around urban centres on Java.

Traditionally, most of the cattle in Indonesia are owned by small landholders who keep cattle as a store of wealth and as draught animals.

Intensive beef production is mostly occurring within feedlots near urban centres. Cattle are imported or brought in from domestic cattle farmers to be fattened. Most of the commercially produced beef is sold into nearby urban centres, limiting transport cost and reducing the need for chilled supply chains.

Beef and buffalo meat is also imported, either chilled or frozen, from multiple sources including Australia, India, Brazil, or Argentina. However, the supply from some countries can be interrupted by outbreaks of foot and mouth disease, a highly contagious virus that presents risks to Indonesia's domestic cattle industry.

The domestic beef value chain is long incorporating seven to nine stages, with most beef sold in wet markets as large cuts.

The livestock value chain in Indonesia is relatively long with seven to nine stages with each stage adding costs resulting in a lower price to the producer or an increased price to the consumer.

As with poultry, most beef is sold through wet market, although, supermarkets are becoming preferred in wealthier urban centres.

In the wet markets, there are often limited cuts of beef, being: hind, fore, and a premium fillet, and all parts of the carcass are available. In the supermarkets there are many individual cuts of meat, that favour the higher quality cuts, and not all parts of the carcass are used. While the price of the supermarket meat is higher, the quantity of meat being used from each carcass is reduced, meaning the producer may not accrue significantly higher returns from this market, despite higher prices.

Beef productivity and profitability

Cattle feed typically consists of locally sourced lower quality ingredients, though still comprises around 60% of the cost of production.

Feed costs total nearly 60 per cent the operating costs of smallholder beef producers. Table 4 shows the cost of small beef production relative to dairy and pigmeat production (BPS, 2020). Smallholder beef cattle are typically fed locally sourced ingredients including forages and crop residues while beef feedlots will rely more on agro-industrial by-products (e.g., onggok) and silage (see section 3). Neither enterprise use large volumes of manufactured feed/ concentrates compared with dairy production where manufactured feed concentrates make up to nearly 12 per cent of feed costs.

Table 4: Revenue and operating costs within select animal enterprises in Indonesia (BPS 2020)

Description	Beef Cattle**	Dairy Cattle	Pigs
A. Revenue (RP 000s)	4,990	11,008	1,164
Production (%)	100%	100%	100%
Weight Change	96%	39%	99%
Milk		59%	
By-products	4%	2%	1%
Sales of Elderly Livestock		1%	
B. Production Cost (RP 000s)	3,851	9,035	950
Production Cost (%)	100%	100%	100%
Wages	29.0%	23.6%	33.6%
Feed	58.9%	67.1%	49.8%
a. Forage Animal Feed	*46.4%*	*40.1%*	*10.8%*
b. Manufactured Feed/Concentrate	*1.5%*	*11.8%*	*3.6%*
*c. Other Feed **	*11.0%*	*15.2%*	*35.4%*
Fuel	2.6%	2.6%	4.8%
Electricity	0.4%	0.3%	0.2%
Water	1.4%	0.5%	1.7%
Health Care (Vaccinations)	1.9%	0.8%	0.7%
Other Expenses	5.7%	5.2%	9.2%
Operating Margin (per head/year)	1,139	1,973	214
C. Percentage of Expenditures to Revenue	77%	82%	82%

** (Agricultural waste, household waste, tofu waste, oilcake, palm, bran, salt, etc.)*

*** Value per head for a year, for all animal industries presented.*

Animal products: dairy and eggs

Indonesia is a minor milk producer (1.5 mmt) on a global scale, but a major egg producer (2.1 mmt).

Indonesia is a small dairy producer on a global scale, with about 1.5 mmt of milk produced in 2019 (FAO). This compares to over 21 mmt produced by New Zealand and 9 mmt produced by Australia. Nevertheless, Indonesia is the largest dairy producer in South East Asia producing 50 per cent more than Thailand, the next biggest producer. Indonesian production supplies less than 25 per cent of its demand with most milk and milk products being imported from New Zealand, Australia, the United States and elsewhere. There is substantial potential for increased productivity within Indonesian's dairy sector and fresh milk production is expected to increase by 20-30% by 2030 (OECD-FAO, 2020).

In contrast to dairy, Indonesia is a significant global egg producer. Production totalled more than 2 mmt in 2019 making it the largest egg producer in South East Asia, almost twice as large as Thailand, the next largest producer. However, Indonesia does not import or export a significant amount of egg products. If Indonesian egg production continues to grow at the same pace as it has done since 2010 the total production will be nearly 80% larger in 2030 compared with 2020.

Structure of the dairy industry

> *Nearly all production is currently on Java, though some expansion to Sumatra is occurring.*

The dairy sector consists of small holders and modern integrated dairy companies. Smallholders typically own one to five cows and sell milk surplus to their own needs to integrated dairy companies. The integrated companies produce milk in large modern farms while also operating processing facilities. Smallholders account for 77 percent of Indonesia's fresh milk production.

Most smallholder dairy farmers graze their cattle on forage and milk yields are less than 10 litres per cow per day. Profitability is variable and producers often sell animals for beef meat when beef prices are favourable.

Modern, integrated dairy companies comprise ten percent of the dairy herd yet contribute 23 percent of fresh milk production. The integrated dairy companies average 5,000 head of lactating dairy cows per farm. In general, output on these farms is more than 20 litres per animal per day.

Almost all dairy producers are located on Java close to the dairy processors (Figure 21). Indonesian government policy encourages development of dairy production outside of Java and two new farms have recently been built on Sumatra. Policies are in place to increase integration between milk processors and independent dairy producers as well as partnerships between cooperatives and processors.

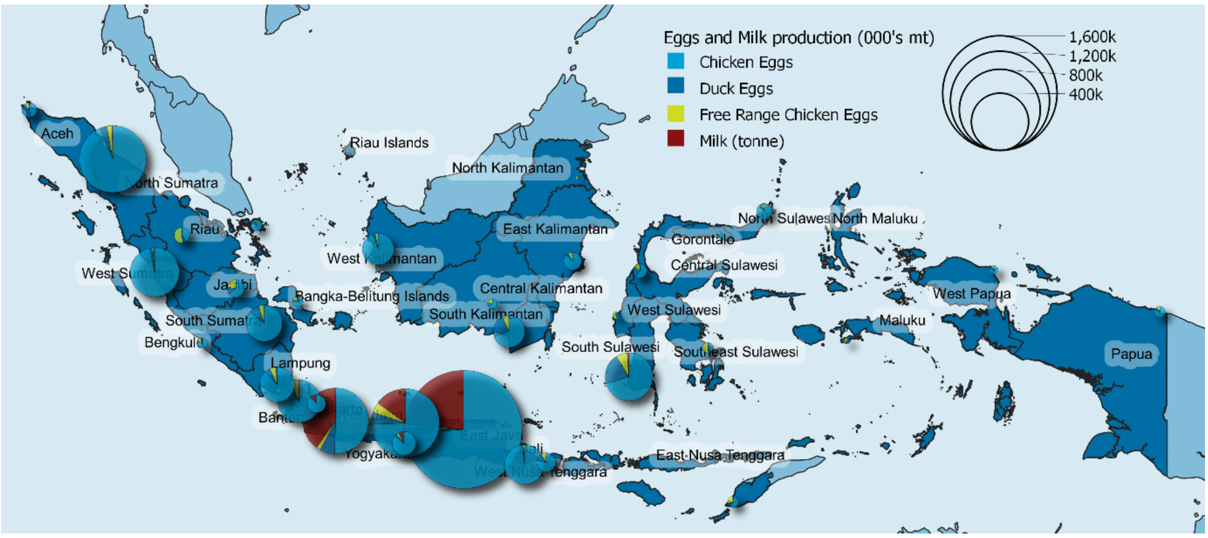


Figure 20: Production of dairy and eggs by province (000's mt) (BPS 2020)

Most dairy farmers are members of local village co-operatives.

Most small holder dairy producers are members of a local village co-operatives (Koperasi unit desa or KUD). There are about 220 KUDs in Indonesia involved in the dairy industry with almost 100,000 dairy producers as members. A “dairy” KUD provides a range of services including milk collection, quality checks, and payment oversight. Price incentives are used to encourage better farm management practices and higher quality milk.

Aquaculture: fish and shrimp

Indonesia is becoming less reliant on wild captured fish as aquaculture production grows to meet domestic demand.

Indonesia is the third largest aquaculture producer globally after China and India. producing 5.5 million tonnes of fish and shrimp per annum. Wild caught fish (both inland and marine) are the main source of fish in Indonesia. Over the past 20 years most capture fisheries have become fully exploited or over exploited and supply has plateaued. Aquaculture has rapidly become an alternate and important source of supply to meet the continued growth in demand for fish (Figure 22).

About 85 per cent of total fish production (wild caught and aquaculture) is supplied to the local market with the rest exported mainly to other South East Asian countries, China, and USA.

Since 2000, fish from aquaculture production has increased at an average annual rate of more than 12% compared with growth in wild-caught fish of just under 3%. Indonesia is well suited to aquaculture production and continued strong growth is projected to 2030. Most of the 2 mmt forecast increase in Indonesia’s fish consumption over the next decade will be supplied by increased aquaculture production.

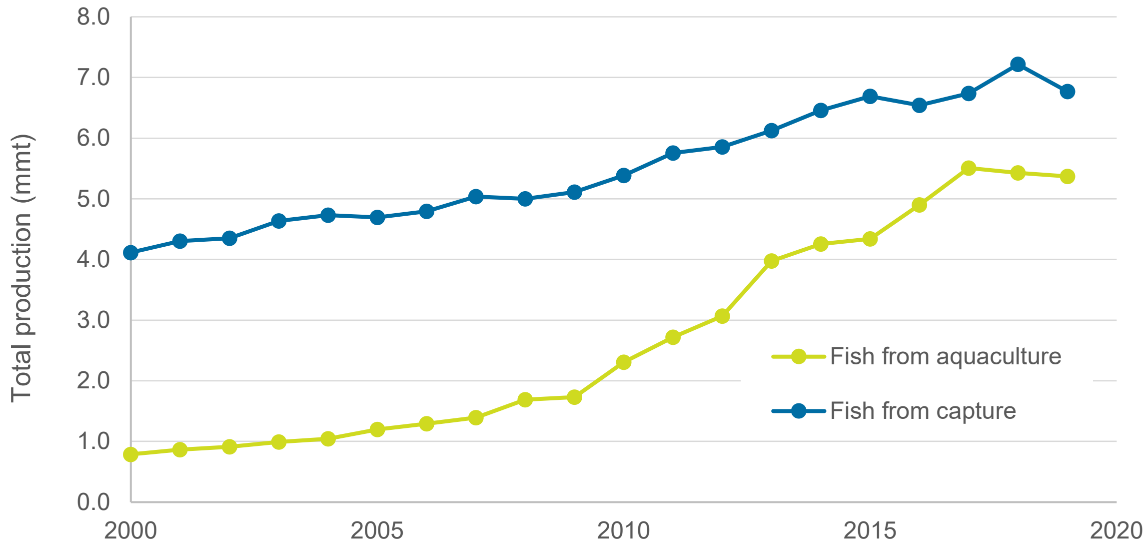


Figure 21. Total supply of fish in Indonesia from wild caught fisheries and aquaculture. (OECD-FAO, 2020)

Structure of the aquaculture industry

Aquaculture in Indonesia is undertaken in fresh, brackish and marine water with eight species making up the bulk of production. Freshwater aquaculture production (mainly tilapia, carp and catfish species) is the largest sector accounting for about 65% of production followed by shrimps and prawns in brackish water making up 17%. Diadromous (mainly milkfish) account for about 16% of production. Marine aquaculture (mainly gropers and mullets) makes up only a minor proportion of total fish output, the predominant use of marine aquaculture is for seaweed production (production figures are not considered here).

Shrimps and prawns are the main aquaculture species exported from Indonesia because they are considered an expensive protein source and domestic Indonesian consumption of shrimps and prawns remains relatively low.

Aquaculture value chains are long and complex, with multiple models of production, and are dominated by large players.

Production is conducted in a range of farming systems from small independent contract farmers (10-20% market) to larger independent corporate farmers (50%) that often have contract purchase arrangements with preferred companies and integrated corporate farmers (30-40%). Intensive farms account for 75% of production while representing only 20% farmers (Rubel *et al,* 2019). As in the other livestock industries the aquaculture value chain can be long. For example, Rubel *et al*, (2019) reported that Indonesia's farmed shrimp supply chain includes feed mills, hatcheries, farmers, middlemen, processors, exporters, and retailers with interrelationships common.

The aquaculture industry has relatively small consumption of commercially manufactured feed. Fish feed for *Clarias* catfish (35%), tilapia (25%) and common carp (25%) dominate Indonesia's aquaculture feed production and consumption (1.4 mmt), followed by shrimp feed (0.35 mmt). Marine fish feed production is minor at around 16kt.

Rapid expansion in aquaculture has brought with it a range of social and environmental challenges, including loss of mangrove and wetland ecosystems, pollution of waterways, and marginalisation of local farmers. Innovations and improved farming practices are required to lift productivity to meet ambitious production targets to satisfy future demand (Henriksson *et al*, 2019). More efficient use of plant-based feed sources is an important mechanism to lift future productivity. This could include a greater production of omnivorous fish that can be raised on plant-based proteins as well as fish meal that are also suitable for the domestic market.

Commercial feed manufacturing and distribution

Consumption of commercial feed in 2020 is estimated at 21.7 mmt and growing at 7.1% per annum.

Indonesia is the second largest user of commercial feed in Asia after China. Commercial feed consumption was 11.3 mmt in 2011 and was estimated at 21.7 mmt in 2020 (Figure 23). Demand growth has been consistent at 7.1% per annum between 2011 and 2020 and is projected to continue to increase at a similar rate beyond 2020.

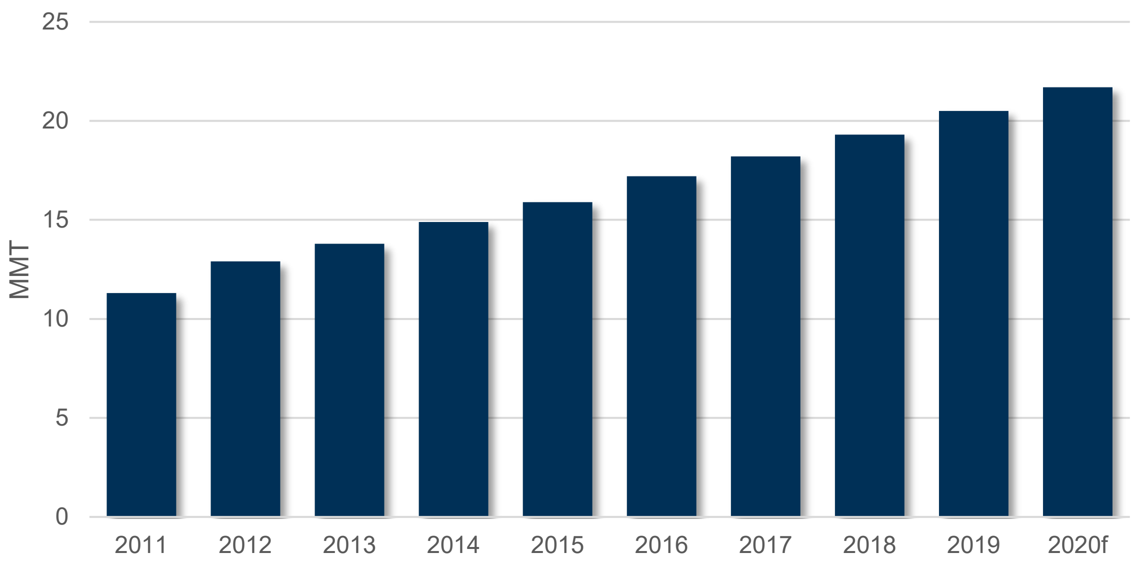


Figure 22: Consumption of animal feed in Indonesian livestock industries. (Desianto 2019)

There are 103 feed mills in Indonesia with a capacity of 25.4 mmt, around 15% more than current utilisation (Figure 24). Around 35% of mills and mill capacity is in the Banten, West Java and Jakarta regions. Around 26% of the capacity and mills are in East Java. These areas have the highest population and good access to port facilities, many mills are near corn producing areas, and in some cases, centres where rice bran is produced. On Java, feed mills are often nearby to ports, where they can more easily access imported ingredients.

Table 5: Indonesian Feed Mills Capacity by province

Area of plants	Number of feed mills	(mmt/year)
North and West Sumatra	12	2.8
Southern Sumatra and Lampung	6	1.4
West Java and Jakarta	37	9.2
Central Java	12	2.5
East Java	26	7.2
Kalimantan	3	0.8
Sulawesi	7	1.5
Total	103	25.4

Figure 24 shows most of the major feed mills in Indonesia. Smaller mills are not shown. Smaller animal production groups have mills available to customise feed rations. These smaller mills can process up to 160kg per day, enough to service up to 50 animals[3]. The approximate number of primary and secondary mills is presented in Table 5, highlighting the dominance of feed production in West and East Java.

[3] Animals are consuming 16-17kg of feed a day, of which 20% is grain

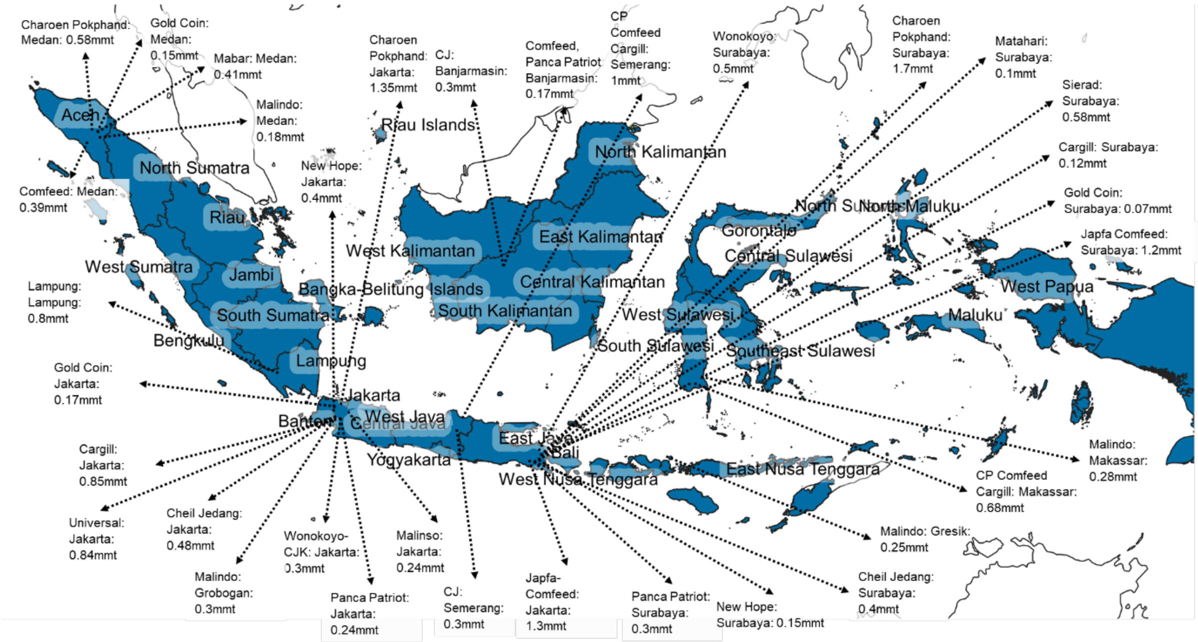


Figure 23: Feed milling capacity in Indonesia (Sudharma 2019)

> *The poultry industry is the dominates compound feed ingredients use.*

The poultry industry is the largest user of commercially produced feed using 86% of the available commercial feed, or approximately 17.5 mmt. The broiler industry consumes 52% of the feed volume, 32% for layers and the balance across other livestock, including aquaculture, cattle, and dairy (Figure 25). Production of compound feed for aquaculture is around 1.6 mmt with around 81% used for fish production, the balance for shrimp production. The proportion of feed used by the broiler industry will remain dominant and is expected to increase by about 1% by 2025.

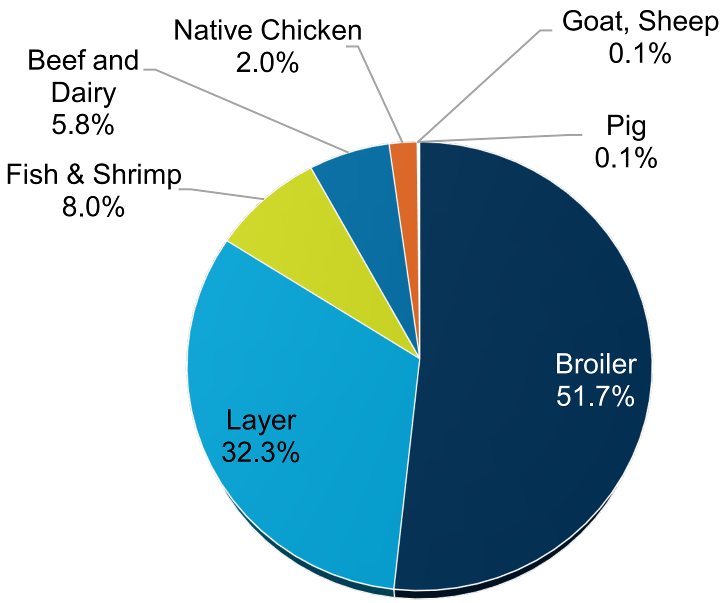


Figure 24: Percentage of feed stock used in Indonesian livestock industries in 2020 (based on USDA, 2020)

Six companies, mostly foreign owned, hold around 80% feed market share.

Commercial feed supply is dominated by six companies, mostly foreign owned. Companies include CP Indonesia, JAPFA, MAIN, New Hope, CJ, and others (Figure 26). Many feed companies are vertically integrated producing more than just feed. For example, all major feed companies supply day old chicken (DOC) to the poultry industry in addition to feed production (Figure 27).

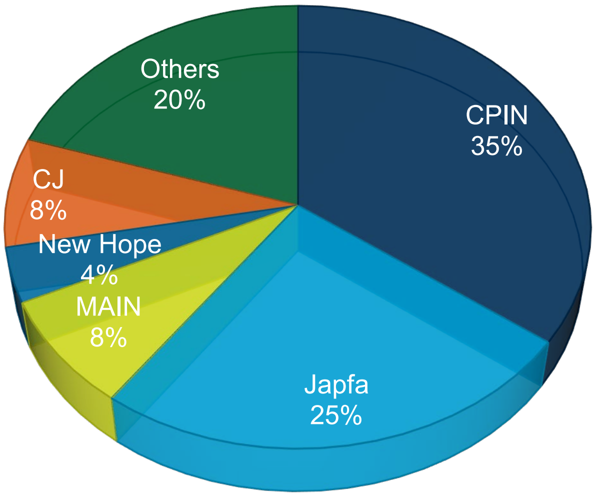


Figure 25: Indonesian feed production capacity share (2019) (Malindo 2020)

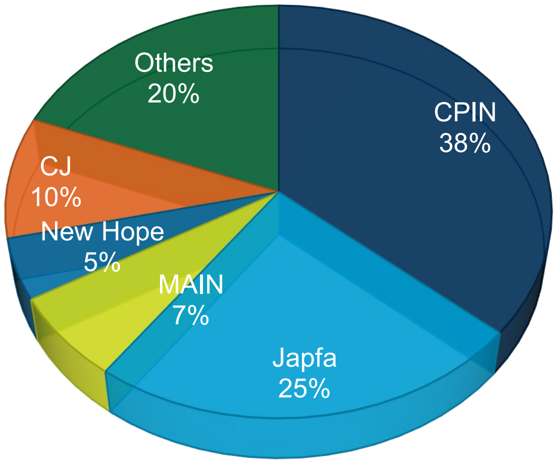


Figure 26: Indonesian DOC production capacity share (2019) (Malindo 2020)

GPMT is the peak industry organisation for the Indonesian feed industry

Many feed mills are members of the Indonesian Feed Millers Association (Gabungan Perusahaan Makanan Ternak (GPMT). The association works with industry stakeholders including the community and government to establish an efficient commercial environment for the stock feeding industry.

Indonesia's geography and infrastructure present challenges to the transport of animal feed within Indonesia – a country made up of 13,000 islands and 5,000 km from west to east. Animal feed is transported across Indonesia and between islands often in 50 kg bags on multi-purpose trucks or shipped by small vessels. The imported feed grains are usually bagged at the port, prior to being loaded on trucks. Anecdotally it can cost US$100 per tonne to transport feed from West Java to the inland regional locations in central and east Indonesia. Given the high internal transport cost, the feed mill location has important implications for the relative cost competitiveness of imported and domestic feed ingredients.

Indonesia's geography and infrastructure increases the cost of feed distribution.

Processing methods

The broad scales in animal production lend to a broad range of feed processing methods.

The typical size of commercial feed mills in Indonesia ranges from about 10,000 tonnes per month up to 100,000 tonnes per month. At the other end of the scale, small hand mills are used by some smallholders. A wide range of local and imported feed ingredients are used to manufacture feeds at least cost (see section 3 for further information). Cost, safety and reliability of supply of feed ingredients are important considerations for all feed manufacturers.

Outside the feed mill sector, processing methods vary depending on the size and scale of the feed use, the origin of the feed material and the nutritional requirements of the animal. For example, many beef feedlot producers source waste from the agro-industrial sector (e.g., cassava waste or fruit pulp), they dry the products, and then combine these with other ingredients.

The cost of feed stock is heavily influenced by the price of domestically produced grain.

The cost of feed is heavily influenced by the availability and price of the major raw materials required to meet the nutritional needs of the animals. For example, the availability and price of corn and soybean meal are particularly important in commercially produced poultry feed as the two products represent 75 per cent of the finished product. The corn used is often produced domestically, while soybean meal is imported. The price of local corn is heavily influenced by Indonesian seasonal production conditions as well as government policy. The imported soybean meal is influenced by international conditions (e.g., global soybean production, exchanges rates, global freight costs etc).

Local production and processing of other domestically produced crops such as rice – itself a major food crop in Indonesia – also influences the base-cost of feed ingredients. For example, rice processing results in 57-60% polished rice, 18-20% husk and 8-10% bran. Rice bran is an important feed ingredient, so the domestic environment for rice production and processing influences its cost and availability.

Feed mill operating costs

Raw materials account for 83-90% of commercially produced feed costs

The Indonesian Feed Mill Association reported the 2019 broiler and layer feed cost structure as per Table 6. Raw materials for feed can account for around 83-90% of the feed cost. The manufacturing cost, marketing and overheads combined are 10-15% of the total cost. Give that raw materials contribute a high proportion of the operating costs mills seek lowest cost ingredients where possible.

Table 6: The proportion of costs distributed within the Indonesian feed mill industry

Cost component	Broiler (%)	Layer (%)	Notes
Raw Material	83 - 89	84 - 90	Raw material includes premix and medicine
Manufacturing	3.6 - 3.8	4.1 - 4.4	Manufacturing includes packaging
Overhead	3.7 - 3.8	4.2 - 4.4	Overheads include operating expenses
Marketing	3.7 - 9.4	2.7 - 7.2	Marketing includes transport

Reports indicate that gross margins in the poultry feed business have been relatively stable over the past decade. For example, JAPFA has reported that gross margins on poultry feed were over 10 per cent for every financial period between 2010 and 2017 despite the high level of volatility in the key raw material prices and a weakening rupiah over this period affecting import costs.

Sources of feed

75 % of Indonesian feed ingredients are produced domestically.

Indonesia uses a wide range of feed ingredients from locally produced and imported sources. Corn and by-products from agro-industrial processing are the main domestic feed sources while soybean meal and wheat are the main imported feed ingredients (Figure 28).

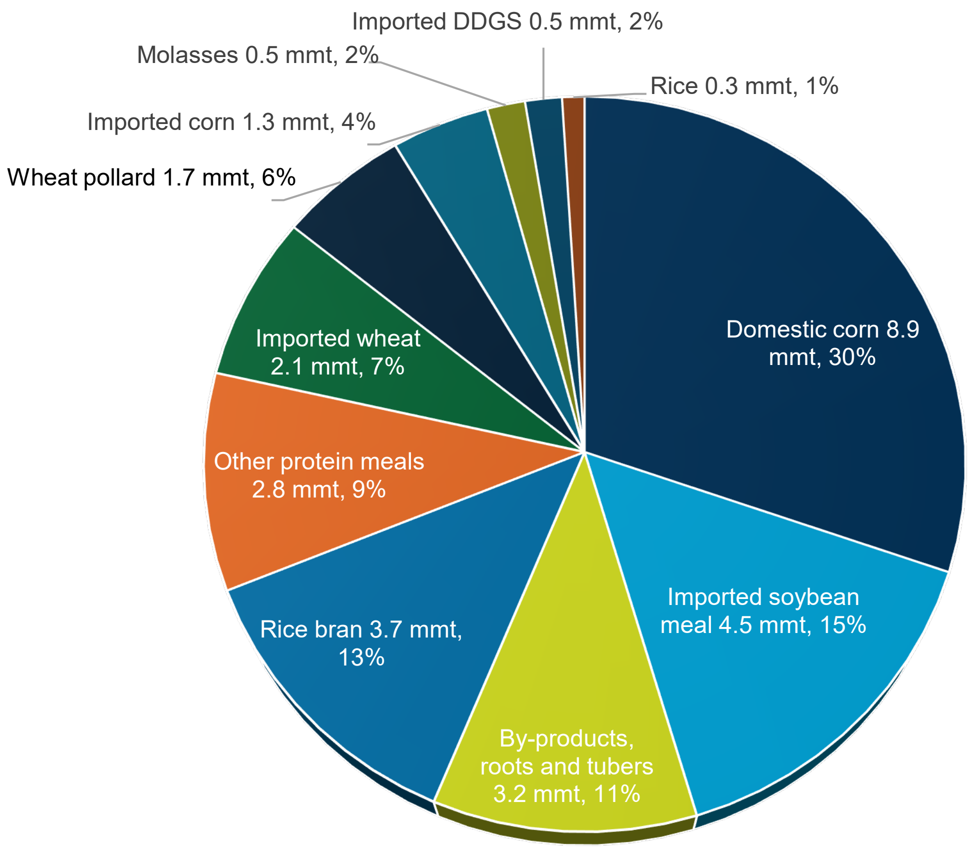


Figure 27. Quantity of major plant-based feed sources produced in Indonesia or imported (excluding crop residues, silage and forages) - five-year average 2015-2019. (OECD-FAO, 2019, USDA 2020, Newby 2020)

Protein meals include palm kernel expeller, groundnut meal, copra meal, sunflower meal, and cottonseed meal. By-products include onggok, fruit pulp waste, molasses, coffee husks.

Corn

Indonesia corn production has increased substantially, buoyed by strong feed demand and government initiatives.

Corn is grown throughout Indonesia and is used for feed, food and industrial purposes. The largest use of corn is as a feed grain where it makes up nearly 30 per cent of all feed concentrate materials used in Indonesia.

Corn produced for grain is cropped two to three times per year. An extra corn silage crop can also sometimes be grown. Producers rely on rainfall with the crop planted and harvested from October to February (49%), March to June (37%) and July to September (14%) dependent upon regional and seasonal influences (USDA 2020a).

Most corn is produced on Java (58% of production), followed by Sumatra (13%), Sulawesi (11%), and Nusa Tenggara (7%) (Figure 29). Feed production sites are often located close to major corn producing regions.

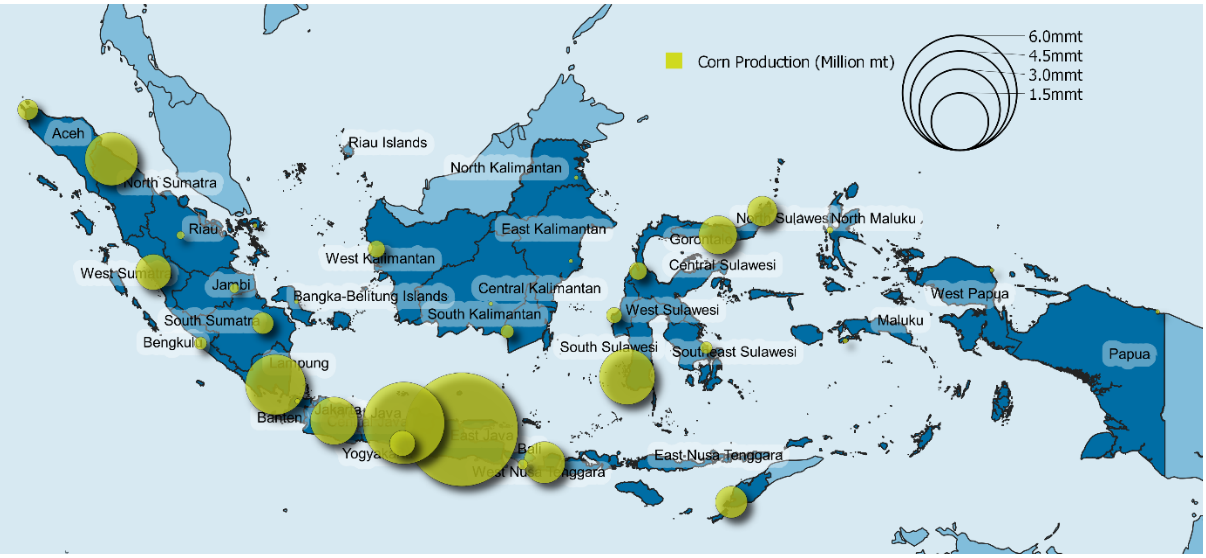


Figure 28: Location of corn production, percentage of total Indonesian corn produced in each province, based on 2013-2015 production seasons. (BPS 2020)

Production estimates for Indonesian corn vary widely. BPS reported the production of corn in 2020 as 25 mmt, while the USDA report corn production in 2020 was closer to 12 mmt (Figure 30). Using BPS data, corn production has more than doubled over the past 15 years despite the area sown only increasing by 20 per cent.

Increased feed mill demand has improved producer margins, as have other government and industry initiatives including support for fertiliser and seeds, and pricing regulations at farmer and feed mill level. Higher yielding corn hybrids and technical improvements have also assisted productivity. Despite this increase, domestic corn production has been insufficient to meet the combined demand for food and feed use, leading to corn being imported regularly.

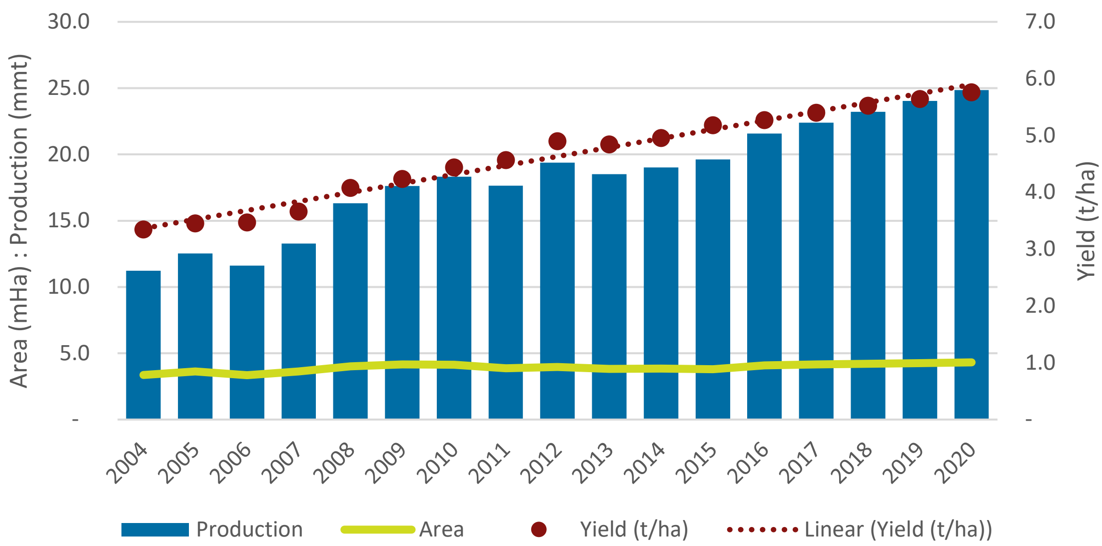


Figure 29: Indonesian corn production (mmt), area (mHa) and yields (mt/ha). (BPS 2020)

Moisture levels in Indonesian corn are usually high impacting on quality and logistics.

Indonesia's growing environment generally produces corn with a higher moisture and protein content, and lower sugar level compared with corn imported from the United States or Argentina. Moisture levels can be high particularly if farmers harvest early, hoping to gain higher prices by selling their crop before the main harvest period. This can result in corn moisture levels of up to 35% compared to 15-20% if harvested normally. High moisture levels increase risk of grain spoilage and mycotoxin contamination which substantially lowers it's value as a feed. Some of the larger feed mills have installed corn dryers and silos to allow increased flexibility in purchasing grain at different times, while also mitigating the risk from high moisture levels.

Other feed ingredients

Aside from corn, Indonesia produces a range of other feed ingredients.

Forages, crop residues and by-products from Indonesia's agro-industrial processing sector are readily available and are used widely for animal feed. A brief overview of production levels is presented below and additional information on nutrition is supplied in section 3.

Onggok

Cassava waste, known as Onggok in Bahasa, is a by-product from cassava flour production. According to BPS, cassava production in Indonesia has averaged about 15 mmt annually over the past five years. Of total cassava production, approximately 10% to 30% becomes Onggok or waste material, (Edama, 2014 and Permana *et al,* 2020). Increasing industrialisation and improvements in the capacity to extract starch has reduced the energy and nutrient content remaining in onggok with anecdotal reports indicating that its value as feed stock is diminishing.

Rice bran

Rice bran is a by-product of milling rice. Based on Indonesian rice paddy production of about 46 mmt annually (OECD-FAO, 2020), rice bran production is about 3.7 mmt. Rice brans turn rancid relatively quickly subsequently impacting storage and utilisation.

Wheat Pollard

Wheat pollard is an important domestically produced feed source in Indonesia. The flour milling industry, processes about 7-8 mmt of imported wheat annually consistently producing just under 2 mmt of wheat pollard per annum which is sold to feed manufactures and other users.

Crop residue, forage and silage

The Indonesian livestock industry and especially the cattle and dairy industries are reliant on a wide range of crop residues, forages and silage feeds. Volumes are difficult to quantify.

Imported feeds

Indonesian import of wheat, soybean meal, and DDGS are forecast to grow over the next decade.

Indonesia imports protein meals and feed ingredients when domestic resources are insufficient to meet needs, or if there is no domestically produced product available to meet animal feed requirements. Commodities imported for feed mostly include soybean meal, wheat, corn, DDGS and corn gluten meal. The volume of imports can vary substantially from year to year. Except for corn, OECD-FAO forecasts that import of most feed materials will continue to grow significantly over the next decade (Figure 31).

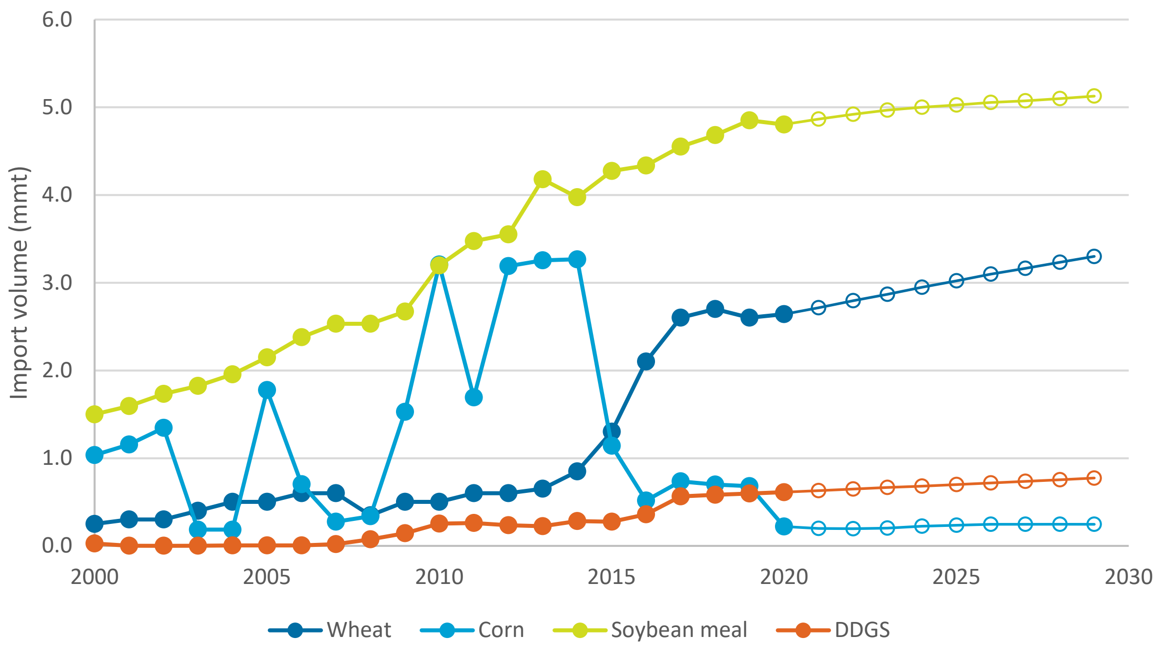


Figure 30: Main feed materials imported by Indonesia from 2000 to 2019 and forecast imports from 2020 to 2029 (FAO-OECD, 2020).

The importation of feed grains and feedstocks is regulated by the state-owned Indonesian Bureau of Logistics (BULOG), which is Indonesia's sole authorized importer of corn for feed. To effectively manage the domestic corn supply, the Indonesian government has strongly controlled corn imports since 2015. On occasion the government has instructed BULOG to import corn for feed to supplement its domestic production. The impact of limited feed corn imports has been an increased use of wheat for feed (see Figure 31).

Imported feed raw materials are supplied by major international traders and shipped in Panamax and Handymax vessels, typically in volumes of 35,000 to 60,000 mt. Most of this imported feed is channelled through ports in Jakarta and Surabaya then delivered to feed mills incurring handling, transport and clearance costs. Bagging of the imported goods will often occur at the port, prior to transport to the feed mills.

Storage

There is scope for improving grain and feed storage infrastructure.

Indonesian corn has a high moisture content at harvest and requires drying and good quality storage to prevent spoilage and wastage. Storage of corn and other feed materials in Indonesia, however, can be problematic because smallholder farmers or small enterprises have limited access to capital or adequate storage infrastructure.

Inadequate storage facilities result in grain spoilage reducing the utility and value of the grain. As an example, some small holders use woven plastic sacks to store grain, which leave it susceptible to rodent and weevil infestation. The plastic sacks are often stored within a communal warehouse. In some cases, there has been up to 30% to 70% loss of grain from these infestations (Kopernik 2017). Kopernik suggests simple storage options such as hermetically sealed storage bags or drums are an efficient way of reducing the number of insect pests, and are affordable, given the level of improvement they provide in managing pests.

Feed mills are increasing their drying facilities to manage the moisture levels in domestic corn, increasing the flexibility to purchase grain at various moisture levels when prices are favourable. Importing low moisture grain and combining it with other ingredients assists mills in the moisture management of feed.

The Indonesian government is working to improve the efficiency of the warehousing receipts system. This system seeks to improve the grain storage and pricing mechanisms, as well as the grain aggregation, standardisation and distribution systems.

Pricing

The Indonesian government supports corn producers by providing buying reference prices for farmers and selling reference prices for customers, in essence providing a floor in the market. In February 2020, the Ministry of Trade (MOT) set the reference price as per Table 7 below. The transactional price for corn may be much higher than these prices.

Table 7: Corn references prices. June 2020 (Based on US Export Soybean Council, July 2020)*

No.	Corn moisture content	Farmer gate reference prices (Rp /kg)	Consumer gate reference prices (Rp /kg)	Consumer gate reference prices (USD/mt)
1.	15%	2,450	3,800	279.9
2.	20%	2,350	3,700	272.6
3.	25%	2,150	3,500	257.8
4.	30%	2,050	3,400	250.6
5.	35%	1,800	3,150	232.1

** Reference prices are the floor prices set by government and not the transacted price in the market*

The average price of corn at the consumers gate declined from 6,000 Rp/kg (A$590 per tonne) in late 2018 to 3,800Rp/kg (A$389 per tonne) in June 2020 (Figure 32). The February 2020 reference price at consumers gate of 4,500 Rp/kg (US$277/mt) is consistent with prices paid by feed millers over the last two years. During this period feed millers have paid between 3,600-6,000 Rp/kg at feed mill gate for 15% moisture corn.

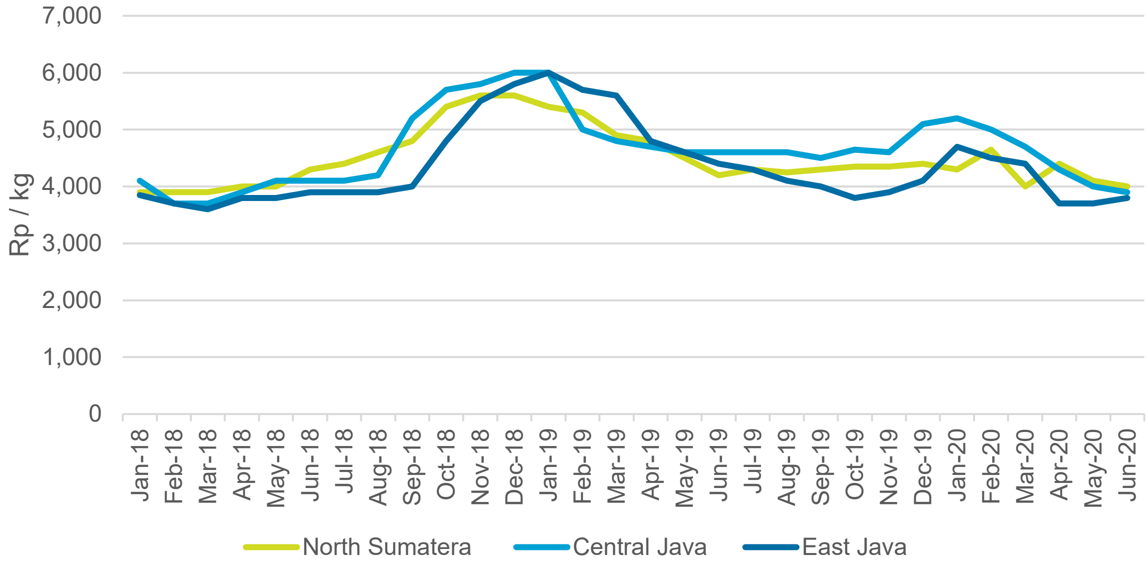


Figure 31: Corn prices at feed mills gates (Rp/ kg) (US Export Soybean Council, July 2020)

In December 2018, the Indonesian Feed Mills Association indicated that if local corn prices were “normal” at around 3,700-3,800 Rp/kg, the mills would require around 9.5 mmt of corn. If prices were high at about 6,000 Rp/kg, around 7 mmt of local corn would be used. To maintain feed production at constant levels the 2.5 mmt of corn would need to be replaced by other equivalent energy feed ingredients.

2. Australia's livestock sector, grain production and use

Animal protein consumption and production trends

White meat consumption is increasing in Australia at a faster rate than red meat.

Each year Australians eat about 115kg of meat and fish per person which is twice as much meat and fish consumed by the average Indonesian (Figure 33). Unlike Indonesia, however, meat and fish consumption in Australia is not growing, and the types of meat Australians consume is changing. Over the past 20 years chicken and pigmeat (white meat) consumption has steadily increased while beef and sheepmeat consumption has decreased. White meat consumption now constitutes 55 per cent of total meat and fish consumption in Australia.

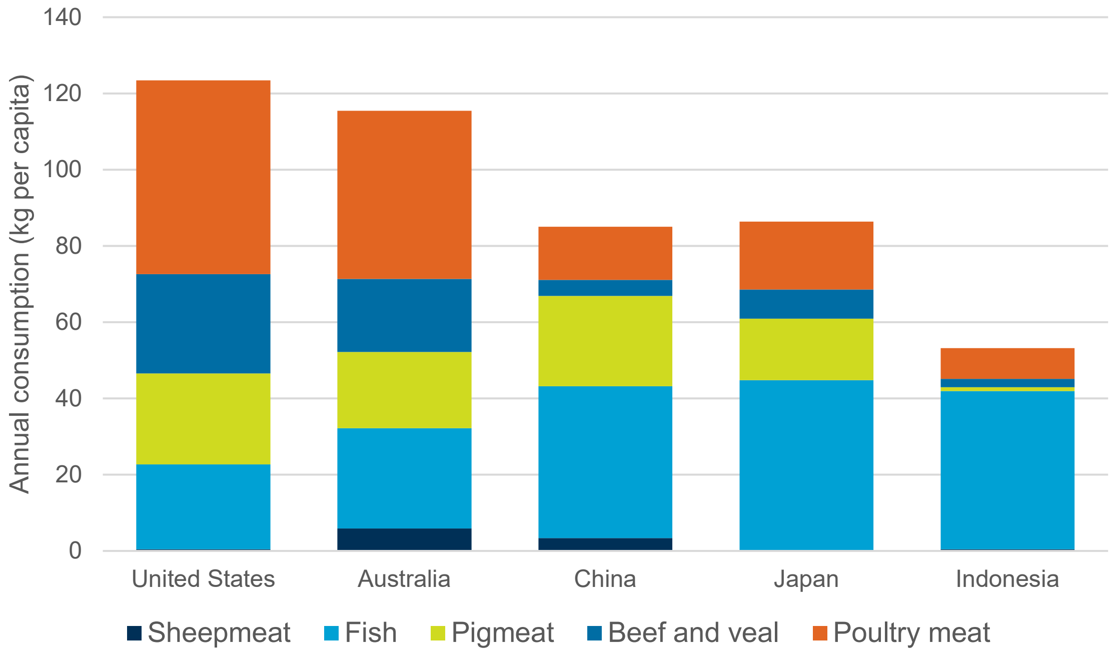


Figure 32. Annual average use of meat and fish for human consumption in selected countries. (OECD-FAO, 2020).

Australian poultry meat production has been growing faster than production of other meats at about 3% per annum since 2010, largely in response to increasing domestic consumption (Figure 34). Meat production from beef and sheep is also increasing, but at a lower rate driven mostly by export demand.

Australian production of beef and sheepmeat for export is growing.

Australia is a large exporter of meat, particularly beef and sheepmeat, often as live animals. Meat exports are expected to grow modestly over the next decade.

Changing trends within domestic meat consumption and export demand impact the mix and use of feed grains used within Australia and the availability of Australian grains to export markets, including Indonesia (Figure 35).

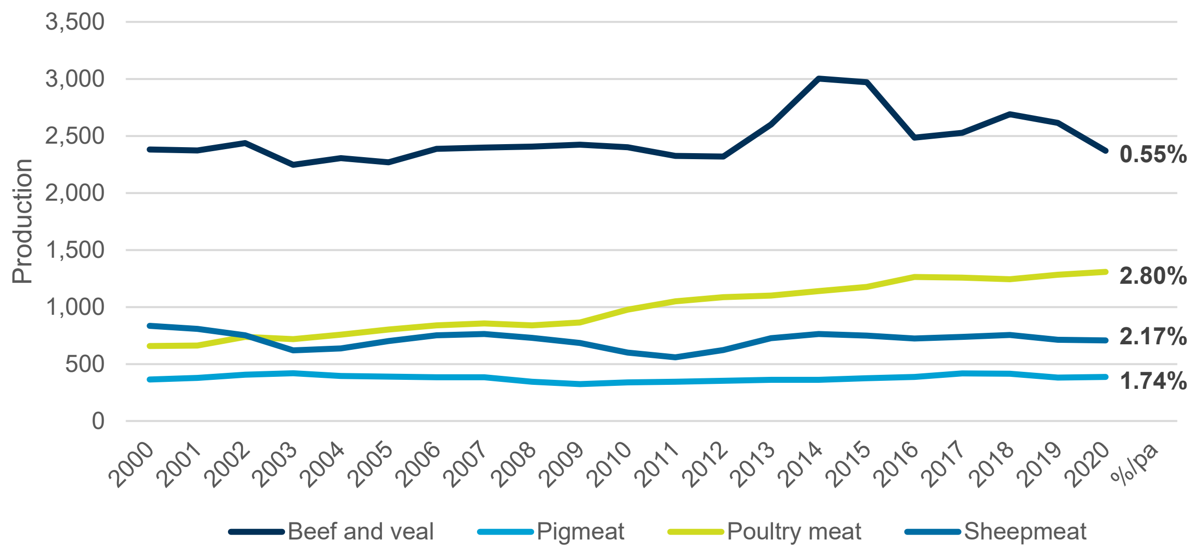


Figure 33: Production of meat in Australia (000's mt), and annual growth rate, 2000-2020 (ABARES 2020)

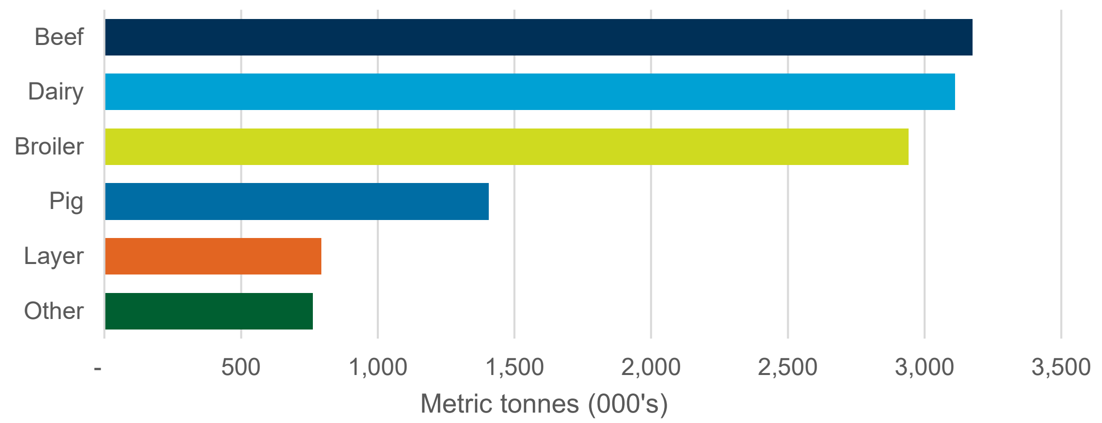


Figure 34: Use of feed grains in Australian livestock industries (mmt) (Hosking 2019).

Grain production and distribution

The five-year average for winter and summer crop production in Australia is 46 million metric tons.

Australian feed manufactures use a range of domestically produced feed sources as well as imported soymeal meal to meet plant-based feed needs. Domestically produced sources include: cereals (mainly wheat, barley, sorghum, oats), legumes seeds (mainly lupins and pulses) protein meals (mainly canola meal a by-product from the local canola oil crushing industry) and hay. Annually in Australia over the past five years just over 9 mmt of cereal grain has been used for feed together with 0.5 mmt of canola meal and about 1 mmt of imported soybean meal.

Australian grain crops are mostly grown in the Australian winter but also over summer with crop production extending from the west to east coast of Australia (Figure 36)

Figure 35: Map of production regions in Australia, showing geographical separation between production on the west and east coast

Winter crops has averaged about 42 mmt annually over the past five years and mostly comprise wheat, barley, canola, lupins, and pulses (chickpeas, field peas and lentils) (Figure 37). Summer crop production annually averages around 4 mmt and includes sorghum, cottonseed and a small amount of corn and mung beans.

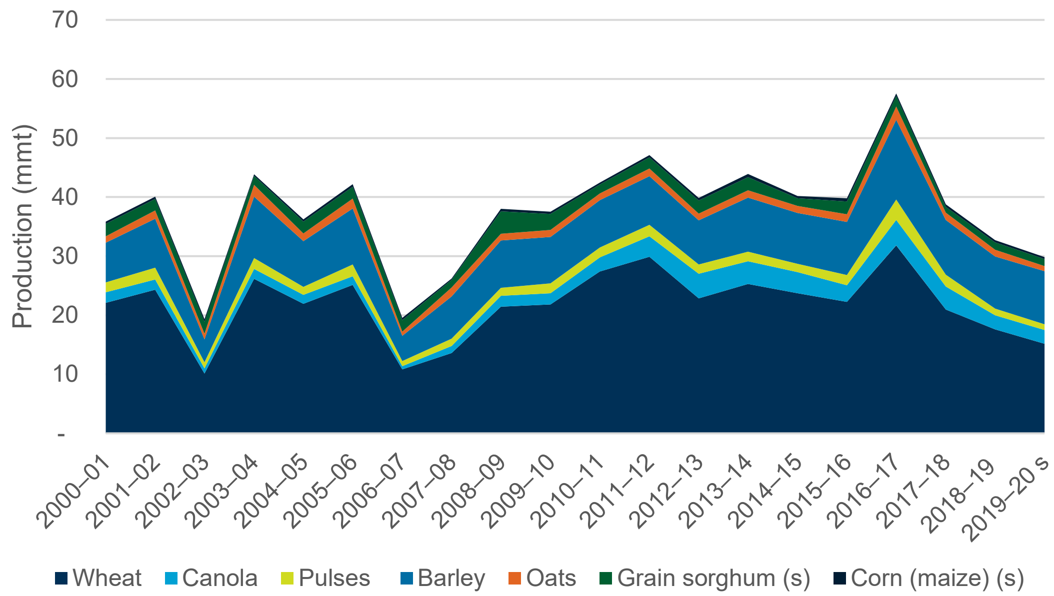


Figure 36: Production from major winter and summer crops in Australia in (millions metric tonnes). Summer crop denoted by (s) (ABARES 2020)

Australian exports about 7.5 mmt of the grain annually to be used as feed.

Most of Australia's annual cereal and legume production is of food quality, nevertheless, about 7.5 mmt, or 16 per cent of Australia's annual grain production, on average, is exported for feed purposes (Figure 38). Australian grain is harvested under warm dry conditions and so has a low moisture content providing processing and safety advantages when used for food or feed purposes.

Most Australian grain that is sold into global markets for feed originates from Western Australia and South Australia. Grain exports for feed from eastern Australia are variable. This is because most of Australia's animal production is located on Australia's east coast, hence in low production years (e.g. drought in 2019) grain surplus to domestic food needs finds its way to domestic feed industries rather than being exported.

In Western Australia and to some extent South Australia, the domestic industry is less able to absorb production volumes, with a lesser impact on the availability of grains for export. As such, these states will in, most cases, export more grain.

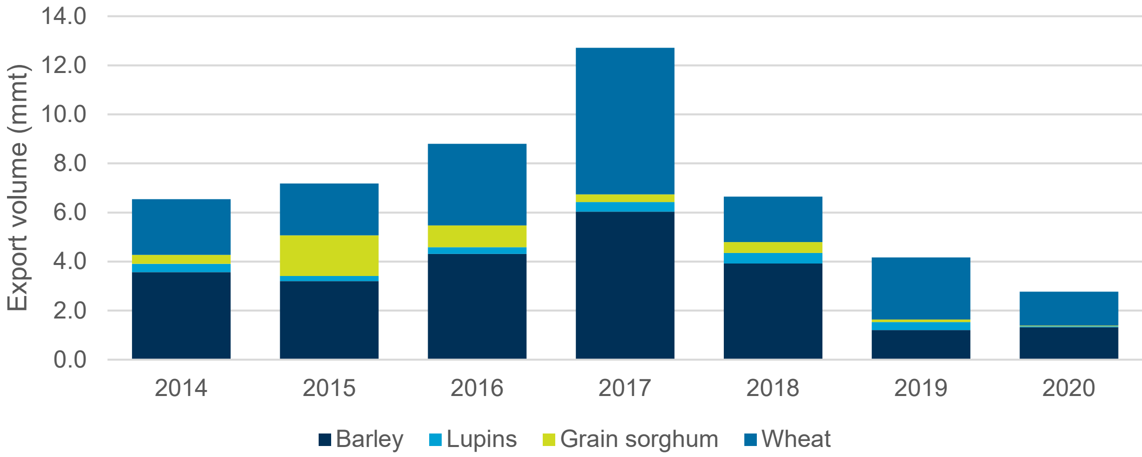


Figure 37: Estimated volume of export grains used as feed 2014-2020 (ABARES (2020), Australian Crop Forecasters (2020), ABS (2020))

Major crops and use by domestic and export markets

Changing patterns of domestic consumption and animal production methods has seen a 50% rise in Australia feed grain use over the past 20 years particularly for poultry and beef feedlots production. Feed grain use is affected by seasonal conditions that affect the availability of the range of alternative feed sources with strong fluctuations from year to year. Over the past 20 years the annual domestic use of feed grains, particularly wheat and barley, have increased from about 6 mmt in 2000 to nearly 10 mmt in 2020 (Figure 39). Feed grain use is expected to increase by a further 2 to 2.5 mmt annually over the next decade.

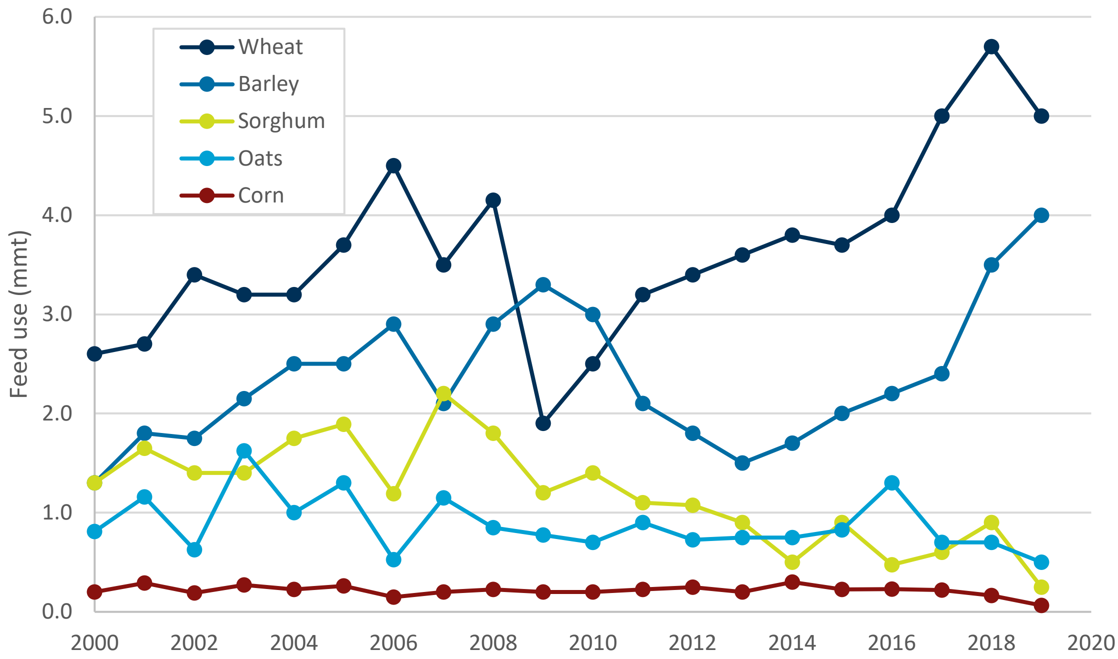


Figure 38. Volume of grains used for feed in Australia from 2000 to 2019 (USDA, 2020).

Australian wheat

Five-year average annual wheat production is 23.3 mmt. 7.7 mmt is used domestically and 15.6 mmt exported.

Australia produces hard, white grained wheat varieties typically with a protein content ranging from 9.5 to 12.5 per cent. Wheat is used widely across all animal livestock industries in Australia and can be incorporated up to 80 per cent of the animal diet dependent upon livestock type. It is typically coarsely ground or rolled before being used as a feed.

Most Australian wheat is exported to Asian countries where it is used primarily for noodle manufacture and bread. A proportion of the exported Australian low protein wheat also finds its way into feed rations, particularly in the Philippines, Indonesia, Vietnam and Thailand. The amount of Australian wheat used for feed varies substantially depending on seasonal production and the volume of wheat Australia has to export. Most of the wheat Australia has exported to the Philippines over the past five years (averaging 1.4 mmt annually) has been used for feed.

In Australia wheat varieties are allocated into a range of classes with distinct quality attributes and processing characteristics. At harvest, wheat can be segregated into one of several grades depending on the grain quality and initial class, with the grades indicating a likely use of that grain[4]. Figure 40 presents indicative volumes of wheat of each grade, as an average over the past 6 years. Approximately 1.4 mmt of Australian wheat is general purpose or left ungraded and separated for feed (Figure 40). In some seasons higher grade wheat may also be used as feed, e.g., ASW (Australian Standard White).

[4] See www.wheatquality.com.au and www.graintrade.org.au for an explanation of classes and grades, respectively.

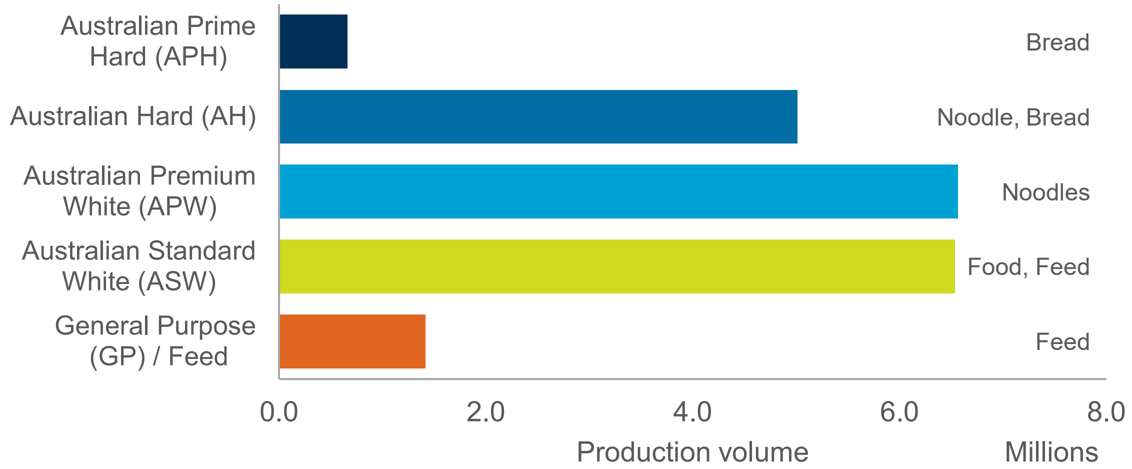


Figure 39. Estimated production volumes of the main Australian wheat grades and their principal use (Australian Crop Forecasters and AEGIC, 2020).

Australian barley

Australia is a major exporter of malt and feed barley.

Australia produces around 9 mmt of barley annually. Australian barley is classified upon delivery from farms into food (e.g., malting) or feed grades. Farmers are usually paid a premium for malting barley compared with feed barley and this often drives production goals.

Barley that does not meet the malting standards (for example it exceeds maximum protein levels) is classified as feed. Some malting barley is also exported for feed despite being classified as food grade. Each year more Australian barley is sold for feed (around 60%) than for malting.

Australian feed barley has a protein content of about 10 per cent but can range from 8 to 12 per cent and can be readily incorporated in a range of animal diets. Australian barley is low in moisture – usually lower than 11% - compared to alternatives, a function of harvest occurring as Australia moves into summer, a time when the weather is warm, and there is little rain. This results in grain with a very low risk of mycotoxin contamination and a bright uniform colour.

Annually around 60 per cent of the Australian barley crop is exported to about 25 markets, including the primary markets of Japan, Saudi Arabia, United Arab Emirates, Thailand, Kuwait and until recently, China (Figure 41). Since 2014 and up until mid-2020 China has been a major user of Australian barley. China's imposed new import tariffs on Australian barley in 2020.

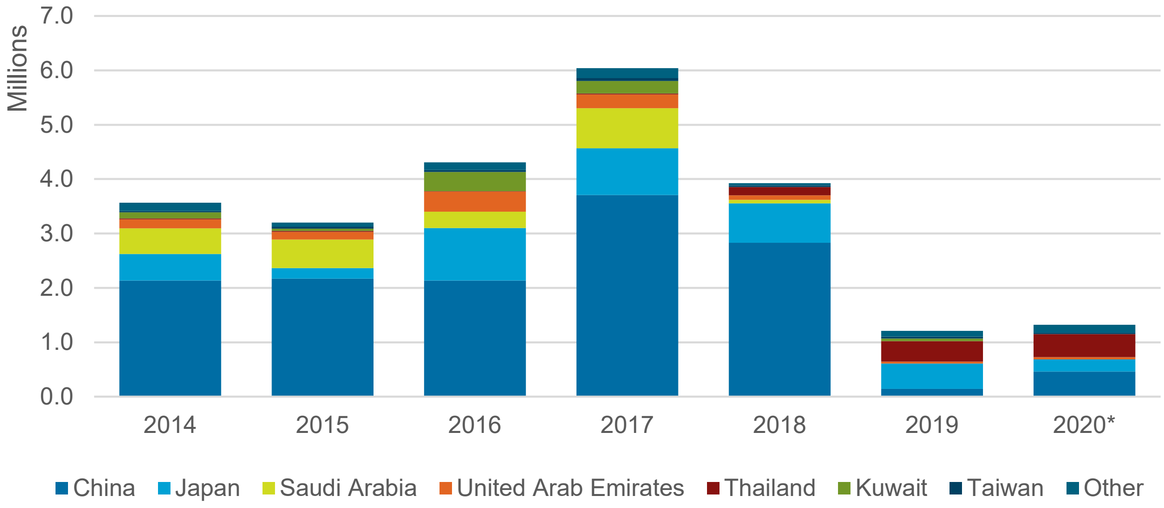


Figure 40: Main export destinations for Australian feed barley 2014-2020 (mmt) (ABS 2020).

** Note: estimates for 2020 are not yet complete.*

Australian sorghum

Australia produces low tannin sorghum used for feed and food in domestic and export markets.

Sorghum is the main cereal crop grown in summer in the north east regions of Australia. Annual production is between 1 to 2 mmt. About 0.4 to 1.0 mmt is used annually in Australia mainly for cattle, pigs and for poultry feed. Sorghum is also exported for food and feed use.

More than 95 per cent of the sorghum grown is “red” sorghum and has been bred for very low tannin content. Commercial feed sorghum varieties grown in Australia contain no condensed tannins. Sorghum is classed as a non-viscous grain, similar to corn because of its low total fibre content which is much lower than wheat or barley.

China in recent years was the main export market for Australian sorghum (Figure 42), receiving up to 95 per cent of annual Australian sorghum exports. China uses Australian sorghum mostly for animal feed and production of Baijiu, a Chinese alcoholic beverage.

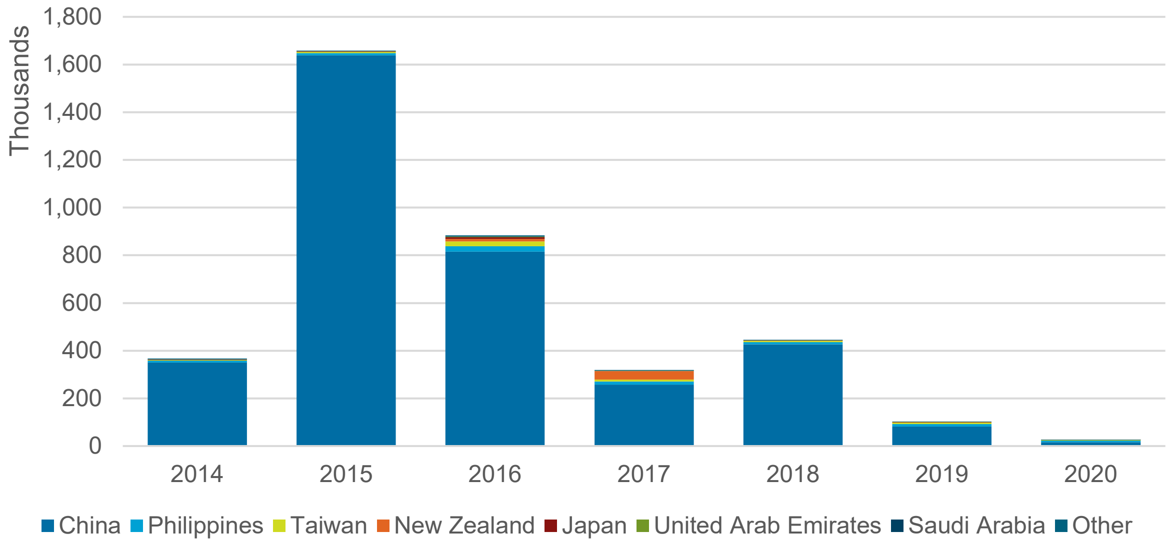


*Figure 41: Main export destinations for Australian sorghum (000's mt) (ABS 2020). * Note: estimates for 2020 are not yet complete.*

Australian lupins

Lupins are a valuable protein and energy source for a range of animals.

Around 0.8 mmt of lupins are produced annually in Australia, mostly in Western Australia with up to 50 per cent of the crop being exported mostly for feed (Figure 43).

Australia narrow-leafed lupin (*Lupinus angustifolius*), also known as Australian sweet lupin, is a unique grain because it has few anti-nutritional factors and low starch levels making it a very safe feed. In Australia lupins are a major protein and energy source used for animal production.

Markets within the EU (Netherlands and Spain) and South Korea have been using Australian lupins for feed for decades. In Europe they are a preferred for pig, ruminant and aquaculture production. South Korea imports Australian lupins for processing (e.g., cracked or dehulled) and use across a range of livestock types.

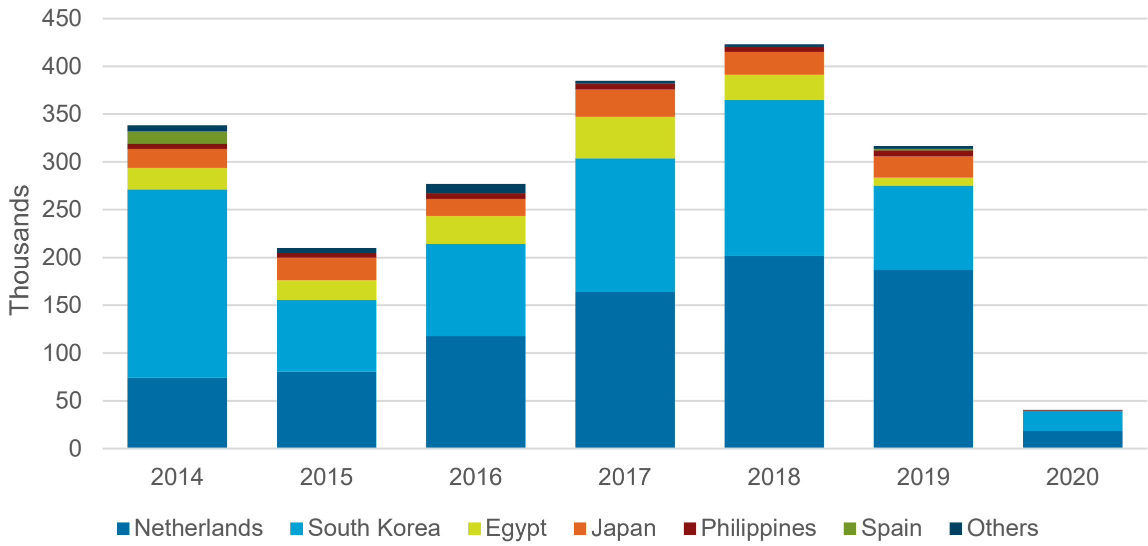


Figure 42: Main export destinations for Australian lupins (000's mt) (ABS 2020)

Canola meal

Canola meal is a major protein ingredient in animal rations in Australia

Canola, Australia largest oilseed crop, is processed to produce oil for food and biodiesel and the by-product meal used primarily for feed. Annual average production of canola in Australia from 2015 to 2019 was 3.1 mmt with around 2.3 mmt of canola exported annually to markets in the European Union, Japan, China, Pakistan and the United Arab Emirates. Canola is processed for its oil in these markets with the resultant meal widely used as an animal feed.

Australia processes around 1 mmt of canola a year producing about 550,000 mt of meal. This meal is mostly used in the dairy, pig and poultry sectors. While not traditionally used in beef feedlots, canola meal has been used for this purpose during the recent low grain production seasons in Australia, and further research work is verifying its value when used in this capacity.

Oats

Australia produces about 1 to 1.5 mmt of oats per year. Oats crops may be cut for hay or for grain and used in a wide range of commercially produced compound feeds. Australian oaten hay or grain is exported to many countries including China and Japan, Export volumes are relatively small compared to Australia's major cereal crops. Japan uses oats primarily for horse feed.

Harvest and shipping

Australian feed grains are readily available when Indonesian corn stocks may be low.

In Australia, winter crops (wheat, barley, canola and lupins) are usually harvested during October through to January with grain shipped soon thereafter (Figure 44). Exported grain is therefore potentially available to Indonesian feed users when the availability or quality of Indonesian stocks of corn may be low, e.g. January to February or August to September (Figure 44).

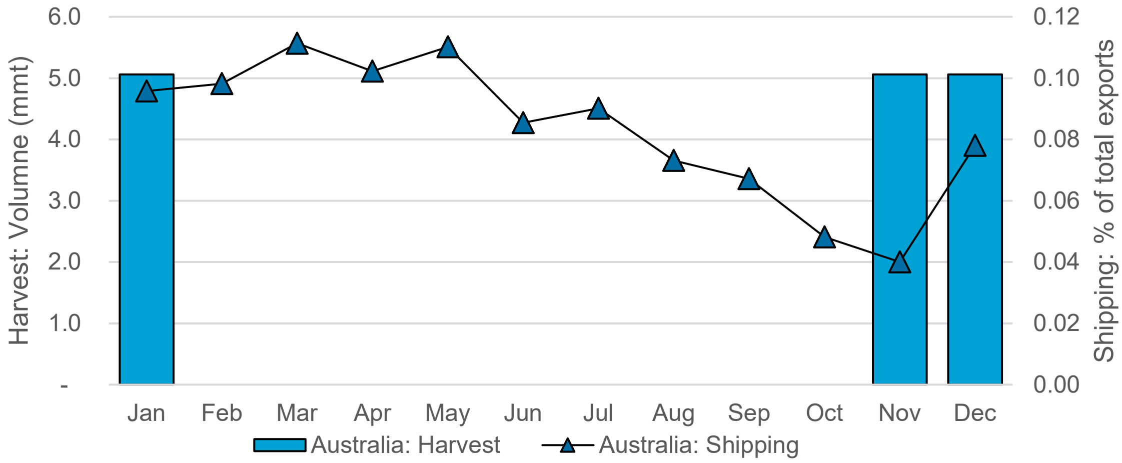


Figure 43: Schedule of Australian harvest and shipping

3. Feed sources and feed formulation and price sensitivity

Introduction

Indonesian animal producers have a wide range of local and imported ingredients available to meet their feed needs. Managing the seasonal supply and quality of these ingredients over the year requires careful feed formulation to combine the different elements and provide a consistent, low cost and reliable supply of high quality, safe feed to end users. Indonesian feed mills can use Australian feed grains to help meet their feed formulation objectives.

Here we describe characteristics of the main feed ingredients used in Indonesia. Price and sensitivity analysis are presented to show potential optimal combinations of Indonesian and Australian feed ingredients for a range of important animal diets. This section documents the feasible pricing at which Australian feed ingredients could be used in Indonesia in poultry, beef, dairy and aquaculture feeds using least cost ration formulation analysis. The pricing point in Indonesia are an average of Surabaya and Jakarta ingredient costs for November 2020. As markets inevitably vary, the shadow prices have also been expressed in *Relative Value* so that the results can be interpreted under changed market conditions.

Indonesian animal diets

Indonesian animal feed millers use a range of local and imported feed ingredients. Local corn is the main grain used.

Indonesian poultry and aquaculture production use feed rations with the energy and protein requirements generally supplied by cereal grains, (mostly corn, but also wheat) together with protein meals (mostly soybean meal or fish meal). Beef feedlot and dairy production have a lower requirement for high protein meals and greater emphasis on using local agro-industrial by-products, although, cereal grains and protein meal are still used, particularly in larger, more industrialised dairy operations.

As in most sophisticated feed industries have flexibility in diet formulation with a range of ingredients sourced and included in rations to develop low-cost diets as shown by the Indonesian poultry example below (Table 8). Corn, an energy source for animals, is included at 50% in one diet (e.g. Diet A in Table 8 below) without wheat or cassava. If corn availability is limited or prices are high it is possible to create a nutritionally equivalent diet (e.g., Diet B in Table 8 below) with less corn and greater amounts of wheat, cassava and rice bran.

Table 8: Representative example of a ration formulated as Indonesian chicken feed.

Ingredients	Use % Formula	
	Diet A	Diet B
Corn	50	35
Soybean Meal (SBM)	20	20
Corn Germ Meal (CGM)	5	5
Rice bran	12	17
Wheat	*0*	*5*
Cassava	*0*	*5*
Crude Palm Oil (CPO)	2.5	2.5
Meat and Bone Meal (MBM)	6	6
Poultry Meat Mix (PMM)	4	4
Premix	0.5	0.5

Desianto (2019)

Substitution of feed ingredients to develop least-cost diets requires consideration of the physical characteristics and nutritional content of the range of ingredients on offer. Appendices 1 and 2 provides a summary of the nutritional characteristics of the main Indonesian and Australian feed ingredients potentially available to Indonesian feed millers.

Evaluation of Australian feed grains in Indonesian feed rations

The price at which Australian feed grains could be used as ingredients in Indonesia animal feed rations is determined here using Least Cost Ration Formulation (LCRF), standard Indonesian feed diets and ingredient prices delivered to the feed mill gate as of November 2020. Prices are an average of Surabaya and Jakarta ingredient costs and are expressed as United States Dollars (USD) using an exchange rate of IDR14,900 per USD.

Two methods have been used to indicate the relative value of the ingredients:

1. Shadow Pricing – the highest price at which an ingredient will come into an optimised formula (also referred to as the entry price). If the ingredient price is equal to the shadow price in a particular formula, then the new formula will use the new ingredient and the formula cost will remain unchanged. Usually, purchasing below the shadow price will allow the ingredient to be used and the formula cost will be reduced. It does not necessarily indicate how much of an ingredient will be used at a particular price. Shadow pricing is explained further below.
2. Demand curves – the volume of a feed ingredient included in feed rations at a range of prices.

Appendix 2 provide the nutrient value for ingredients tested here. Full details are found in Clark (2020) and Permana *et at* (2020).

Poultry

Poultry feed mills in Indonesia range from 10,000 tonnes per month up to 100,000 tonnes per month. In the analysis below, we have used an enterprise producing a total of 10,000 tonnes per month across 15 poultry feed types. Table 9 the shows the typical production tonnages of these different feeds in a 10,000 per month enterprise.

Table 9. Production tonnages of different feeds used to calculate shadow pricing in poultry diets.

Feed Type	Monthly Production (tonnes)
Layer starter	80
Layer grower	320
Layer developer	240
Layer pre-layer	160
Layer early-phase	400
Layer phase 1	1,440
Layer phase 2	1,360
Cobb pre-starter B	150
Cobb grower B	1,200
Cobb starter B	1,500
Cobb pre-starter C	150
Cobb grower C	1,200
Cobb starter C	1,500
Broiler-breeder layer 1	150
Broiler-breeder layer 2	150

Barley

Barley's value is higher in low energy poultry feeds.

Shadow prices in Table 10 shows the poultry feeds where the value of Australian barley with a dry matter of 89.5% (11.5% moisture) is highest. For example, when the corn price is at US$300 per tonne the price at which barley is included in layer grower diets is US$312 per tonne. At this price barley is included and the total cost of the diet remains the same. Above this price barley is excluded. Below this price barley is included and the cost of the ration is lower. The typical mill producing 10,000 t of feed per month however is usually only producing about 320mt/month of layer grower feed. For barley to be included in higher volume feed, such as Layer phase 1 the price of barley needs to drop to US$231 per tonne.

To demonstrate the value of the low moisture content of Australian grain two levels of barley grain moisture have been included in the least cost barley evaluations. In Table 10 lower moisture barley has a higher price of up to US$15 per tonne in broiler feeds.

The layer grower, starter and developer feeds that are relatively low in energy show the highest value for barley (US$297 – US$314 per tonne) when corn is priced at US$300 per tonne and the barley has an 89.5 dry matter content. The broiler breeder feeds follow, but at a lower shadow price – in the range US$252 to US$258 per tonne. These figures, however, will depend on the fibre levels that the nutritionists will specify when developing the feeds. The Cobb feeds (broiler) show that barley starts to be included in the ration at a value range of US$249 – US$252 per tonne with the layer feeds at a slightly lower range of US$244 to US$247 per tonne.

Table 10. Shadow prices for barley compared to corn used in a range of poultry diets. Barley compared with corn priced at US$300 per tonne and 10% lower (US$270) or higher (US$330). Barley is presented at two moisture contents (88% dry matter (DM) and or 89.5 DM) at a corn (87% DM) price of US$300.

Feed Type	US$270 (89.5% DM)	US$300 (88% DM)	US$300 (89.5% DM)	US$330 (89.5% DM)
Layer grower	286	312	314	342
Layer starter	278	300	303	326
Layer developer	274	291	297	320
Broiler-breeder layer 1	221	243	258	290
Broiler-breeder layer 2	221	243	258	307
Cobb pre-starter B	221	237	252	286
Cobb grower B	218	237	252	286
Cobb starter B	218	234	249	283
Layer phase 1	214	231	247	277
Layer phase 2	238	252	246	277
Layer early-phase	215	229	244	277
Crude average	237	255	265	297
Relative barley value %	88	85	88	90

The demand curves for barley are shown in Figure 45 and Figure 46. The high-volume feed types (for example Layer phase 1- see Table 9) generally show lower relative values than the lower energy feeds. The highest volume demand for barley occurs when the price is below US$255 per tonne for low moisture barley or US$240 per tonne for higher moisture barley (Figure 45). Barley is included in higher volumes mainly in the lower energy feeds (details shown in Figure 46 which is equivalent to that presented in Figure 45 but with a smaller scaled y-axis given the lower production volume).

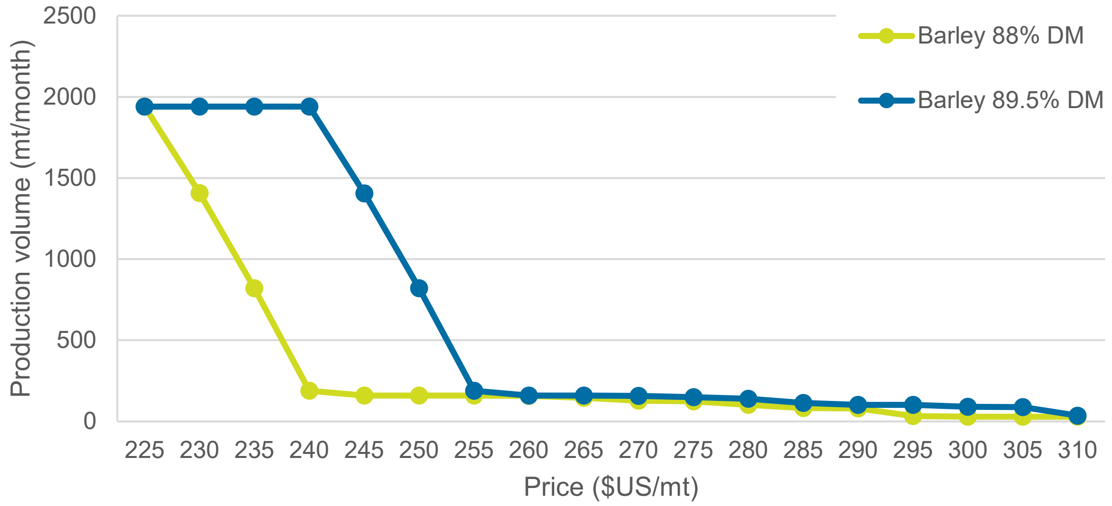


Figure 44. Production volume of barley demanded with a barley price ranging from US$225 to US$310 per tonne with the corn price set at US$300.

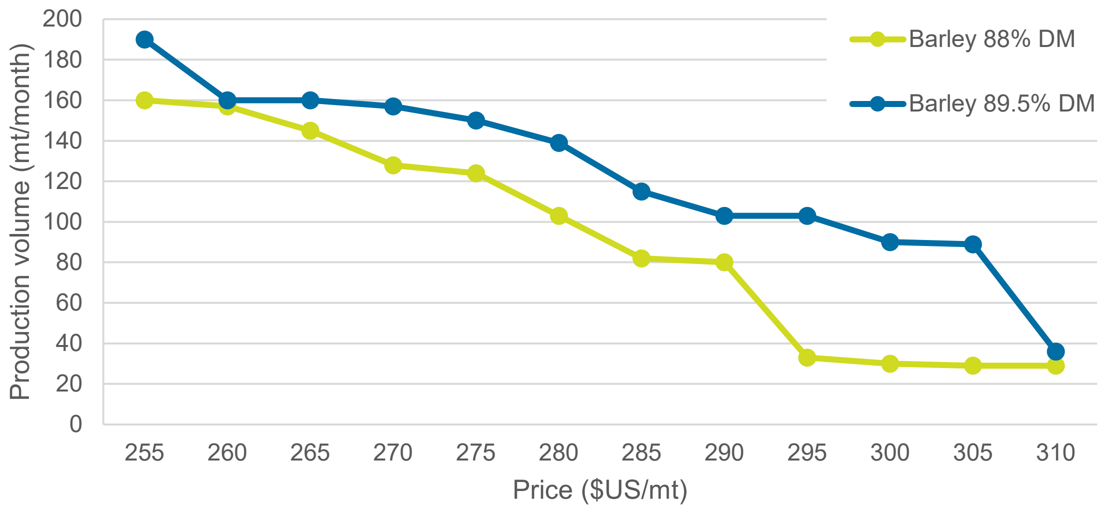


Figure 45. Production volume of barley demanded with a barley price ranging from US$255 to US$310 per tonne with the corn price set at US$300.

The lower moisture barley shows a differential value of about US$15 per tonne due to the increased nutrient concentration. The bulk of barley usage occurs at price range lower than US$240 per tonne where the low moisture barley is being used in the broiler feeds. At prices above US$250 per tonne barley is mainly restricted to into the specialised feeds. At these low volumes, however, storage and segregation may add to the relative cost of the grain.

Wheat

When priced competitively with domestic corn, wheat is an effective substitute.

Table 11 shows the shadow prices for wheat with 12.5% protein given a corn price of US$270, US$300, and US$320 per tonne. Wheat appears to have a higher relative value compared with corn, particularly at lower corn prices where the relative value is 104% at a corn price of US$270 per tonne and 101% at a corn price of US$330.

Table 11. Shadow prices for wheat (88% DM) compared to corn used in a range of poultry diets with corn (87% DM) priced at US$300 per tonne and 10% lower (US$270) or higher (US$330).

Feed Type	US$270	US$300	US$330
Layer grower	296	323	342
Layer developer	292	317	343
Broiler-breeder layer 2	291	316	342
Layer starter	287	314	342
Broiler-breeder layer 1	285	313	339
Cobb pre-starter B	270	299	329
Cobb grower B	268	299	329
Layer phase 2	277	298	324
Layer phase 1	271	298	324
Cobb starter B	268	296	326
Layer early-phase	272	295	324
Crude average	280	306	333
Relative wheat value %	104	102	101

The demand curve for wheat shows highest use when the price is lower than US$300 per tonne. Above US$300 per tonne lower volume demand occurs, and, as with barley, this second consumption phase is in the lower energy poultry feeds.

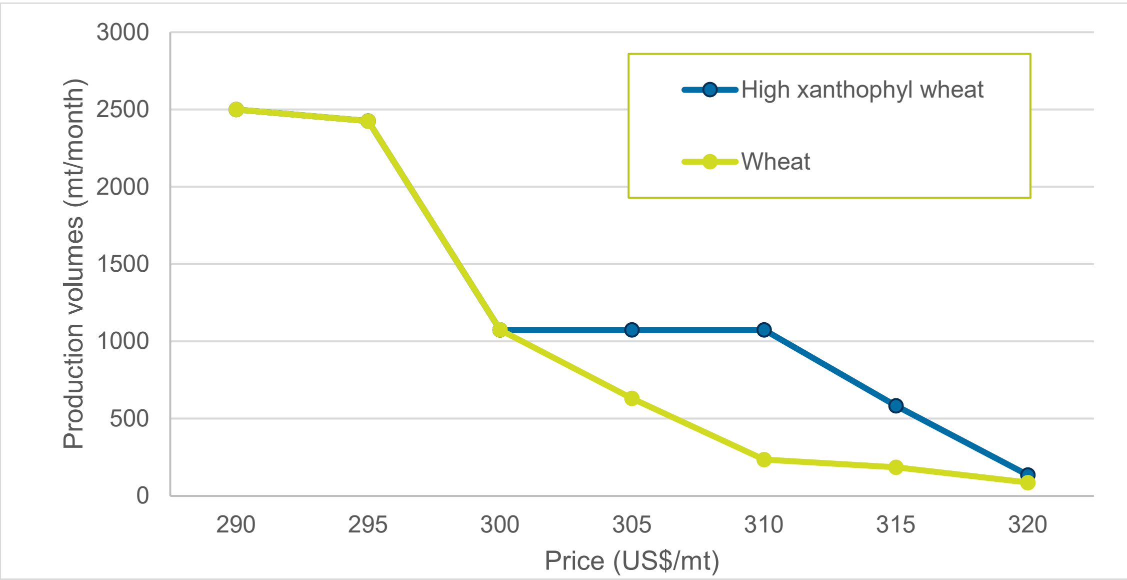


Figure 46. Production volume of wheat demanded with a wheat price ranging from US$290 to US$320 per tonne and the corn price set at US$300.

Substituting wheat for corn in poultry rations require the addition of synthetic xanthophyl. Corn contains about 21 ppm of xanthophyll depending on the origin. Commercial varieties of wheat have a low xanthophyll content, although breeding lines with high xanthophyl levels exist but are not commercially available. To demonstrate its value a hypothetical high xanthophyl wheat variety has been constructed containing 21 ppm xanthophyl (Figure 47).

The value of high xanthophyl wheat is about US$10.00 per tonne higher than standard wheat in this analysis. High xanthophyl wheat shows greatest utility at a higher price in the layer feeds. This can also be seen from the shadow price examples for the layer feed series (Table 12). There are also smaller opportunities for the high xanthophyll wheat varieties in special broiler feeds.

These differences would apply in the fresh markets or for kampung chicken (village chicken) rather than the modern, commercial broiler production. Yellow shank colouring caused by the xanthophyl is particularly important where live birds are sold. Other parts of the industry have become accustomed to using standard wheat as a response to the limited corn supply so market adjustments on colour have already largely taken place.

Table 12. Shadow pricing for standard and high xanthophyl wheat.

Feed Type	Wheat	High xanthophyl wheat
Early layer feed	306	317
Layer phase 1	306	317
Layer phase 2	310	320
Crude average	307	318
Relative wheat value %	102	106

Sorghum

Sorghum is close to corn in nutrient content and value.

The shadow price of sorghum is similar to the price of corn. The nutrient profile of sorghum is closer to corn than either barley or wheat – the protein content is slightly higher while the energy is slightly lower than corn. Out of the three alternative cereals, sorghum has the highest energy level which is the main reason for its close equivalence to corn and hence, the overall the economic value being similar (Table 13).

Table 13. Shadow prices for sorghum (87% DM) compared to corn used in a range of poultry diets with corn (87%DM) priced at US$300 per tonne and 10% lower (US$270) or higher (US$330).

Feed Type	US$270	US$300	US$330
Broiler-breeder layer 1	283	314	340
Broiler-breeder layer 2	282	310	338
Layer grower	276	305	334
Layer developer	275	304	332
Layer starter	272	301	331
Layer phase 2	269	299	325
Layer phase 1	268	297	325
Layer early-phase	269	296	325
Cobb starter B	263	294	325
Cobb pre-starter B	263	294	325
Cobb grower B	263	294	325
Crude average	271	301	330
Relative sorghum value %	100	100	100

The consumption curve for sorghum as of November 2020 shows that a sorghum price between US$290 and US$300 per tonne was favourable (Figure 48). The curve shows a tighter range of values than for wheat. At US$290 to US$295 per tonne, sorghum is included in all the feeds. From US$295 to US$300, layer feeds are the main users while above US$305, sorghum is used in the lower energy layer replacer and broiler breeder feeds.

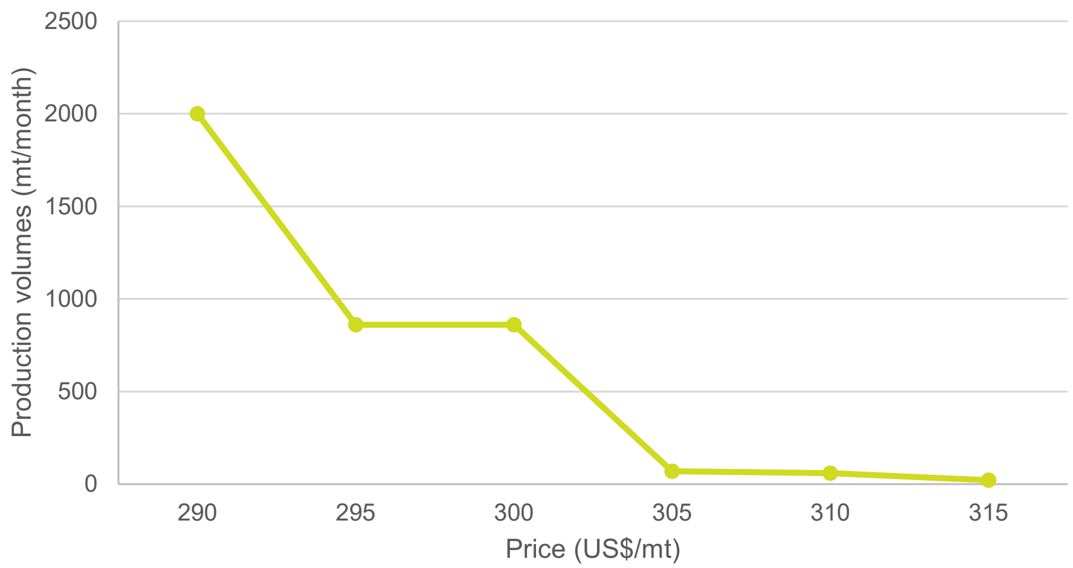


Figure 47. Production volume of sorghum demanded with a sorghum price ranging from US$290 to US$315 per tonne and the corn price set at US$300.

Canola meal and lupin seed meal

Canola meal may have higher value than lupin seed meal in Indonesian poultry diets.

The shadow pricing for canola meal (36.7% crude protein) and lupin seed meal (32% crude protein) has been determined against SBM (45.5% crude protein) priced at US$503 per tonne. The shadow price for canola meal is reasonably consistent with the lower average value in the broiler feeds reflective of the lower energy requirements for the broiler feeds. In comparison the shadow pricing of the lupin seed meal is quite variable (Table 14).

Some of the variation is due to the different amino acid profiles of the protein meals. For example, soybean meal has the highest lysine level, lupin seed meal is high in arginine while canola seed meal is high in both methionine and cysteine (see Table A2-1). Lupin seed meal is also low in both methionine and cysteine.

Table 14. Shadow prices for canola meal and lupin seed meal compared to SBM priced at US$503 per tonne in a range of poultry diets.

Feed type	Canola meal	Lupin seed meal
Cobb pre starter	428	466
Cobb starter B	403	414
Cobb grower B	403	414
Crude average broiler	412	432
Broiler-breeder layer 1	452	454
Broiler-breeder layer 2	452	454
Average broiler breeder	452	454
Layer starter	458	405
Layer grower	459	425
Layer developer	448	395
Crude average layer replacer	455	408
Layer early-phase	465	236
Layer phase 1	451	236
Average phase 2	459	279
Crude average layer production	458	251

The cost impact of the variation in amino acid levels is mitigated by the ease with which synthetic amino acids can be used to balance deficiencies inherent within the feed ingredients. Different amino acids vary in cost and availability. Valine and tryptophan are generally more expensive and therefore soybean meal would have an advantage when these amino acids are limiting while lupin seed meal would have a significant disadvantage.

Arginine and isoleucine are more critical because synthetic versions of these amino acids are not readily available. Soybean meal is a good source of Isoleucine. It is interesting to note that lupin seed meal has the highest Arginine concentration. This amino acid can be limiting in broilers, but not necessarily in layers.

The differences in amino acids explain the apparent inconsistency in the shadow pricing for lupin seed meal in Table 14. In layer feeds where tryptophan is limiting and arginine is not, then the shadow pricing is relatively low, at an average of US$251 per tonne. In contrast, the shadow price of lupin seed meal shown in Table 14 is relatively high in the set of broiler feeds formulated here in which Arginine is limiting.

The formulation exercise is very dependent on the amino acid profiles that a nutritionist uses. Differences will also occur where feeds are sold simply on a guaranteed crude protein basis or based on the Standardized Ileal Digestibility (SID) amino acid levels. If a nutritionist has formulas that are limiting in arginine, the lupin seed meal is a noticeably cost-effective feed ingredient.

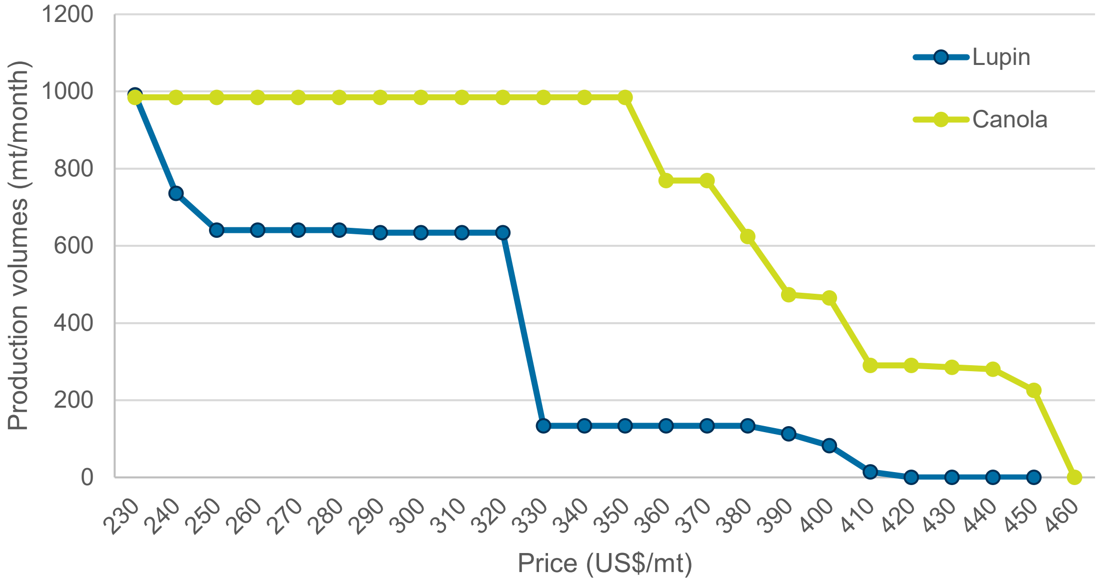


Figure 48. Production volume of canola meal and lupin seed meal demanded within a price ranging of US$230 to US$460 per tonne and the soybean meal price set at US$503.

The demand curves show that the inclusion of lupin seed meal drops sharply at US$320 per tonne compared to the more gradual decline for canola seed meal once the price reaches US$350 per tonne (Figure 49). In this analysis canola meal priced at US$350 to US$370 per tonne will be cost effective in most feeds when soybean meal is priced at US$503 per tonne delivered to the feed mill.

Lupin seed meal in this analysis has a protein content of 32 per cent indicating the seed has undergone limited processing. Further processing, by cleanly separating the seed coat from the kernel can increase the protein content to 38-40%. This is likely to produce a higher shadow price for lupin seed meal in poultry diets.

Outside of Australia the nutritional content and value of lupin seed meal and lupin kernel meal is often not well known or understood. Given this, lupins are more difficult to price and bids may vary between different potential users. Opportunities are likely to exist within Indonesia for technical education and training to improve the knowledge and use of lupin seed meal in poultry diets. Further opportunities may exist in cost effective processing of lupin seeds in Indonesia to enhance value.

Beef

Agricultural by-products

Ruminants require some energy in their feed to allow microbial protein to be produced by bacteria in the rumen through fermentation. Energy can be supplied from digestible fibre but starch is a higher fermentable energy source and hence addition of high starch enables the overall fermentable energy to be increased more easily or to higher levels quickly. In the traditional Indonesian cattle diets the starch supply comes from cassava residue and silage. Feed grains, particularly barley could be used as alternative sources of starch. However, based on price assumptions in the analysis used here, wheat, barley and sorghum are all excluded from beef feedlot rations because local feed materials, particularly onggok, silage, and palm kernel expeller are very cheap and therefore, limit the opportunity for grains (including corn) in beef feedlot rations.

Beef feed lots rely on by-products as the feed energy source which currently provide acceptable animal growth without the need for feed grains.

The opportunity for grains inclusion in beef feedlot rations may change over time. While compiling this report, several Indonesian stakeholders revealed concerns about declining starch levels in onggok because new processing technology has improved starch extraction rates. Some beef producers suggested that over the next five years feed grains may become an increasing component of beef feedlot rations. Currently, the industry is using lower grade by-products effectively as animal growth rates in well performing beef feedlots are around 1.8 kg/day, an acceptable rate for cattle with reasonable genetic potential.

Future use of feed grains

Over time, increasing starch extraction in the food processing sector will lead to low residual starch in onggok. Furthermore, with improving productivity the energy requirements for diets are also likely to increase. Hence, with improved genetic potential of beef animals, the energy levels in diets will need to increase to reach the increased growth potential. Similarly, as the quality expectations from customers increase, the energy level in diets also needs to rise to improve carcass quality.

To examine the effect of reduced energy contribution from onggok in beef diets we compared two diets:

- Basal feed - onggok with a residual starch of 53%, representative of current levels.
- Low starch onggok - onggok with a reduced starch level of 24%.

Table 15 shows the price at which grain would be substituted into diets to compensate for the reduced energy in the low starch onggok.

In the basal feed, the shadow price for corn is only US$239.70 per tonne. Assuming the market price for corn is US$300 then corn is excluded from the formulated diets as expected. In the low starch onggok analysis, more starch is needed hence corn is included in the formula, with the shadow price equal to the cost of corn (US$300). Other grains (wheat, barley and then sorghum) are included in the feed containing the low starch onggok with prices varying in line with their protein levels all of which exceed corn. At higher corn values US$320 and US$340 the shadow pricing of wheat barley and sorghum show the same hierarchy of relative values as shown at a corn price of US$300 (data not shown).

Table 15.Shadow pricing for feed grains used in beef feedlot diets with two levels of residual starch in onggok. Shadow prices are relative to the price for corn set at US$300 per tonne. Shadow prices are shown for three levels of moisture in barley and three protein levels of wheat.

Feed grain	Basal feed	Low starch onggok
Corn	240	300
Barley 88.5% dry matter	241	296
Barley 89% dry matter	243	302
Barley 89.5% dry matter	245	313
Sorghum	242	303
Wheat 10% protein	250	311
Wheat 11% protein	257	316
Wheat 12% protein	266	324

Protein differential is the distinguishing factor in the shadow price hierarchy because the energy content of the cereals are all higher than the energy content of the diet.

To further show the value of protein and dry matter, wheat was included at three protein levels and barely at three moisture levels. The value of 1% of protein in wheat was approximately US$4.65 per tonne while the value of 1% dry matter in barley (with the concomitant increase in energy and protein) was US$7.20 per tonne.

As described above there is little need for feed grains to be included in beef feedlot diets given the current nutrient levels in by-products feed materials. We conducted further analysis (data not presented) looking at a range of starch levels in onggok to determine the breaking point at which onggok fails to provide sufficient energy. This analysis shows that the starch content in onggok will need to fall below 40 per cent to allow significant inclusion of corn and other grains into beef diets.

Preference for barley

Feed intake and growth rate are important factors to consider when investigating the potential use of barley (or other grains). If the dry matter intake is below expectation, then inclusion of barley would assist in boosting the dry matter intake and increase growth rate.

Barley is a lower risk feed ingredient in cattle diets.

Barley is preferred to wheat and sorghum in ruminant diets because its level of fibre is a good choice to balance the starch content and reduce acidosis risk. Barley also has an advantage in that it has a high disappearance rate. Given these characteristics, barley has the effect of increasing the daily dry matter intake and thus increasing the overall daily nutrient intake. For example, even though the starch level is not as high as copra meal, diets utilizing barley would tend to have higher net intakes of energy due to the higher feed intake.

The availability of the starch and the higher feed intake will enable efficient use of urea to be used as a protein source. Urea can be converted to amino acids by bacteria and contribute to the amino acid supply in the small intestine. This conversion does require some starch or simple sugars to provide the energy and the carbon skeleton for bacterial growth and protein synthesis.

There may be an application for barley in beef breeding herds and dairy operations. Cattle will lose weight after calving and in the first part of lactation. High fibre levels in Indonesian cattle diets combined with high environmental temperatures limit feed intake. Weight loss is inevitable but can be reduced with increases in the soluble fibre from barley that allows more dry matter intake. Once the weight loss is reversed or stabilised to a low steady loss, a normal calving cycle returns. A farm with low or delayed conception could benefit from barley use in the rations to change early lactation intake of energy in a positive direction.

Low fertility is a problem in Indonesian cross bred cattle and imported Holstein Friesian cattle. It is not, however, as large an issue with domestic beef breeds which tend to have better fertility but low production.

Dairy

Specifications for dairy feeds vary substantially between farms depending on the genetics of the herd, the availability of forages and the general level of resources (e.g., human) and technology. To estimate the relative values of ingredients in dairy feeds a totally mixed ration (TMR) from a large industrial dairy farm has been used to represent feeds in the sector for this analysis. The feed has also been adjusted from a daily feed ration on an as-fed basis to a 100% batch weight formula with the ingredient adjusted to 88% dry matter.

Further, the feed was converted into three formulas to reflect the high, medium, and low producing cattle in a farm group over the lactation cycle (see Figure 50):

- Early lactation diet – high producing cattle from calving until after bodyweight recovery has occurred. The energy is supplemented with a by-pass fat. This diet has the highest energy and protein as well as the lowest silage allowance.
- Mid lactation diet – cattle in the post peak production phase. The diet uses a choice between a lower level of palm oil or by-pass fat to supplement the energy level. Energy and protein were lowered, and the silage allowance increased as the dry matter intake rises.
- Late lactation diet – the low producing cattle at the end of lactation where the bypass protein was lowered as well as the energy. These diets used an increased proportion of silage over mid and early lactation phases.

As the stage of production advanced, the silage allowance was increased.

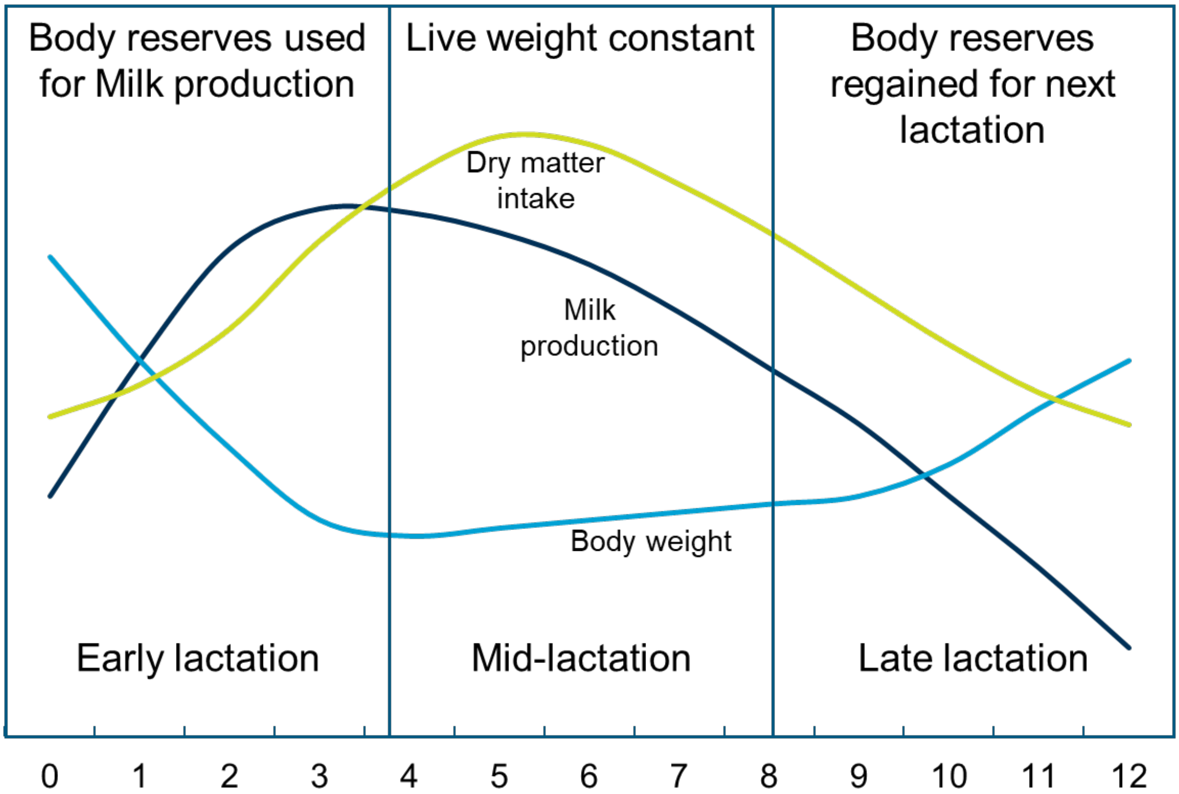


Figure 49. Phases of milk production (The Cattle Site, 2015)

Barley

Barley has its highest value in low energy late lactation dairy diets.

Shadow prices of barley supplied at three different moisture levels are shown in Table 16. Overall, the relative value of barley averaged 96% to 97% of the corn price and increased from US$291 to US$327 as the price of corn increased from US$300 to US$340 per tonne. The relative value of barley is highest in late lactation diets.

- Early lactation – Barley is price at a disadvantage to corn in this feed. The relative value is in the range of 88% to 90% of corn.
- Mid lactation – The relative value of barley increases to 97% as the feed density decreases in both energy and protein.
- Late lactation – The relative value range strengthens further to over 103% in these lower energy intake diets.

It is important to note that there is also variation in barley values depending on grain moisture content. Over the dry matter range covered in this analysis (88.5% to 89.5%) the value of barley increased by up to US$6 per tonne as the dry matter increased, with the effect of moisture being greater in high energy diets.

Table 16. Shadow prices for barley in dairy diets supplied at three moisture levels (DM contents) and three diet phases. Prices are presented relative to corn priced at US$300, US$320 and US$340 per tonne.

Moisture (Barley dry matter %)	US$300	Relative value (%)	US$320	Relative value (%)	US$340	Relative value (%)
	Early lactation					
88.5	268	89	281	88	298	88
89.0	271	90	285	89	301	89
89.5	274	91	288	90	305	90
Crude average	270	90	285	89	301	89
	Mid lactation					
88.5	287	96	308	96	328	96
89.0	289	96	309	97	329	97
89.5	292	97	312	97	331	97
Crude average	290	97	310	97	329	97
	Late lactation					
88.5	312	104	331	103	350	103
89.0	313	104	332	104	350	103
89.5	314	105	333	104	351	103
Crude average	315	104	332	104	350	103
Overall crude average	**291**	**97**	**309**	**96**	**327**	**96**

Wheat

Wheat 's relative value is slightly higher to corn for all dairy lactation diets.

Wheat is at a price advantage to corn in ruminant diets across the price range used in this analysis (corn priced at US$300 - US$340 per tonne). Wheat with 10% protein had a relative value ranging from 101% to 103% of the price of corn (Table 17). Higher protein wheat had an even higher relative value (data not shown) The effect of protein is highest in early lactation diets where the shadow price of 12.5% protein wheat was US$13 to US$18 higher than the price of wheat with 10% protein (and relative values increasing from 101% to 106% of the price of corn).

The shadow pricing range for wheat from early to late lactation diets are substantially narrower for than for barley. The barley shadow price increased by more than US$40 per tonne as diets move from early to late lactation diets (higher to lower energy) with the relative values changing from significantly lower to slightly higher than corn. In comparison wheat (10% protein) only increase by about US$5 per tonne from the early to late lactation diets.

Table 17. Shadow price and relative value of wheat with 10% protein used in three dairy diet phases. Prices are presented relative to corn priced at US$300, US$320 and US$340 per tonne.

	US$300	Relative value (%)	US$320	Relative value (%)	US$340	Relative value (%)
Early lactation	305	101	324	101	343	101
Mid lactation	307	102	326	102	345	102
Late lactation	310	103	329	103	348	102
Crude average	302	101	326	102	345	102

Sorghum

Wheat barley and sorghum all show highest value in late lactation dairy diets.

As the energy and protein levels in sorghum are similar to corn, the average relative value is more constant across the feed types and is very similar to corn (Table 18). This also occurs in poultry diets. As with wheat and barley, the relative value of sorghum increases in the later stage diets as the cost of energy is lower and protein is a more important factor in the feed cost.

Table 18. Shadow price and relative value of sorghum with 10% protein used in three dairy diet phases. Prices are presented relative to corn priced at US$300, US$320 and US$340 per tonne.

	US$300	Relative value (%)	US$320	Relative value (%)	US$340	Relative value (%)
Early lactation	292	97	310	97	329	97
Mid lactation	298	99	318	99	338	99
Late lactation	306	102	326	102	344	101
Crude average	299	100	318	99	337	99

In summary, wheat is showing the highest overall relative value compared with corn in this dairy diet analysis. Shadow prices for wheat, averaged across the three diet phases, were consistently higher than the price of corn. The relative price of barley shows the greatest response to diet phase, moving from a price discount to corn to a price premium as diets move from early to late lactation (Figure 51).

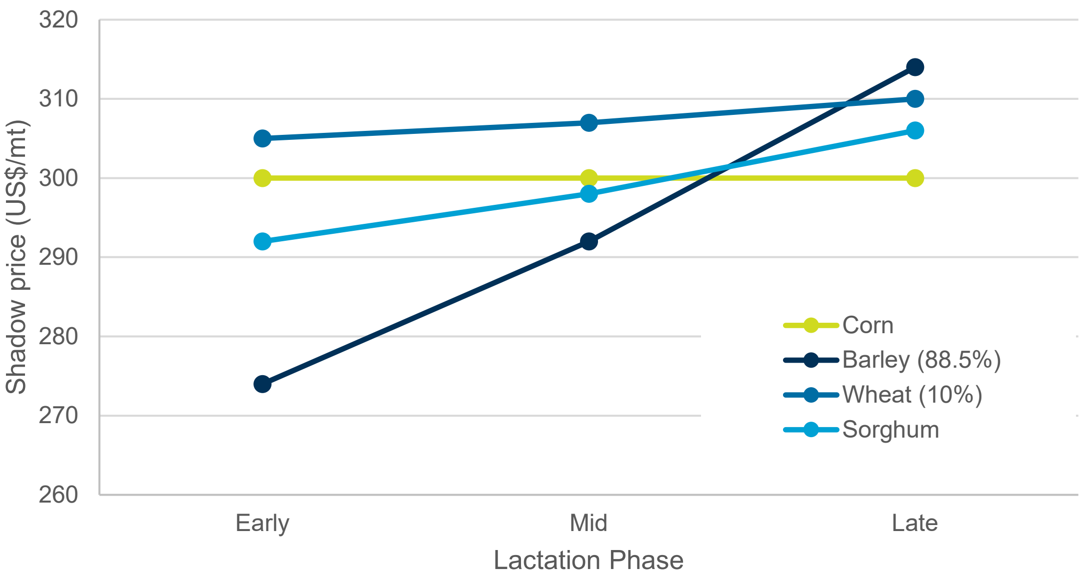


Figure 50. Shadow pricing for barley, wheat and sorghum, compared with corn prices at US$300 in dairy diets formulated for early, mid and late lactation.

Canola meal and lupin seed meal

Canola and lupin seed meal are compared against soybean meal priced at US$500, US$520 or US$540 per tonne. Shadow prices for both canola meal and lupin seed meal varied strongly across diet phases being priced close to soybean meal in some phases and heavily discounted in other phases (Table 19).

Lupin seed meal shows higher value than canola meal in Indonesian dairy diets.

Canola meal was more suited to late lactation diets that required lower levels of dairy nutrition. For example, averaged across each soybean meal price level, the relative value of canola meal changed from 63% of the value of soybean meal to 86% in the late lactation diets. This was an increase of more than US$110 per tonne in the shadow price. Canola meal has a high level of crude protein (approximately 36%) but the energy is relatively low compared to soybean meal thus it has lower value in the early lactation diets that require high energy and high protein. In late lactation feed the energy need is lower and diets also have lower protein allowing canola to closer match the feed specification.

Table 19. Shadow price and relative value of canola meal and lupin seed meal used in three dairy diet phases. Prices are presented relative to soybean priced at US$500, US$520 and US$540 per tonne.

	US$500	Relative value (%)	US$520	Relative value (%)	US$540	Relative value (%)
Canola meal						
Early lactation	320	64	331	64	341	63
Mid lactation	365	73	366	70	366	68
Late lactation	437	87	450	87	463	86
Crude average	374	75	382	74	390	72
Lupin seed meal						
Early lactation	478	96	492	95	506	94
Mid lactation	502	100	511	98	519	96
Late lactation	435	87	447	86	460	85
Crude average	472	94	483	93	495	92

Compared with soybean meal, lupin seed meal has a medium level of crude protein (32% on an as-fed basis) and a higher energy level making it an ideal match for mid lactation feed. The shadow price of lupin seed meal was therefore equivalent to soybean meal priced at US$500 per tonne.

Overall, the shadow price of lupin seed meal was the same or above that of canola meal and did not show as great a variation. Even in late lactation diets where lupin seed meal was least suited, the shadow price was still 86 per cent of the price of soybean meal.

Despite the lower average shadow price for canola meal being almost US$100 per tonne lower than lupin seed meal it is important to also consider other advantageous properties that feed ingredients may have which are not picked up in the least cost ration calculations presented here. For example, canola:

- Stimulates higher intake which is a valuable property in early lactation.
- May increase yield of key milk components.
- Will positively affect the calving interval if the bodyweight decline is reversed earlier in the cycle due to the higher dry matter intake.
- Is a good source of by-pass methionine which is limiting in high yielding dairy feeds.

Aquafeed

Feed grade wheat flour is the predominant cereal used in Indonesian aquafeed diets supplying digestible starch as well as providing binding for pellets. Corn is not commonly included in aquafeeds, but we have used it as a reference point here for pricing feed grains to remain consistent with poultry and ruminant sections of this report. It should also be noted that this analysis presents shadow prices for wheat and other feed grains delivered to the feed mill. This is different from the current situation where wheat in Indonesian aquafeed diets is provided as feed grade wheat flour (aqua flour) sourced from Indonesian flour mills. The preliminary analysis below provides a useful indication of the value of alternative feed

Wheat flour is the major cereal ingredient used in Indonesian aqua feeds.

material in Indonesian aquaculture. More rigorous analysis that reflects the prevailing supply chain circumstances within the Indonesian aquaculture industry will be required to more accurately determine where alternative feed material can most profitably fit within Indonesian aquaculture systems.

Indonesia produces about 1.6 mmt of commercial aquaculture feed per year. Table 20 shows the estimated production tonnages for aquafeeds in Indonesia by feed type. These tonnages have been used to develop the demand curves for feed ingredients (see Figure 52 below). Data is presented for barley at only one moisture level (89% dry matter) and wheat at one protein level (11%).

Table 20. Estimated production tonnages for aquafeeds in Indonesia used to develop demand curves for feed ingredients.

Feed type	Volume produced (tonnes per year)
Tilapia Starter	115,200
Tilapia Grower 1	172,800
Tilapia Grower 2	172,800
Tilapia Grower 3	115,200
Carp Starter 50-200	100,800
Carp Grower 1 200-500	252,000
Carp Finisher 500-1500	151,200
Pangasius Starter 50-200	72,000
Pangasius Grower 200-500	180,000
Pangasius Grower 500-1500	108,000
Shrimp Grower 15-70	180,000
Shrimp Grower 3-15	180,000
Total	1,620,000

Shadow prices for barley wheat and sorghum

Barley may the highest value in aquaculture feeds, wheat has the most consistent value.

Barley showed a higher shadow than wheat or sorghum across all fish diets because of its higher digestibility (Table 21). The highest shadow price for barley occurred in shrimp feeds which was about US$21 per tonne more than in carp feeds. Interestingly, barley is not commonly used in shrimp diets.

Shadow prices for wheat are similar across all diets with less than a US$2 variation. The relative value of wheat, however, diminished slightly from 105% to 103% when priced against corn at US$300 per tonne compared to US$340 per tonne (data not shown). The consistent pricing for wheat across fish diets means that wheat stock at feed mills can move between different formulas without impacting cost.

The shadow price of sorghum was generally similar to corn for tilapia and carp diets but was strongly discounted relative to corn in the dense shrimp diets being priced at US$278 per tonne. The highest shadow price for sorghum was US$311 per tonne in tilapia grower 3 diets which is a lower density feed.

Table 21. Shadow pricing of barley, wheat and sorghum incorporated in a range of aquafeed diets. Prices are presented relative to corn at US$300 per tonne.

Feed type	Barley	Wheat	Sorghum
Tilapia Starter	316	314	301
Tilapia Grower 1	317	314	299
Tilapia Grower 2	317	313	299
Tilapia Grower 3	320	314	311
Crude average	318	314	303
Carp Starter 50-200	317	312	299
Carp Grower 1 200-500	314	313	302
Carp Finisher 500-1500	317	312	299
Crude average	316	312	301
Pangasius Starter 50-200	325	313	293
Pangasius Grower 200-500	325	313	293
Pangasius Grower 500-1500	326	313	291
Crude average	325	313	292
Shrimp Grower 15-70	338	312	278
Shrimp Grower 3-15	338	312	278
Grand average	322	314	295
Value relative to corn @ US$300/mt	107%	105%	98%

Demand curves for barley wheat and sorghum

Demand curves for barley, wheat and sorghum were constructed using the feed tonnages in Table 20 to estimate the annual demand for these grains in aquafeed diets in a price range from US$250 to US$350 per tonne. As with the shadow prices above, prices are comparative to corn priced at US$300 per tonne.

Figure 52 shows that at prices below US$290 per tonne higher amounts of sorghum and wheat are demanded than barley. The prices and volume where demand breaks down however, is higher for barley than for sorghum. Demand breaks down for barley at US$310 with a volume of 315,000 tonnes annually, whereas it breaks down at US$290 with a volume of 370,000 tonnes annually. Demand for wheat breaks down at US$310 with a volume of 453,000 tonnes annually.

These figures should only be taken as a guide because different companies will have different opinions on the maximum usage. It should also be remembered that in some cases the wheat substitutes for wheat starch (sourced as aqua flour) and part of the value of aqua flour is contained in its binding properties. Realistically for aquafeed it is likely that wheat will continue to be supplied as aqua flour through flour mills while barley and sorghum, if substituted into feeds, would be supplied directly to feed mills.

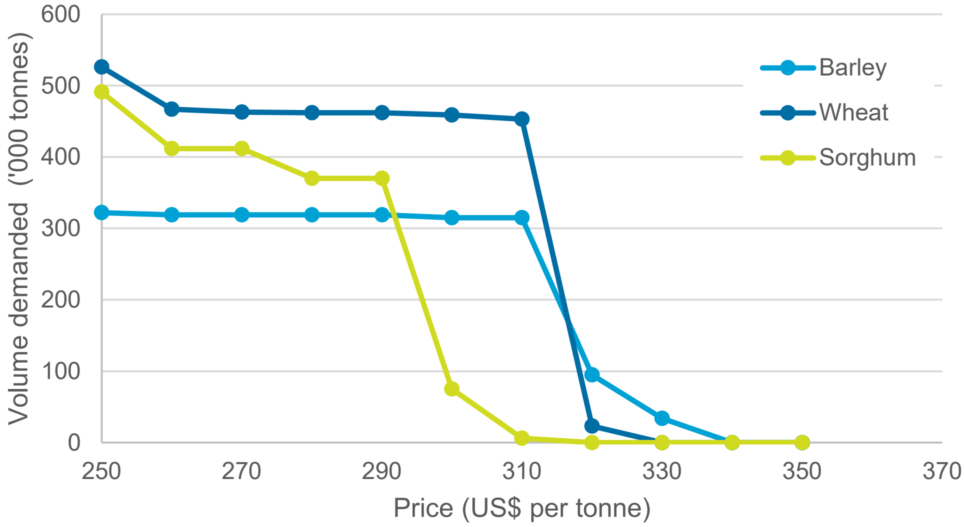


Figure 51. Demand for barley, wheat and sorghum in Indonesian aquafeeds when priced between US$250 per tonne to US$350 per tonne assuming corn is priced at US$300 per tonne.

Shadow prices for canola meal and lupin seed meal

Canola meal (with 36% crude protein) and lupin seed meal at two protein levels (32% and 36% crude protein) were evaluated against a soybean meal price of US$500 per tonne.

The shadow price of canola meal was above lupin seed meal for all diets (Table 22). Canola meal and lupins with 32 per cent crude protein was priced highest in carp feeds, while lupin seed meal with 36 per cent protein was priced highest in shrimp feeds. The lupin seed meal price was lowest in the tilapia grower 3 feed, a low-cost low protein tilapia feed.

The shadow price of lupin seed meal with 36 per cent protein is almost equivalent to the price of canola meal in shrimp feeds. Part of the reason is that shrimp feeds will have a higher energy requirement. Lupin seed meal is high in arginine and while arginine is not limiting in the shrimp feeds, there is some discussion on the immune boosting effect of additional arginine that, although not a feature of least cost ration calculations, is nonetheless a factor to consider in the purchasing and formulation decision (Birmani *et al* 2019).

Table 22. Shadow pricing of lupin seed meal at two protein concentrations and canola meal when incorporated in a range of aquafeed diets. Prices are presented relative to soybean meal priced at US$500 per tonne.

Feed type	Lupin seed meal 32% crude protein	Lupin seed meal 36% crude protein	Canola meal
Tilapia Starter	426	442	455
Tilapia Grower 1	425	445	451
Tilapia Grower 2	424	442	453
Tilapia Grower 3	371	381	449
Crude average	412	428	452
Carp Starter 50-200	424	437	455
Carp Grower 1 200-500	422	439	458
Carp Finisher 500-1500	424	437	455
Crude average	423	438	456
Pangasius Starter 50-200	432	437	446
Pangasius Grower 200-500	432	437	446
Pangasius Grower 500-1500	433	436	444
Crude average	432	437	445
Shrimp Grower 15-70	423	441	445
Shrimp Grower 3-15	423	441	445
Average	422	435	450
Value relative to soybean meal @ US$500/mt	84%	87%	90%

Demand curves for canola meal and lupin seed meal

Demand curves for canola meal and lupin seed meal were constructed using the feed tonnages in Table 20 to estimate the annual demand for these meals in aquafeed diets in a price range from US$360 to US$460 per tonne (Figure 53). Prices are comparative to soybean meal priced at US$500 per tonne.

Lupin seed meal with 36% protein is demanded at the highest volumes (254,000t per annum), while canola meal is demanded at the lowest volumes (144,000t per annum). In contrast the price at which demand breaks down is lowest for lupin seed meal with 32% protein (US$420 per tonne) and highest for canola meal (US$440 per tonne).

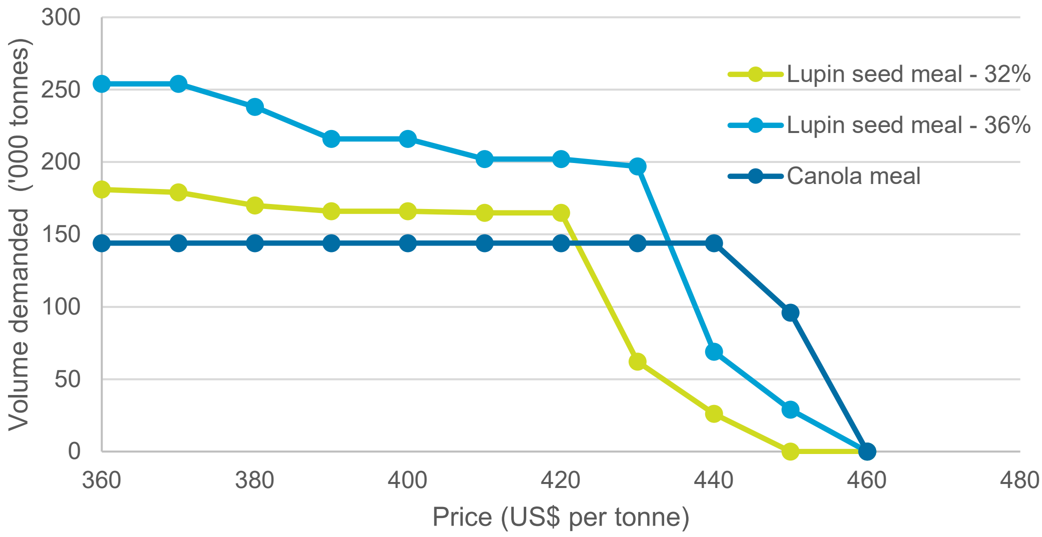


Figure 52. Demand for lupin seed meal at two protein concentrations and canola meal in Indonesian aquafeeds when priced between US$360 per tonne to US$460 per tonne assuming soybean meal is priced at US$500 per tonne.

Canola meal and lupin seed meal provide safe alternatives to soybean meal in aquafeeds.

Formulating aquafeeds is an area of continuous innovation as the feed industry keeps pace with this rapidly growing sector in Indonesia. Further research will improve the use of cereal and protein meals in Indonesian aquaculture feeds. For example, some work on improving the protein/gluten content of wheat varieties and flours may allow improved pellet quality and water holding capacity.

The opportunity for barley in aquaculture feeds appears to be strong despite its higher fibre and current limited use. The use of barley in the shrimp feeds, in particular, is worth investigating further. Some producers are looking at lower cost ingredients that are higher in fibre so the trend to the higher NSP ingredients is an opening for barley.

Canola meal and lupin seed meal are both good sources of protein without significant levels of trypsin inhibitor making these products safe choices for use in aquaculture feeds. There may be value in investigating the use of these protein sources in developing protein derivatives such as hydrolyzed fermented or isolated proteins as they may have nutritional values higher than soybean meal. The aqua protein market in Indonesia is of a significant size to warrant investigation of higher value-added products.

4. Opportunities for the wider use of feed grains in Indonesia's animal protein industries

Introduction

Government and business investment, including that of farmers, continue to modernise Indonesia's animal industries and generate strong growth in the production of fish, chicken, beef, dairy and other animal proteins. Over the past decade the production of meat and fish from aquaculture in Indonesia has doubled, increasing from 5.2 to 10.3 mmt. Substantial potential growth remains, which will enable Indonesia to meet its growing domestic demand and increase exports. Strong growth, however, will inevitably bring with it, new constraints and opportunities requiring new responses from government, industry and farmers. Some of these responses will concern new ways to use feed grains. This chapter, largely based on consultation with Indonesian stakeholders or Australian stakeholders with long experience working in Indonesia, identifies constraints to the wider use of feed grains in Indonesia's animal production industries and highlights the opportunities to be addressed through the Indonesia-Australia Comprehensive Economic Partnership Agreement (IA-CEPA) Economic Cooperation Program (ECP).

It should be noted that Australian feed grains are just one potential part of the feed grain complex used in Indonesia and are largely complementary to Indonesian corn. As such, Australian feed grains are well suited to a wide range of applications in Indonesia's animal production sector. There is no fundamental limitation to Australia meeting the demand from Indonesian industry other than Australian grain price and Indonesian government import policies.

Awareness Building

Constraint	Description	Opportunity
• Many Australian stakeholders have limited understanding of Indonesian feed industry needs. • Many Indonesian stakeholders do not have easy access to feed grains or product information.	There is a reciprocal need to understand each other's feed and livestock industry sectors in much more detail. The various livestock sectors have different levels of understanding of feed grain use, and a different set of information requirements.	• There is an opportunity to jointly develop pathways for Indonesian and Australian feed grain stakeholders to improve their understanding of each other's needs. • Indonesia and Australia could also examine potential value adding options, e.g., 'powerhouse' export models in lupin processing.
• Knowledge of the intrinsic value of some feed grains, is variable within the Indonesian industry	The quality and nutritional value of domestic corn and imported wheat is well understood within the poultry industry, and less so in the beef and dairy industries. Other than wheat, the intrinsic or unique qualities of Australian grains and products are not widely understood across Indonesian users (e.g., with appropriate management Australian grains are able to be stored for long periods, Australian canola meal is processed in different ways influencing nutritional quality).	• Australia and Indonesia could collaborate to increase use of domestic corn in beef and dairy industries and discover and share complementarities of Indonesian and Australian grain in Indonesian production systems.
• Livestock producers and feed enterprises need convincing evidence of the economic merit of substituting alternative grain ingredients.	Feed mill feed margins are often less volatile than the profit from other products produced within their vertically integrated value chains. Substitution of any feed ingredient needs clear advantages (e.g., cost and benefit), particularly for risk averse producers such as smallholders.	• Demonstrate to feed mills and producers the advantages of using feed grains under their individual circumstances.
• Australia lags its competitors in tailoring information packages on feed grains to	Indonesia is not a traditional market for Australian feed grains, hence Australian interaction with the Indonesian livestock industry have concentrated on animal production sectors rather than the feed sector.	• Indonesia and Australia will only fully realise the opportunities opened through the IA-CEPA, by strong and

meet Indonesian requirements.	Many of Australia's competitors (e.g., USA, Netherlands) have been working with Indonesian livestock users and feed sectors for many years, often using a whole value chain approach (e.g., economists, livestock researchers and producers, Government with private sector funding).	consistent mutual engagement around feed grains.

Collaborative research and development

Constraint	Description	Opportunity
• Changes from traditional to modern farming systems are often slow and limit increased grains use.	Changes within smallholder farming systems can be problematic, particularly as these structures provide family employment and social benefits. Other factors also contribute (e.g., lack of technical knowledge or skill, difficulty in obtaining finance). This can result in a reluctance to move to modern farming systems incorporating feed grains. Larger, more modern enterprise, which are also usually integrated production/processing businesses can provide an avenue to introduce new production methodologies to the smallholders connected to their operations.	• The Indonesia-Australia Economic Cooperation Program could deliver feed grain initiatives to leading businesses, with the intent for those businesses to act as a conduit to extend new technologies and practices to segments that are traditionally slower to adopt. e.g., large scale feeding demonstration trials, that include smaller organisations as participants and recipients of findings.
• The nutritional and economic complementarity of Indonesian and imported Australian feed grains has not been regularly or widely demonstrated, other than the use of wheat and corn in poultry diets.	The focus of productivity and profitability improvement programs with Indonesian farmers, has been on the use of local raw materials rather than imported feed grains. This is consistent with the government policy of self-sufficiency in corn and rice. The use of Australian barley, sorghum, lupins and canola or derivative products is largely untested by many Indonesian stakeholders with the benefits unknown. There are few journal or published articles on Australian feed grain use in Indonesia.	• Indonesia and Australia may jointly examine: ○ the development of feed trials and extension of case studies demonstrating the effective use of feed grains in Indonesian animal production systems. ○ technical training initiatives and exchange visits between Indonesian and Australian animal producers and feed specialists, including farm visits. These will

		need to be on-line interactions initially and will extend to personal visits as COVID-19 restrictions ease.
• Antinutritional factors and inefficient use of grain can negatively affect animal productivity	Grains have unique characteristics that provide opportunities if managed correctly, or limitations if managed improperly. As an example, the use of new and improved enzymes can increase an animal's access to nutritional value from feed grain.	• Participation in the feed grains research and ongoing access to the latest research findings, could improve the benefit from using grain

Grains supply and value chains

Constraint	Description	Opportunity
• The ease of disseminating new information and creating rapid change is more difficult in smallholder systems and SMEs.	Smallholders and SMEs are spread across the archipelago and produce a range of agricultural products on small lots. These independent farmers may have less consistent access to information, and technical advice resulting in greater management and profit risk. For these farmers, a switch from local ingredients to feed grain use presents multiple challenges and consequently, rates of change are slow.	• The Indonesia-Australia Economic Cooperation Program provides opportunity to support smallholders and SMEs through innovation in the way information is provided (e.g., mobile phone messaging), and through presenting alternative organisational structures that increase profitability and reduce risk.
• Smallholders and SMEs are less likely to access benefits from using grain in production systems.	Smaller independent operators do not have the scale and capacity to purchase large quantities of grains or high-cost inputs such as enzymes. Storage and processing capacity, finance, and access to sophisticated feed ration calculators, are limited.	• Examine pathways and new initiatives to efficiently aggregate and deliver feed grains to small regional users (e.g., containers) and large entities.
• Some small holders have limited access to price information outside of local broker and village networks.	The presence of multiple middlemen within long and complex value chains means that the transmission of price information is opaque. Producers may miss opportunities to	• Appraise the value and suitability of improved phone-based services that provides pricing transparency to Indonesian sellers and buyers of feed

	maximise returns through inadequate access to price information.	grains and a platform for secure transactions.
• The consumer's preference for buying whole poultry, or large cuts of meat in wet markets, limits opportunities for animal producers to add value through differentiated product offerings.	Traditional food production and consumption remains strong in non-urban areas. (e.g., market purchased freshly slaughtered chickens are preferred rather than chilled product, native chickens are often preferred in rural areas because of their small size and flavour). Obtaining a higher value for meat products enables producers to purchase and utilise feed grains to a greater extent.	• Leveraging the shift of consumer's preferences to higher value cuts of pre-packaged meat purchased from supermarkets, will improve the use of feed grains and provide options consumers. It will also benefit the livestock industries.
• Competition from imported meat and dairy products constrains local opportunities within higher value markets.	Pre-packaged imported beef and dairy products are increasingly popular and compete in higher value markets. This crowds the opportunity for high value locally produced meat, and fresh local milk.	• Increase productivity of beef and dairy production, especially in high value segments by using feed grains to increase the competitiveness of local production against imported competition.

Infrastructure and capital

Constraint	Description	Opportunity
• Corn is produced by small farms across a wide area and storage is of varying quality. • Pressure on feed mill storage due to timing and nature of corn harvests, lack of available storage at SME's.	Post-harvest management of domestic corn is challenging with difficulties drying and storing grain. The requirement to dry corn increases domestic storage needs, placing pressure on available storage space particularly at small mills. Aggregating viable parcel of grain is time consuming and expensive.	• Potential for sharing expertise in storage technologies and strategies to assist in managing domestic crops. Indonesia and Australia can jointly examine the potential for improved grain storage options on farms and private warehousing.
• Unfamiliarity with the physical, storage and transport characteristics of some of	While some Indonesian stakeholders are familiar with the broad handling and storage properties of Australian cereals (wheat, barley and sorghum) the characteristics of	• Building awareness of the logistic, and handling characteristics of feed grains.

imported grain commodities or products.	other Australian commodities and products are less understood (lupins, lupin kernel meal, canola meal).	
• Indonesia is reliant on three major ports, with most of the feed grain imported via these increasingly busy facilities.	Infrastructure is less advanced at secondary ports, Transfer of feed between islands is limited mainly because of inefficiencies resulting from lack of port capacity or infrastructure and as vessels are limited in their size.	• Indonesia continues to enact its strategy to develop the port infrastructure and hubs, that includes planning for bulk grain receivals, grain storage at port, and streamlined container processing.
• The complexity in modernising port infrastructure and internal transport systems, results in costs that are currently higher than Asian neighbours.	While the government has plans in place to update port facilities by 2025, at present there are improvements needed within the system, and labour considerations constrain improvement in systems and processes. For example, technology systems such as electronic tracking of containers have only become available in Tanjung Priok since 2015, though these technologies are not duplicated at other ports. This combination of factors increases the cost of importing feed grain. Road transport is preferred in Indonesia due to its relative speed and reliability but is expensive to transport feed. Major feed mills have sought to reduce the impact of high transport costs by locating mills close to major ports, raw materials and on islands with higher livestock production.	• Consider research that aims to understand how improvement in the current port and transport infrastructure can assist the domestic feed and livestock industry.
• Infrastructure required by the feed grain and livestock sector, is less developed in the east and north of the country, than within Java and Sumatra.	Indonesian domestic cargo distribution is mainly orientated towards west and central regions, with return shipments from eastern islands often being empty. Poor port infrastructure, wharf congestion and small vessels results in inefficiencies in inter-island transfers. Additionally, it is uneconomic to import grain in bulk through port facilities, and then trans-ship to the east and north.	• An increasingly integrated and globally connected logistic network may improve the viability of utilising feed grains within profitable animal production systems.

	Indonesian government action is assisting to build locally integrated and globally connected logistic networks that will reduce the internal supply chain costs, benefitting the livestock industry amongst others.	

General

Constraint	Description	Opportunity
• Government policies designed to support needs of smallholders impacts the rate of transition to modern feeding systems.	Traditional, integrated, small scale farming remains important, providing food security, employment and social connection while also contributing substantially to the economy. Subsequently, agricultural and food policies are often framed to support this sector. Policy effects may not always be optimal for larger feed and livestock enterprises.	• Economic research could outline options to de-risk the potentially adverse social consequences of moving to increasingly profitable and productive livestock and feed systems.
• Regulatory environment for imports of agricultural commodities to Indonesia is “complex, ambiguous and changeable”, and not well understood by many Australian stakeholders (DFAT)	Indonesia’s agricultural policy is centred on increasing domestic production of food to meet the country’s current and future needs rather than increasing grain imports, e.g., limits corn and feed wheat imports to support domestic corn production. Import policy is revised and changed regularly, and at time rapidly, e.g., import bans on feed grains.	• Upholding IA-CEPA commitments by Indonesian and Australian stakeholders will improve certainty of access to Australian feed grains that support growth in the profitability and productivity of Indonesian livestock producers.
• Australia does not always have a large exportable surplus of all grains at prices suitable for the Indonesian feed market.	Australia’s grain production is mostly rainfall dependent. At times Australia will have limited export availability of some grains. Supply disruptions need to be signalled in advance and feed grain trade easily resumed when possible.	• To increase the information exchange between industries, that expands existing grain trading relationships already deeply embedded within the Indonesian milling industry, to the Indonesian feed sector. • Opportunity for ABARES to develop crop production forecasting systems

		that provide the Indonesian industry with better visibility over the quality and quantity of grain available from Australia.
• The volume of Indonesia's grain imports is carefully managed, to support domestic production, and food sovereignty	Indonesian government agencies are tasked with managing imports of some agricultural products, e.g., BULOG is effectively the sole importer for feed corn. The import of strategic commodities (rice, corn, soybeans, sugar, and beef) is carefully managed.	• Identify and act on synergies between Indonesian needs and Australian feed grain supply. For example, tailoring Australian feed grain varieties or future products to complement Indonesian requirements.
• Women's contribution to Indonesia's agricultural economy is yet to reach full potential.	Economic empowerment of women in agriculture is well recognised by the Indonesian government. Further education and development of women will contribute to the growth of agriculture and use of feed grains.	• Within the IA-CEPA Economic Co-operation Program, which has a strong gender equality and social inclusion focus, support the Indonesian government in its women's empowerment initiatives.
• The environmental impact of the animal protein industries will increase as production expands and increasingly face scrutiny.	Environmental constraints are increasingly impinging on current production practices and will likely change animal protein production and feed use patterns in Indonesia.	• Improving the productivity of the intensive animal production industries will increase the scope for managing environmental impact.
• The social licence of the livestock industry will increasingly face scrutiny	As with all countries, consumers will place increasing pressure on Indonesian food and feed industries to ensure animals are managed according to future social expectations, impacting livestock production systems and feed use patterns.	• Indonesia and Australia could jointly examine social licence issues in the feed grain and livestock industries and act on opportunities that build acceptance.

5. Implementing recommendations: approach, cost and benefits

As Indonesia's per capita wealth continues to grow over the next decade, its feed grain production and use will also grow in sophistication and importance. This is required as the animal production sector meets the expanding demand for greater consumption of high-quality animal products. As listed above, however, there are a range of constraints and opportunities affecting the wider use of feed grains in Indonesia's animal protein industries. We have listed here a portfolio of investments for consideration by the Grains Partnership Program (GPP) within IA-CEPA that directly address these constraints and opportunities and which may contribute to more efficient use of feed grains in Indonesia. The main impacts of these activities are:

- More efficient production and use of local and imported feed grains in Indonesia.
- Better informed Indonesian producers and users of local and imported feed grains.
- Enhanced supply of higher quality local and imported feed grains in Indonesia.

Preliminary costings of the activities listed in Table 23 amount to an expenditure of US$1.91 million over a 5-year period.

Several of the activities could be on-going, most of the benefits will occur in Indonesia and the impacts of the activities are potentially long-lasting.

Although no specific attempt is made to quantitatively assess the benefit cost ratios (BCR) of each suggested activity; it is possible to refer to the published literature to identify the likely beneficial impacts of these sorts of activities. For example, in their meta-analysis of 2,126 benefit cost appraisals of agricultural research and development projects, Rao *et al* (2020) found that the median BCR for agricultural research and development (R&D) projects in the Asia and Pacific region's developing countries (that included Indonesia) was 8.9. By contrast the median BCR for agricultural R&D projects in Australia and New Zealand was only 4.8. Hence, investing in R&D activity in a developing country like Indonesia is highly likely to generate sizeable economic returns. The convenient rule-of-thumb is that every dollar invested in agricultural R&D activity, such as the activities listed in Table 23, is likely to generate about US$9 in benefits. Moreover, as pointed out by Hunt *et al*. (2014) there are lag times in the realisation of the benefits from research, development and extension (RD&E) investment. Lag times of 15 to 35 years are possible before the full dividends from the initial investments in RD&E activity are achieved.

Under the (IA-CEPA) agreement Australia has a tariff-free quota to export 525,250 tonnes of feed grain (wheat, barley, and sorghum) to Indonesia in the first full year of the agreement's operation, with an allowance for 5 per cent growth each year thereafter. From a theoretical economic perspective, the value of this market access is roughly the freight savings from not diverting that volume of grain to another nearby feed market. The freight advantage to Australia of Indonesia's proximity is worth under US$4 a tonne; or potentially up to about US$2.1 million in the first full year of the agreement. However, from a practical perspective the value to Australia is realised by the opportunity to access Indonesia's market and therefore broaden selling opportunities.

The impacts and timeliness of the activities recommended in Table 23 are summarised in Figure 54.

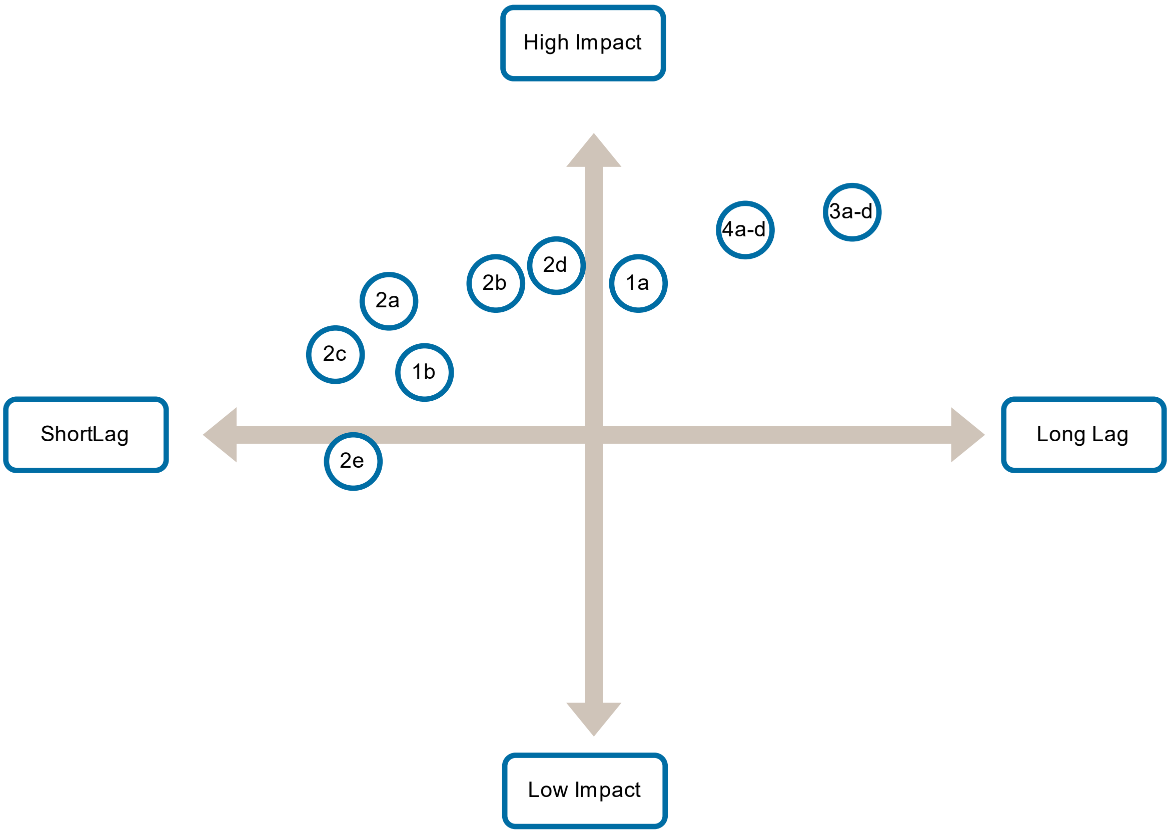


Figure 53: Impact and timeliness of recommended activities

Table 23: Key activities, estimated costs, impact description and likely beneficiaries

Recommendation: 1 Constraint: Awareness building Proposed action: Increase the availability of relevant, easy-to-access information on the use of feed grains[5] in Indonesian animal production systems Estimated cost of activity: US$150k				
Activity code	Activity description	Proposed actions	Impact – Informed decisions on the use of feed grain, trade and policy.	Anticipated social benefits in Indonesia
1a	Create and maintain a feed grain information portal. If housed in Australia setup, promotion and ongoing maintenance costs: US$50k, US$50k and US$10k per annum for five years.	○ Design and construct the feed grains information portal and supporting systems. ○ The information portal could contain: ▪ Technical information and data on feed grains, specific to Indonesia. ▪ E-Learning training modules on the use of feed grains in Indonesia. ▪ Historic pricing trends for a range of feed grains that will assist in formulating least cost rations. ▪ Information that government and business managers can use to inform policy and strategy (e.g., ABARES crop forecasting, TraNSIT, and economic modelling). ○ Promotion, oversight and maintenance tasks are ongoing.	Accurate, timely information about feed grains helps ensure: ○ Decisions that explore new feed formulations using Australian ingredients can be easily and accurately undertaken because relevant information is readily available. ○ Indonesian users improve the cost-efficiency of using local and imported feed grains. ○ Feed grain policy decisions in Indonesia are well-informed. ○ Trade decisions are well-informed.	Easy and cheap access to information reduces barriers to entrepreneurial activities making it easier to participate in the feed industry.

[5] Feed grains means Indonesian domestically produced grains such as corn as well as imported grains.

Recommendation: 1 Constraint: Awareness building Proposed action Increase the availability of relevant, easy-to-access information on the use of feed grains in Indonesian animal production systems. Estimated cost of activity: US$130k				
Activity code	Activity description	Proposed actions	Impact – more Indonesian and Australian stakeholders understand the opportunities for feed grain use in Indonesia	Anticipated social benefits in Indonesia
1b	Develop and extend case studies that demonstrate the effective use of feed grains in Indonesian animal production systems (20 case studies over 3 years @ US$5k per case study: plus US$30k for printing and other media communications)	With support from feed experts and key organisations or industry associations in Indonesia and Australia, identify cases where animal producers have incorporated feed grains or adopted new approaches to using feed grains (e.g., women taking on management roles) into their business to increase productivity and profitability. Cases may include incorporation of corn in beef feedlots, successful women-led businesses, development of export power-house models, use of barley in dairy, canola meal in aquafeeds or other examples. Cases studies in the first two years will focus on the poultry and aquaculture industries then include other industries. Case studies will be communicated via: • Feed grains information portal • Training modules • Feed grain workshops • Conferences • Social media and other avenues	Stories about successful use of feed grains in animal production businesses will validate and reinforce the use of feed grains (both new and existing uses) in Indonesian production systems. By exposing animal producers to successful models of feed grain use and production systems, the adoption rate of feed grain use will be increased.	Examples of successful women-led businesses and small holder producers will positively reinforce the role of women and small holders' success in the Indonesian animal feed industry and contribute to the Indonesian government social equality agenda.

Recommendation: 2 Constraint- Awareness building Proposed action: Deliver technical information regularly and consistently on feed grains directly to Indonesian stakeholders Estimated cost of activity: US$285k				
Activity code	Activity description	Proposed actions	Impact – better informed Indonesian users of local and imported feed grains.	Anticipated social benefits in Indonesia
2a 2c 2e	Feed grain use workshops (8 locations @ US$25K each over a 2-year period; plus US$40K in initial training costs) Presentations at local and regional feed conferences (4 presentations @ US$5K each over a 5-year period; plus US$25K for social media support)	Train the trainer • Indonesian stakeholders (e.g., University, specialised feed experts) that have the capacity to conduct regular workshops or deliver timely, bespoke technical information will be identified and trained. • Bespoke information will be delivered to Indonesian stakeholders when the pricing of Australian feed grains provides substantive value. Workshops – these will: • Describe the nutritional characteristics and complementarities of different grains (local and imported). • Describe feed rations including different grains that have nutritional and economic merit. • Provide a regular and important platform for mutual information exchange between the Indonesian and Australian feed industries. Opportunistic information delivery • Continually identify events within Indonesia that provide optimal opportunity to present feed grains information. • Provide timely delivery of current information on the nature and best use of local and imported feed grains in response to changed conditions. • Utilise multiple delivery channels – including social media, webinars, journal papers – to keep the use of Australian feed grain visible and topical.	• A broader range of Indonesian stakeholders (e.g., smallholders to large feed mills) will improve their understanding of the cost-efficient use of local and imported feed grains • Efficient use of feeds improves the technical efficiency of feeding activities; lifting feed conversion ratios, enabling more food products to be produced from each tonne of feed including locally produced corn, other grains including imported grains. • Indonesian stakeholders have improved technical knowledge and can use a wider range of feed grains. • Indonesian feed users remain aware of Australian feed grains and can seamlessly incorporate them into the ration when economic.	• The improved knowledge and capacity of Indonesians trained will enhance their earning capacity. • Work safety and women's equity considerations will be a component of training contributing to the Indonesian government's social initiatives.

<table>
<tr><td colspan="5">Recommendation 2 - Continued
Constraint- Awareness building
Proposed action: Deliver technical information regularly and consistently on feed grains directly to Indonesian stakeholders
Estimated cost of activity: US$150k</td></tr>
<tr><td>Activity code</td><td>Activity description</td><td>Proposed actions</td><td>Impact - De-risking use of new local or imported feed grains.</td><td>Anticipated social benefits in Indonesia</td></tr>
<tr><td>2b</td><td>Demonstration trials of local or imported feed grains focussing on beef feedlots and dairy

Demonstrations trials over minimum of three locations involving integrated processor and small farmers.

Six trials @US$25K each over a 5-year period.</td><td>Identify Indonesian stakeholders that have appropriate capacity to conduct technically sound demonstration trials across a range of Indonesian livestock industries. The stakeholders should vary in size but occupy leading positions and be capable of sharing and extending information to their peers, particularly small holders.
Identify Australian stakeholders that are willing to support Indonesian counterparts in demonstration trial activities. This may include livestock nutrition specialist, industry associations and grain traders. Australian businesses should consider accessing other available funds (e.g., Export Market Development Grants).</td><td>The practical learnings from these trials within normal business operations will:
Demonstrate techniques to efficiently integrate feed grains into Indonesian feeding operations that are currently reliant on agro-industrial by products and cassava.
De-risk decisions to purchase and use feed grains.
Improve the technical efficiency of feeding activities; lifting feed conversion ratios, enabling more food products to be produced from each tonne of Indonesian (and imported) corn and other feeds.
Enable Indonesian stakeholders to transition to greater feed grain use if Indonesian by-products become less available.
Familiarise Australian stakeholders with the Indonesian operating environment enabling them to contribute ongoing support more effectively.</td><td>Small holders will benefit through direct or indirect participation in the trials. They will have the opportunity to observe the safety and other improved practices of the leading businesses and can adopt improved practices as appropriate.

Beef feedlot and dairy farmers will use practical learnings to increase their productivity and profitability providing stability for rural families and economies.

In the case of small holders, these systems improvements may provide non-financial benefits, i.e., less reliance on family labour to complete manual tasks such as collecting forage (cut and carry model), allowing time for additional schooling.</td></tr>
</table>

Recommendation 2 Constraint - Awareness building Proposed action: Deliver technical information regularly and consistently on feed grains directly to Indonesian stakeholders Estimated cost of activity: US$300k				
Activity code	Activity description	Proposed actions	Impact – Improved understanding and inter-country linkages between value chain participants	Anticipated social benefits in Indonesia
2d	Technical training and exchange programmes between Indonesian and Australian animal producers and feed specialists. (US$175 study visits; plus US$25K annually, over five years, in administration and mentoring costs.	Annually identify up to 5 Indonesian stakeholders (including men and women) or organisations to participate in study visits to Australia, and up to 2 Australian stakeholders or organisations to participate in study visits to Indonesia, each year for 5 years. The study participants will learn about the fit, value, constraints and opportunities for feed grain in each country. To do so, they will visit leading organisations and individuals throughout the entirety of the value chain. The hosting organisations to provide in-kind contributions. The number of people able to participate in exchange visits may be able to be increased provided they fund their costs (e.g., a government official or industry association from either country may wish to participate).	Australia will better tailor its feed grain supply to meet Indonesia's needs. Future technical and information exchange will be facilitated more easily. Indonesian stakeholders will source feed grains most suitable for each livestock application and have ready access to support networks within Australia.	Participation of men and women in the technical exchange visits provides opportunity for them to become leaders in the livestock and feed industries in their respective countries. Their leadership capacity will be strengthened through the linkages and relationships formed with inter-country counterparts.

Recommendation 3 Constraint – Collaborative research and development Proposed Action: Undertake research and extension to improve the adoption and use of feed grains. Estimated cost: US$450k				
Activity code	Activity description	Proposed actions	Impact – Accelerated adoption of feed grains	Anticipated social benefits in Indonesia
3a-d	Applied research projects designed to develop solutions to technical barriers or constraints limiting the efficient use of feed grains in Indonesian systems. Results from research projects will be extended to Indonesian and Australian stakeholders in the feed and animal production industries.	Through the GPP group and other Indonesian and Australian collaborators, identify information deficiencies or potential improvements, including system improvements, in Indonesian livestock feeding systems. Conduct relevant Research, Development and Extension	Fewer constraints to the adoption of feed grains within Indonesia. Creation of a critical mass of research capability, focussed on feed grain use in Indonesian systems.	Investing in new and innovative research activities will provide a platform for men and women, across the breadth of the Indonesian livestock sector (e.g., Universities, Industry Associations, commercial companies, and government) to work and learn together.

Recommendation 4 Constraints– Grain's supply and value chains, Infrastructure, and capital Proposed action: Identify joint Australian and Indonesian investment opportunities that will ease or solve supply chain constraints currently limiting; the use of domestic corn and imported feeds, and lowers the cost of exporting products. Estimated cost: US$450k				
Activity code	Activity description	Proposed actions	Impact – Fewer obstacles in Indonesian feed grain supply chains	Anticipated social benefits in Indonesia
4a-d	Desktop analysis and in-market research projects designed to identify and report supply chain constraints limiting increased use of feed grains in Indonesia. The focus of the analysis and expenditure could be determined by the GPP. Reports will be supplied to the Indonesian and Australian governments, industries and the GPP for consideration and subsequent actions.	Through the GPP group and other Indonesian and Australian collaborators, identify factors limiting the use of feed grains that have short to medium term remedies and are potentially attractive to government or private investment. Identify key elements that could be used by interested parties to develop business cases for priority opportunities.	Higher quality grain moves through Indonesian supply chains more efficiently. Innovation in feed grain sourcing and sales transactions.	New initiatives will provide the opportunity to make supply chains more efficient, profitable and safe.

Appendix 1 Properties of the main Indonesian and Australian feed ingredients

Indonesian feed ingredients

Corn

Corn is one of the most important grain crops produced in Indonesia. It is used for food, feed and industrial purposes, with feed being the principal use. About 9 to 10 mmt of corn was used as feed in Indonesia on average from 2016-2019.

Most feed corn goes to poultry where it is the main energy source for Indonesian poultry rations and its inclusion is usually not restricted except in breeding birds where high energy diets cause excess fat and disrupted reproduction. Compared with other feed grains corn contains minimal anti-nutritional factors and holds few feeding concerns although the lysine content is low.

Yellow corn contains about 18-21 mg/kg of xanthophylls which is the yellow carotenoid pigment that, when fed to poultry, gives the colouring to egg yolks and chicken skin preferred by Indonesian consumers. Indonesian farmers are also accustomed to seeing corn in the diets as an indication of a high-quality feed.

A potential problem with Indonesian corn is contamination with the naturally occurring fungus *Aspergillus flavus* which produces aflatoxin a compound extremely toxic to mammals. High moisture at harvest in Indonesia combined with warm, moist storage are ideal for the growth of the fungus and aflatoxin levels.

Corn is not commonly used in Indonesian beef feedlots with other lower cost energy sources available and suitable as ruminant feeds. Maize silage is more commonly fed and has starch level up to 24 per cent. The silage will also contain volatile fatty acids after the silage has fermented. Indonesian corn plants, however, are relatively low in sugar at silage harvest time due to the lower daylength compared to temperate zones. The low daylength during the growing season limits the sugar production so that energy levels are approximately 70 per cent of those in US silage.

Cassava

Cassava is the third most important crop in Indonesia following rice and corn. It is grown mainly for food and industrial processing and some direct feed use. Production statistics are variable and have shown a decline in recent years. About 15 to 20 mmt has been produced annually in Indonesia since 2016. Over half of this was used directly as food and about 40 per cent for industrial use (mainly tapioca starch). Less than five percent of cassava is used directly as a feed with most of this being direct on-farm feeding. Feed use of cassava is mostly indirect as a by-product of industrial processing.

Onggok is a by-product from cassava processing. It is primarily used in ruminant rations but can also be used in poultry at low inclusion rates. Traditionally it has been a high energy, low protein feed. The average residual starch is around 50 per cent, but anecdotal reports suggest that this has been steadily declining as cassava processing technology has improved enabling higher starch extraction rates. Of all the available ingredients, onggok has the lowest energy content despite the high starch because the digestibility is poor. It is, however, cheap and readily available.

Onggok contains hydrocyanic acid (HCN) which can be toxic to animals, although the level is lower than in cassava and cassava flour. Drying onggok significantly reduces the HCN content and prevents mould.

Gaplek in Bahasa is chipped cassava made by cooking, cutting into chips 6-8 inches in size, then drying. The chips can be used as either human food or directly as an animal feed. Gaplek has a higher energy content than onggok.

Rice Bran

Rice is Indonesia's main crop with about 46 mmt being produced annually on average from 2016 to 2019 (FAO-OECD, 2020). The majority of Indonesia's rice is consumed within the country for food as a milled product. Rice milling produces about 8 to 10 percent rice bran. The main use of rice bran in Indonesia is animal feed.

Rice bran can be included up to about 25 per cent in poultry rations with the main restriction being high crude fibre content leading to loose droppings in poultry. It also contains high phytate acid levels an antinutritional compound.

The quality and price of rice bran is variable because its availability is seasonal, following paddy harvesting, and it can easily turn rancid during storage.

Wheat Pollard

Wheat pollard is an Indonesian by-product produced from milling imported wheat for flour. Indonesia has milled about 7.5- 8 mmt of wheat for flour annually on average from 2016-2019. Wheat pollard constitutes about 25 per cent of the products of wheat milling. A large proportion of wheat pollard is used as animal feed in Indonesia.

Wheat pollard has high fibre content (13%) and is widely used in ruminants' rations although a small amount is also used in poultry feeds. Wheat pollard does not contain antinutritional factors of significance, but the high fibre causes loose droppings in poultry.

Soybean Meal

Soybean Meal (SBM) is a by-product from soybean oil production and is the main protein source in Indonesian poultry rations. Indonesia does not produce SBM, and imports supplies mostly from the USA, Brazil, and India.

SBM has an excellent amino acid profile that complements cereal grains in diet formulation, with methionine typically being the only limiting amino acid for poultry. Soybean seeds also contain some antinutritional factors which are denatured by heat in well processed SBM. Trypsin inhibitor is the primary antinutritional factor present in poorly processed soybean meal.

In aquaculture, feed formulators can use as much SBM as the diet will allow while in poultry, SBM can only be used to about 40 per cent inclusion rates in diets. The lower protein requirement for ruminant feed generally means that SBM inclusion rates are low.

Copra Meal

Copra meal is by-product from extraction of oil from coconuts. Indonesia is the world's largest producer of coconuts with a production volume of just over 2.8 mmt on average from 2016-2019 resulting in an annual production of about 0.51 mmt of copra meal, about half of which is exported.

The quality of copra meal is highly variable depending on the processing techniques use to extract the oil. Based on chemical composition after processing it can constitute both a protein and energy source. Generally, copra meal is not well suited for poultry rations because of an imbalance in amino acid composition, particularly lysine and histidine. The fat and fibre content must also be managed carefully in poultry ration and inclusion rates are limited to 5 per cent. Inclusion rates for ruminant are much higher at up to 20 per cent however it has high acid detergent fibre (ADF) which would limit the feed intake.

Poorly and incorrectly processed copra meal will have high levels of mycotoxin.

Coffee Husk

Coffee husk is a relatively limited resource for animal feeding in Indonesia. Production of coffee in Indonesia has averaged about 660,000 mt annually for the five years to 2018. Processing yields about 20 per cent of this as coffee pulp and husks. Production areas are mostly located well away from the main poultry, beef feedlot and dairy producers on Java. Tannin and alkaloids concentration limits the inclusion rate of coffee husks in feed rations. Processing through drying or silage production can reduce tannin and alkaloid concentration. Research has shown an effective use of coffee husk is as a source of fibre to replace Napier grass use during Indonesia's dry season particularly for small producers.

Palm Kernel Expeller

Palm kernel expeller is a by-product from palm oil industry. Indonesia palm kernel meal production has average 5.3 mmt for the five years to 2019, at least half of the meal exported. Protein and energy level of palm kernel meal are generally mid-range but varies depending on the processing techniques. The main limitation is the very high neutral detergent fibre (NDF) content that will limit feed intake if large quantities are used in the beef rations. Methionine deficiency and β-mannan availability can also constrain use. Indonesian palm kernel meal can also often be high in mycotoxins.

In poultry rations, palm kernel meal can be used at inclusion rates of less than 5 per cent, while in ruminant diets it can be included at rates up to 20 per cent without major detrimental effect. The high NDF levels will limit feed intake if large quantities are used in the beef rations, but it is a useful ingredient in high cereal dairy rations to maintain a minimum NDF/ADF ratios.

Australian feed grains

Wheat

Wheat is well suited for poultry, beef, dairy, and pig production in Indonesia, but the Indonesian feed industry remains conservative in its use of wheat. The quantities of wheat used for animal feeding started to rise when corn imports were controlled in 2016, but use has been inconsistent because of subsequent restrictions on feed wheat imports. Wheat flour is commonly used for its binding properties and energy content in aquaculture feeds.

Poultry

Physically, wheat is an easy ingredient to handle in Indonesian feed mills. It is generally easier to store than corn and the grinding qualities are similar. There are also production advantages in pelleting and extrusion because wheat has better binding capabilities than corn. Further, Australian wheat is low in aflatoxin compared with Indonesian corn because of the dry growing and storage conditions. Low toxin wheat can be mixed with higher aflatoxin concentration corn to dilute the total aflatoxin level in the feed to improve its value.

Wheat contains some anti-nutritional factors that can potentially reduce its feeding value. The main problem is the higher xylan content of wheat compared with corn which is usually managed using the enzyme xylanase.

Most commercial enzyme formulations used in South East Asia are formulated to be effective when wheat is used in monogastric diets, but, achieving a consistent and reliable response to xylanase across all diets requires a careful focus on the dose and type of active xylanase reaching the site of action (stomach and small intestine). Improved use of xylanase through training and information provision will allow greater energy extraction from wheat and improve its value in poultry diets.

A limitation to the use of wheat as a substitute for corn is its low xanthophyll level. This can be corrected with synthetic or natural xanthophyll products, but Indonesian farmers are accustomed to seeing corn in the diets as an indication of a high-quality feed. Simply on a visual basis, substitution of more than half wheat for corn is problematic for most feed mills.

Ruminants

Wheat is used in ruminant diets as an energy source. It can substitute corn as a high-energy ingredient in concentrates or a Total Mixed ration (TMR) and has the benefit of having a higher protein content than corn (11.5% v 8.0%) although the metabolizable energy (ME) is slightly lower at 96 per cent of that of corn.

Wheat is generally low in toxins compared to corn, particularly when sourced from Australia due to the dry growing conditions. This is particularly important in dairy feeds because it is it is important to minimise aflatoxin in the milk. A disadvantage of wheat is that it can be fermented more rapidly than other grains so there is some bloat risk. However, the Indonesian inclusion rates are typically low, and the rapid fermentation characteristic of wheat can be ameliorated by coarse grinding.

Aquaculture

Wheat is a common ingredient in Indonesian aqua feeds, but it is included in the form of "Aqua flour". It is a product with about 1 to 1.5% fibre and is finely ground. It is available as a customised product from most flour mills.

Wheat is considered to be a good base cereal for fish diets. The fibre is relatively low, and the starch is more digestible than corn. It also has good binding properties in both extruded and non-extruded pellets.

Wheat is particularly preferred in shrimp diets for the binding capability. Shrimp feeds require high levels of protein meals and fats which makes pelletisation difficult. High protein wheat flours are therefore preferred in shrimp feed production as the gluten assists with maintaining the pellet structure.

Usually, the wheat flour would be made by the local flour mills to the feed mill specifications, so this market is usually not accessed by direct sales of wheat to feed mills. Wheat flour has a high digestibility of its starch content (93%) compared to barley (85%) and corn (81%).

Barley

Compared with wheat or corn, barley has a lower starch content, but higher fibre content. It is suitable for a range of feed applications in Indonesia particularly beef, dairy, pig and poultry production, but, it has rarely been used in Indonesia and most animal producers remain unfamiliar with barley.

Poultry

Australian barley is similar to Australian wheat in that that it is relatively easy to store and mill and has low aflatoxin levels compared with Indonesian corn because of the dry growing and storage conditions. Low toxin barley can be mixed with higher aflatoxin corn to dilute the total aflatoxin level in the feed to improve safety and value.

Barley contains elevated beta-glucans levels, a non-starch polysaccharide (NSP) that can cause sticky faeces in poultry. It also has higher levels of xylan than corn. It is considered necessary to use enzyme combinations containing beta-glucanase to break down the NSP, decrease the effect on the gut and to release the available energy. Without enzymes it would be possible to include 5-10% barley in most poultry feeds. With the addition of a beta-glucanase enzyme, these levels can be double.

The high fibre content of barley when compared to wheat or corn is generally a disadvantage because the higher fibre leads to lower available energy. However, in some diets, the lower energy is an advantage. Nearly all the broiler breeder feeds, and the layer pullet grower and developer feeds require energy to be relatively low.

The fibre also has application in some special feeds such as pre-layer or early layer feeds where higher fibre levels are required. Layers are prone to feather picking in the transition to the layer feeds and this problem can usually be averted with increased dietary fibre to raise gut fill and reduce the stress of feed change on the young layers.

Ruminants

Compared with standard rations used for Indonesian beef feedlot production barley has a low NDF value and a high disappearance rate. Barley when fed to beef or dairy cattle as a complement to cassava chips (gaplek) or cassava waste (onggok) will help balance the rapidly, moderately and slowly degrading starch sources in the rumen. If the fermentable metabolisable energy supply to the animal is limited, then microbial protein production will slow. The inclusion of barley in the feed which is a more fermentable energy feed source can allow more rumen degradable protein to be assimilated as microbial protein. This will reduce the need for other more costly protein sources to be included in feed rations. Barley may also be useful if the diet contains high levels of rapidly degradable protein and nonprotein nitrogen.

Barley can also be used in dairy diets as an energy-dense concentrate to mitigate body condition loss in early lactation, and to achieve higher body condition scores at mating. Both factors will improve cow fertility.

There is interest in using barley as a source of rumen fermentable starch to increase cows' plasma insulin levels after calving, as research has been shown that this can increase follicular development in the ovary, leading to increased ovulation rate. (Garnsworthy *et al*., 2008, Burke *et al*., 2010).

Barley is usually rolled, or steam flaked to improve the digestibility. It has a slower rate of digestion compared to corn or wheat and offers less of a risk of acidosis.

In general, barley is a technically excellent feed ingredient for cattle in combination with a grass silage. It can be used as the sole feed stuff balanced with straw if the price is right.

Aquaculture

Barley is not commonly used in aqua feeds due to the high fibre content. Barley fibre is not well digested by most fish or shrimps. The starch is also less digestible than wheat or corn. However, if the barley is in extruded feeds, then the digestibility improves.

The starch in ground barley is more digestible than the starch in ground corn, so it could be included in an aquafeed program if aqua flour (wheat) is unavailable.

In aquafeed diets barley has a higher energy level than wheat, sorghum or corn, despite also having the highest fibre content. The amino acid profile of barley also compares favourably to wheat, corn and sorghum, particularly for lysine, methionine, tryptophan and valine.

Tilapia can be successfully reared on diets where barley is the main cereal with inclusion levels up to 55 per cent showing no loss of performance.

Sorghum

Unlike wheat or barley, Sorghum is cultivated in Indonesia, but it is not commonly used as a feed grain, being grown mostly for food. Local varieties have had high levels of tannins that reduce the availability of proteins and affect performance of most types of poultry. The very low tannin concentration in Australian sorghum makes it suitable for a range of Indonesian feed applications including poultry, beef, dairy and pig production.

Poultry

Sorghum is a high value feed grain with an energy levels only about 50 Kcals/kg lower than corn. The fibre levels are also similar to corn as are the amino acid levels. Despite the comparable nutritional profile with to corn, sorghum has been treated with caution by Indonesian feed millers due to the experience with high tannins in local varieties.

Australian sorghum, as with other Australian grains is relatively easy to store because of its low moisture and aflatoxin levels. Sorghum however has a higher milling cost compared to corn.

In terms of performance, the growth rates achieved using sorghum in broiler feeds are not significantly different from those obtained using corn as the base cereal, but, as with wheat, sorghum contains little xanthophyll which must be corrected with synthetic or natural xanthophyll products. Further, without the visual appearance of corn in feeds formulated with a majority of sorghum the value of the feed is perceived to be lower by Indonesian farmers that are accustomed to seeing corn in the diets.

Ruminants

In ruminants, sorghum should be rolled or flaked. Flaking can improve the digestibility, but steaming and flaking are found to increase the energy level of sorghum by up to 20%. When sorghum is used as the only cereal, a steamed source of sorghum will increase the milk yield by approximately 2kg per day.

The low tannin levels in Australian sorghum are less of an advantage in ruminants because tannins will slow down the rate of starch digestion and hence reduce the possibility of acidosis or bloat. In addition, there are some reports of the tannins acting as antioxidants and improving the flavour of meat.

As with wheat and barley the low mycotoxin levels in Australian sorghum provide a particular advantage in dairy feed in helping prevent aflatoxin contamination of milk.

Aquaculture

Sorghum is not commonly used in aquafeeds. Vietnamese trials indicate that there is opportunity to replace cassava meal with sorghum with no significant differences in growth rate or feed conversion rate (Hung Vuong, 2017). One potential limiting factor for use of sorghum in aqua diets is the tannin content. Australian sorghum with low tannin contents may be suitable for some aquafeeds in Indonesia.

Canola

Canola meal (also called double zero rapeseed, particularly in the European Union) is the by-product remaining after oil has been extracted from canola seed. Oil is extracted physically or with solvents. Solvent extraction produces a meal with less than 1 per cent oil residue. Meal that has only undergone physical extraction can contain 8-12% oil. Canola meal is mainly used in monogastric diets, particularly poultry, where the solvent extracted meal is suitable. Worldwide canola is the second most cultivated oilseed behind soybean.

Canola is a Brassica species that has been developed from rapeseed and is sometimes perceived as potentially containing antinutritional factors: erucic acid and glucosinolates. Glucosinolates are common in Brassicas and can inhibit feed intake due to the bitter taste (the flavour of mustard is from its glucosinolate content). Erucic acid was historically found in rapeseed oil at levels of 40 per cent or more and had a bitter taste. There were some adverse effects reported on the health of broilers and pigs which have largely disappeared now that the levels of erucic acid have been lowered. Modern varieties of canola are low in both factors (hence the name 00 or double zero). Current Australian trading standards restrict aliphatic glucosinolate in the oil-free meal to less than 30 μmols/g.

Poultry

Canola meal is not as popular as soybean meal, nevertheless it is gaining acceptance in monogastric feeds. There are some limitations to usage due to the high fibre which will affect young poultry feed intake and digestibility. There is good evidence that most monogastric species can utilise 15 per cent canola meal effectively.

The protein content of canola meal is approximately 35 to 37% and has a good amino acid profile with relatively higher levels of methionine and cysteine compared to soybean meal, making it a particularly suitable ingredient for poultry diets. The energy level is similar to soybean meal. Amino acid digestibility coefficients are also similar, although the digestibility of the lysine is lower (78% v 88%)

Canola meal is relatively high in choline. The average content is approximately 5,000 mg/kg compared to 1,800 mg/kg in soybean meal. The excess choline supplied by the canola can be converted to trimethylamine (TMA) by intestinal bacteria. TMA has a strong fishy smell. In most strains of poultry, TMA is metabolised to TMA N-oxide which is odourless, but some strains of brown egg birds lack a gene that enables this conversion. Breeding programs are actively removing this gene from the breeding stock and the concern is now low.

Ruminants

Canola meal has some nutritional qualities that make it comparable or superior to soybean meal. Measures of the degradability of canola protein in the rumen vary, with some studies showing the Rumen Degradable Protein (RDP) is higher for canola meal than soybean meal. In addition, the bypass fraction of the protein is high in methionine which is a limiting amino acid in dairy production especially in the high yielding groups.

Aquaculture

Canola meal is a substitute for soybean meal in some aqua feeds especially in lower density feeding systems where the cost of crude protein must be minimised. For aquafeed diets, canola meal has a good amino acid profile with relatively higher levels of methionine and cysteine compared to soybean meal.

Lupins

Lupins are not commonly known in Indonesia. Compared with soybean, they have a relatively high fibre content (12.4% for lupins v 4.3% for Argentine Soybean meal), caused mainly by the thick seed coat. Low-cost processing to remove the hull from the kernel removes much of the NSP and produces a meal with increases in the dry matter digestibility as well as improvements in the digestibility of protein, fat and starch (~ 38% protein and ~8% fat). Once the hull has been removed the resulting product is called de-hulled lupins or lupin kernel. We have also used the term lupin seed meal in this report to indicate whole ground lupins seeds. De-hulled lupins are well suited to poultry and aquaculture feeds while whole seeds are well suited to ruminants.

Poultry

The high protein content of lupins allows their potential use in poultry rations to reduce the protein meal component of feed rations (e.g., soybean or canola meal), while also supplying energy comparable to some cereal grains. The biological value of lupin protein however is limited by low concentrations of methionine and lysine which must be supplemented in poultry diets.

The yellow colour of lupin kernels and relatively high xanthophyll levels, similar to that in corn, allows lupins to complement wheat, barley or sorghum when replacing corn in poultry diets providing a yellow appearance for the missing corn. Lupins also lack major anti-nutritional factors (e.g., such as trypsin inhibitors, lectins and saponins) compared with soybeans.

The NSP content is the main nutritional disadvantage of lupins. The high oligosaccharide levels will cause sticky faeces in poultry and this leads to loss of performance. There may also be traces of alkaloids although Australian varieties have low levels. These factors limit the use of lupins as the sole protein source in a diet, but levels between 10 to 20% are practical.

Ruminants

Whole seeds, cracked or intact, or lupin kernel meal together with removed hull material are usable in ruminant diets. When used in dairy diets whole seeds should be ground on medium screens (3mm or less) or also flattened using a roller. The ‘flattened’ seeds will degrade less in the rumen and more in the small intestine compared and are more suitable than fine ground lupins.

Aquaculture

For aquafeeds the lupin seed coat is removed, and the kernel milled to a fine powder. Trials with rainbow trout (*Oncorhynchus mykiss*) and red seabream (*Pagrus auratus*) have shown that the digestibility of dietary energy is typically less than that of soybean meal, however, because of the higher gross energy content of lupins, the overall level of digestible dietary energy is similar. Lupins also have some advantageous physical properties; including lupins in an extruded fish feed pellet makes the product stronger so that dust production and breakages are reduced.

There is also scope to reduce the anti-nutritional risks that soybean meal presents (mainly its allergenic property and the presence of trypsin inhibitors), particularly in aqua diets through blends with lupin seed meal. Australian lupins are regularly exported for use in aquafeeds.

Comparison of Indonesian and Australian feed ingredients

The cost of energy and protein within feed ingredients provides an indication of their value for animal diets. Figure A1-1 and Figure A1-2 plot the price of protein and energy in Australian feed grains together with the main Indonesian feed ingredients using November 2020 pricing. These figures provide a mechanism to compare feed ingredients in terms of their protein and energy content. For example, in Figure A1-1, corn is a relatively cheap source of energy (8.2 cents/kcal ME) slightly lower than Australian wheat (8.7 cents /kcal ME) but, corn is a more expensive source of protein than wheat. The higher price of protein in corn is due to its low protein content. As ingredient prices change over time the comparative values will also change.

Figure A1-1. Quadrant prices of feed ingredients commonly used in Indonesian poultry production compared with Australian feed grains. Modified from Permana et al, (2020). Australian feed ingredients have been highlighted in different colours.

In general, energy feed sources are cheaper than protein feed sources. Figure A1-1 also shows that for poultry diets, Australian wheat and barley are similar priced sources of energy compared with Indonesian corn, while Australian sorghum is slightly more expensive. Similarly, Australian canola meal is a comparatively cheap protein source, whereas, lupin kernel is more expensive than soybean on a pure cost of protein basis.

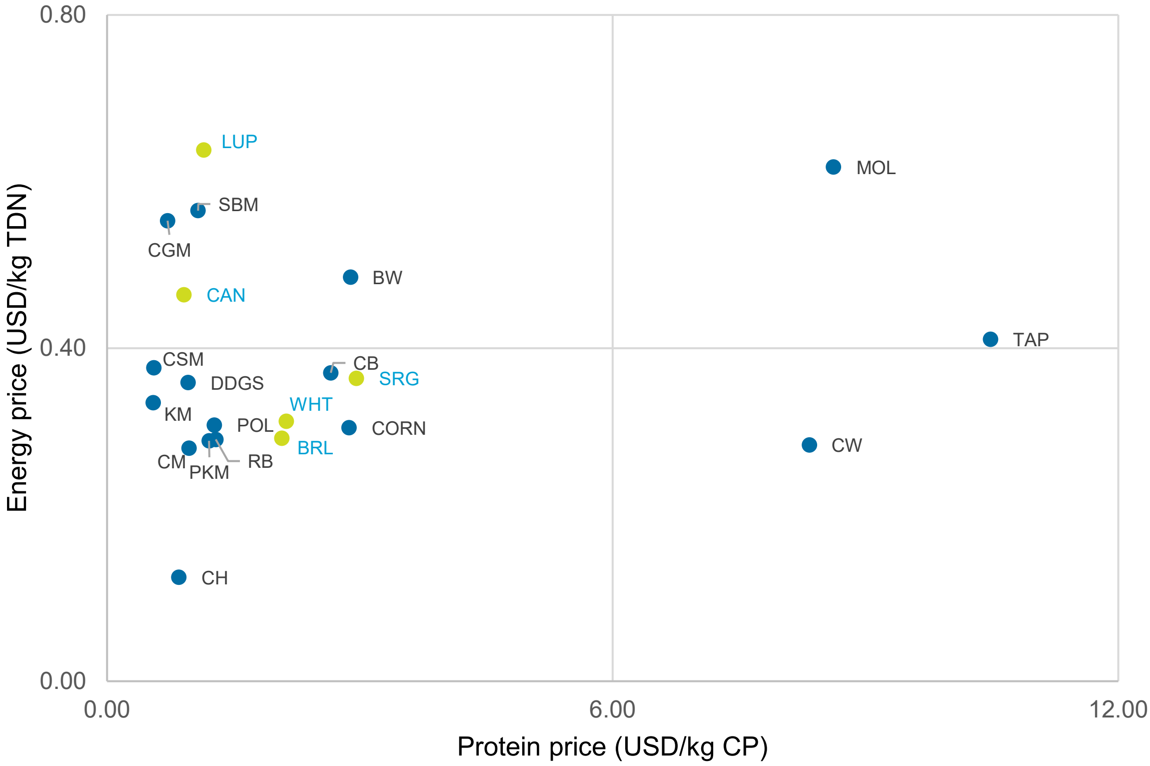


Figure A1-2. Quadrant prices of feed ingredients commonly used in Indonesian beef feedlot and dairy production compared with Australian feed grains. Modified from Permana et al, (2020). Australian feed ingredients have been highlighted in different colours.

For ruminants, the Australian feed grains do not stand out as being a particularly cheap source of protein or energy, although barley, wheat and sorghum do sit within the quadrant categorised as cheap energy and protein sources (Figure A1-2). Coffee hulls, copra meal and cassava waste are the cheapest ingredients per unit of energy, while soybean meal, molasses and Australian lupin kernel are among the most expensive. It should be noted that nutrient composition of lupin kernel does vary in analysis depending on the efficiency of de-hulling, so data would have to be verified for plant specific nutritional profiles to get more accurate shadow price profiles for the lupin kernel meal.

For protein, several ingredients provide cheap protein sources with cottonseed meal and kapok meal showing the lowest price per unit of protein. Canola meal provides a relatively cheap protein source as does lupin, but these are grouped in the expensive energy quadrant. The nutrient contents of feed materials are provided in Appendix 2.

Appendix 2 Nutrient values for ingredients used in feed ration formulations

Table A2-1. Nutrient values for ingredients in poultry feeds.

	Corn Indonesia	Wheat 12.5%	Barley 88% DM	Barley 89.5% DM	Sorghum	Soybean meal Argentine	Canola meal	Lupin seed meal
Crude Protein %	8.3	12.53	10.49	10.85	9.32	45.5	36.7	32
AMEn Poultry	3,306.39	3,088.00	2,748.93	2,843.62	3,248.00	2,251.00	2,200.00	1,911.00
AMEn Broiler	3,306.39	3,088.00	2,748.93	2,843.62	3,248.00	2,251.00	2,200.00	1,911.00
AMEn Layer	3,306.39	3,088.00	2,748.93	2,843.62	3,248.00	2,251.00	2,200.00	1,911.00
Crude Fat %	4	1.98	2.46	2.46	3.37	1.66	3.3	7.86
Crude Fibre %	2.1	2.42	4.41	4.41	2.27	4.32	11.2	12.38
Dry Matter %	87.1	88	88	89.5	87	88	88	90
Moisture %	12.9	12	12	10.5	13	12	12	10
Calcium %	0.02	0.04	0.05	0.05	0.02	0.34	0.65	0.39
Total Phos %	0.24	0.27	0.28	0.28	0.24	0.67	0.99	1.03
Phos Av Poultry %	20	33	30	30	30	39	35	30
Av Phos (Poultry) %	0.05	0.09	0.08	0.08	0.07	0.26	0.35	0.31
Sodium %	0.01	0.01	0.01	0.01	0.02	0.03	0.07	0.02
Chloride %	0.09	0.08	0.06	0.06	0.05	0.05	0.01	0.15
Potassium %	0.31	0.37	0.44	0.44	0.33	2.32	1.13	1.37
El Balance	57.53	76.36	100.03	100.03	79.03	595.06	317.32	317.12
Digestible Lys %	0.21	0.29	0.32	0.33	0.19	2.42	1.68	1.38
Digestible Met %	0.16	0.17	0.16	0.16	0.14	0.54	0.64	0.17
Digestible M & C %	0.32	0.43	0.36	0.37	0.28	0.96	1.3	0.59
Digestible Thr %	0.26	0.31	0.26	0.27	0.25	1.4	1.17	0.97
Digestible Trp %	0.07	0.13	0.09	0.09	0.1	0.52	0.44	0.22
Digestible Ile %	0.29	0.39	0.31	0.32	0.32	1.74	0.96	1.17
Digestible Val %	0.38	0.48	0.42	0.43	0.4	1.82	1.37	1.1
Digestible Arg %	0.37	0.52	0.42	0.43	0.32	2.7	2.09	3.09

See Table A2-6 for an explanation of abbreviations and units of measure.

Table A2-2. Nutrient values for ingredients in ruminant feeds.

	Corn Indonesia	Wheat 11%	Wheat 12.5%	Barley 88.5% DM	Barley 89.5% DM	Sorghum	Soybean meal Argentine	Canola meal	Lupin seed meal
Dry Matter %	87.1	88	88	88.5	89.5	87	88	88	90
Crude Protein %	8.3	11.03	12.53	10.55	10.85	9.32	45.5	36.7	32
RUP %	2.91	3.86	4.39	3.69	3.8	3.26	15.93	11.34	11.2
ME Ruminant Kcal/Kg	2,880.00	2,860.00	2,860.00	2,628.45	2,658.15	2,805.11	3,000.80	2,331.26	3,177.00
Crude Fat %	4	1.79	1.98	2.46	2.46	3.37	1.66	3.3	7.86
Crude Fibre %	2.1	2.37	2.42	4.41	4.41	2.27	4.32	11.2	12.38
NDF %	10.44	11.18	11.65	17.78	18.29	11.93	9.57	25.4	25.2
ADF %	2.95	2.86	3.17	5.5	5.66	3.38	5.69	16.2	18.18
Calcium %	0.02	0.03	0.04	0.05	0.05	0.02	0.34	0.65	0.39
Total Phos %	0.24	0.23	0.27	0.28	0.28	0.24	0.67	0.99	1.03
Total Lys	0.25	0.31	0.34	0.38	0.39	0.21	2.82	2.13	1.52
Total Met	0.17	0.17	0.19	0.17	0.18	0.16	0.62	0.7	0.2

See Table A2-6 for an explanation of abbreviations and units of measure.

Table A2-3. Nutrient values of local feed ingredients used in ruminant feeds

	Onggok	Palm kernel meal	Maize silage	Copra meal	Barley
Dry matter %	89	91.2	28.2	91.5	89.5
Crude protein %	2.4	16.7	7.2	22.4	11.8
Crude Fibre %	17.2	19.8	21.4	14.2	5.2
NDF %	36.9	73	46.1	54.7	21.7
ADF %	28.6	44.8	24.6	28.7	6.4
Lignin %	3.9	9.2	2.9	6.7	1.1
Total Sugars %			0.5	11.4	2.8
Starch %	53	-	24.4		59.7
OM Digestibility %	56.4	71.6	71.7	79.7	83.9
ME Ruminant MJ/Kg	7.7	11.6	10.8	12.8	12.4
ME Ruminant	1,838.15	2,769.16	2,578.18	3,055.62	2,960.13

See Table A2-6 for an explanation of abbreviations and units of measure.

Table A2-4. Nutrient levels of cereals used in aquaculture feeds.

	Wheat 11%	Barley 89.0% DM	Sorghum	Wheat Flour	Corn Indonesia
Crude Protein %	11.03	10.67	9.32	13.9	8.3
Crude Fat %	1.79	2.46	3.37	1.87	4
Crude Fibre %	2.37	4.41	2.27	1.18	2.1
Ash %	1.63	2.2	1.37	1.2	1.2
Gross Energy	3,813.97	3,861.84	3,841.61	3,879.82	3,870.68
DE Fish Omnivore	3,127.46	3,213.35	3,018.05	3,181.45	3,096.54
DE Shrimp	3,127.46	3,213.35	3,018.05	3,181.45	3,096.54
Total Lys %	0.31	0.39	0.21	0.35	0.25
Total Met %	0.17	0.17	0.16	0.22	0.17
Total Cys %	0.26	0.23	0.17	0.3	0.18
Total M & C %	0.43	0.41	0.33	0.52	0.35
Total Thr %	0.31	0.36	0.3	0.39	0.31
Total Trp %	0.15	0.13	0.12	0.16	0.08
Total Ile %	0.37	0.37	0.36	0.47	0.31
Total Val %	0.47	0.52	0.46	0.58	0.43
Total Arg %	0.53	0.53	0.36	0.63	0.4

See Table A2-6 for an explanation of abbreviations and units of measure.

Table A2-5. Nutrient levels of protein meals used in aquaculture feeds.

	USA SBM EU	Canola Meal	Lupin Seed Meal	Lupin seed meal, 36%CP	Fish meal, Chile, 64% CP
Crude Protein %	47.08	36.7	32	36.3	63.6
Crude Fat %	1.69	3.3	7.86	7.4	8.4
Crude Fibre %	3.83	11.2	12.38	7.6	0.5
Ash %	6.7	6.7	3.35	3.7	15.6
Dry Matter %	88.5	88	90	91.3	92
Gross Energy	4,297.63	4,244.25	4,469.85	4,518.00	4,549.00
DE Fish Omnivore	3,652.98	3,395.40	3,520.08	3,558.00	4,089.00
DE Shrimp	3,652.98	3,395.40	3,520.08	3,558.00	4,089.00
Total Lys %	2.94	2.13	1.52	1.81	5.81
Total Met %	0.65	0.7	0.2	0.29	2.2
Total Cys %	0.72	0.83	0.5	0.73	0.5
Total M & C %	1.37	1.53	0.7	1.02	2.7
Total Thr %	1.86	1.54	1.11	1.16	2.94
Total Trp %	0.65	0.48	0.27	0.29	0.5
Total Ile %	2.16	1.25	1.3	1.38	3.38
Total Val %	2.27	1.78	1.26	1.31	4.23
Total Arg %	3.49	2.38	3.29	3.92	4.48

See Table A2-6 for an explanation of abbreviations and units of measure.

Table A2-6. Abbreviations and units used in nutrients tables for feed ingredients.

Abbreviation	Full name	Unit
ADF	Acid Detergent Fibre	%
AMEn Broiler	Apparent Metabolisable Energy for Broilers	kcals/kg
AMEn Layer	Apparent Metabolisable Energy (nitrogen corrected) for Layers	kcals/kg
AMEn Poultry	Apparent Metabolisable Energy for Poultry	kcals/kg.
Arg	Arginine	%
Av Phos (Poultry)	Available Phosphorous	%
Cys	Cysteine	%
DE Fish Omnivore	Digestible Energy Omnivorous Fish	kcals/kg
DE Fish Omnivore	Digestible Energy Omnivorous Fish	kcals/kg
DE Shrimp	Digestible Energy Shrimp	kcals/kg
DE Shrimp	Digestible Energy Shrimp	kcals/kg
El Balance	Electrolyte Balance (Na + K -Cl)	mEq
Ile	Isoleucine	%
Lys	Lysine	%
M & C	Methionine & Cysteine	%
ME Ruminant Kcal/Kg	Metabolisable Energy Ruminant	kcals/kg
ME Ruminant MJ/Kg	Metabolisable Energy Ruminant	MJ/kg
Met	Methionine	%
NDF	Neutral Detergent Fibre	%
OM Digestibility %	Organic Matter Digestibility	%
Phos Av	Phosphorous Availability Coefficient (%)	%
RUP	Rumen Undegraded Protein	%
Thr	Threonine	%
Total Phos	Total Phosphorous	%
Trp	Tryptophan	%
Val	Valine	%

References

ABARES (2020). Australian Bureau of Agricultural and Resource Economics and Sciences https://www.agriculture.gov.au/abares

ABS Australian Bureau of Statistics https://www.abs.gov.au/

Australian Crop Forecasters (2020). Australian Wheat Profile, http://www.cropforecasters.com.au/

Birmani, M. W, Raza, A., Nawab, A., Tang, S., Ghani, M.W., Li, G., Xiao, M., An, L. (2019). Importance of arginine as immune regulator in animal nutrition. International Journal of Veterinary Sciences Research 5, 1-10.

BPS (2020). Badan Pusat Statistik https://www.bps.go.id/searchengine/

Burke, C., Kay, J., Phyn, C., Meier, S., Lee, J. and Roche, J. (2010). Short communication: Effects of dietary non-structural carbohydrates pre- and postpartum on reproduction of grazing dairy cows. J. Dairy Sci. 93:4292–4296.

Clark, M. (2020). Ingredient evaluation for AEGIC: Evaluation of value ranges for Australian grains/products in the Indonesian feed. Three reports: poultry, ruminants and aquaculture. AEGIC, Perth Western Australia.

Desianto, U. (2019). Growth and Partnership Opportunities in the Indonesian Feed Milling Sector. Presentation at the Grain Industry Association of Western Australia (GIWA) Forum, October 2019.

FAO FAOStat http://www.fao.org/faostat/en/#data

Ferlito, C. and Respatiadi, H. (2018). Policy reforms on poultry industry in Indonesia. Discussion Paper. Center for Indonesian Policy Studies, Jakarta, Indonesia. https://repository.cips-indonesia.org/media/271878-policy-reform-on-poultry-industry-in-ind-52817e14.pdf

Edama, N., Sulaiman, A. and Rahim, S. (2014). Enzymatic saccharification of Tapioca processing wastes into biosugars through immobilization technology. Biofuel Research Journal. 1: 2-6. https://www.biofueljournal.com/pdf_4745_9805b1af2b58b470230bd9cbe62217ca.html

Garnsworthy, P., Lock, G., Mann, G., Sinclair, K. and Webb R. (2008). Nutrition, metabolism, and fertility in dairy cows: 1. Dietary energy source and ovarian function. J. Dairy Sci. 91:3814–3823.

Hatab, A. A., Cavatino, M. E., Lindemer, A., & Lagerkvist, C.-J. (2019). Urban sprawl, food security and agricultural systems in developing countries: A systematic review of the literature. *Cities*, 129-142.

Henriksson, P.J.G., Banks, L.K., Suri, S.K. Pratiwi, T.Y., Fatan, N.A. and Troell, M. (2019). Indonesian aquaculture futures—identifying interventions for reducing environmental impacts. Environmental Research Letters, 14, 124062, https://iopscience.iop.org/article/10.1088/1748-9326/ab4b79

Hosking, B. (2019). Australian Barley for Pigs: Value and opportunity, Presentation to Australian Barley Quality Technical Workshop – China

Hung Vuong (2017). Sorghum as source of ingredient to replace cassava for feeding Pangasius in Vietnam HUNG VUONG Co. Ltd Sa Dec, Dong Thap, VIETNAM. US Grains Council, South and South East Asia, Kuala Lumpur, Malaysia. https://www.sorghumcheckoff.com/assets/media/pdfs/Vietnam%20Catfish%20Study_USGC_2017v2_web.pdf

Hunt, W., Birch, C., Vanclay, F. and Coutts, J. (2014). Recommendations arising from an analysis of changes to the Australian agricultural research, development and extension system. *Food Policy* 44, 129-141.

Ismoyowati. (2018). The difference in feed quality and egg production performance of Tegal and Mageland ducks on farming in cantral Java. Buletin Peternakan (Bulletin of Animal Science) 42, 197-202. https://doi.org/10.21059/buletinpeternak.v42i3.34465

JAPFA (2018) Serving up a high protein diet, Share Analysis by Maybank Kim Eng Research

Kopernik (2017). Increasing farmer food security and incomes: Grain storage solutions. Phase One. https://kopernik.info/en/insights-reports/project-reports/increasing-farmer-food-security-and-incomes-grain-storage-solutions-phase-one

Malindo (2020) PT Malindo Feedmill Q2 (2020). Result presentation, http://www.malindofeedmill.com/

Merican, Z. (2020). Aquafeeds in 2019: Pulled by Market demand. *Aquaculture Asia Pacific Magazine*.

Newby, J, Smith, D, Cramb, R, Delaquis, E & Yadav, L (2020). Cassava value chains and livelihoods in South-East Asia, a regional research symposium held at Pematang Siantar, North Sumatra, Indonesia, 1–5 July 2019, ACIAR Proceedings Series, No. 148, Australian Centre for International Agricultural Research, Canberra, 114 pp.

OECD-FAO (2020). Agricultural Outlook 2019-2028 https://stats.oecd.org/Index.aspx?datasetcode=HIGH_AGLINK_2019

OECD-FAO (2020). Agricultural Outlook 2020-2029 https://stats.oecd.org/Index.aspx?DataSetCode=HIGH_AGLINK_2020

OECD. (2006). The Returns to Education: Links between Education, Economic Growth and Social. In *Education at a Glance 2006: OECD Indicators.* Paris: OECD Publishing.

Permana, I. G., Despal and Nuraina, N. (2020). Australian feed grains and the least cost ration formulation. AEGIC, Perth Western Australia.

Rao, X., Hurley, T. and Pardey, P. (2020). Recalibrating the reported returns to agricultural R&D: what if we all heeded Griliches? *Australian Journal of Agricultural and Resource Economics* 64, 977–1001.

Rubel, H., Woods, W., Pérez, D., Unnikrishnan, S., Meyer Zum Felde, A., Zielcke, S., Lidy, C. and Lanfer, C. (2019). A Strategic Approach to Sustainable Shrimp Production in Indonesia: the case for improved economics and sustainability. Bostan Consulting Group. United States. https://media-publications.bcg.com/BCG-A-Strategic-Approach-to-Sustainable-Shrimp-Production-in-Indonesia-Nov-2019.pdf

Sudharma, E. (2019). Growth and Partnership Opportunities in the Indonesian Flour Milling Sector, Presentation at GIWA Forum Perth, 2nd October 2019

The Cattle Site (2015). Managing Cow Lactation Cycles.
https://www.thecattlesite.com/articles/4248/managing-cow-lactation-cycles/

US Export Soybean Council (2020) Market Intelligence https://ussec.org/

UN (2020). United Nations Department of Economic and Social Affairs, Population Dynamics World Population Prospects - Population Division - United Nations

USDA (2020). United States Department of Agriculture Foreign Agricultural Service https://apps.fas.usda.gov/psdonline/app/index.html#/app/advQuery

USDA (2020a). United States Department of Agriculture Foreign Agricultural Service. Grain and Feed Update, Indonesia. Report number: ID2020-0014.
https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Grain%20and%20Feed%20Update_Jakarta_Indonesia_07-15-2020

World Bank (2020). *Indonesia's Urban Story.* World Bank
http://pubdocs.worldbank.org/pubdocs/publicdoc/2016/6/45281465807212968/IDN-URBAN-ENGLISH.pdf

Perth

3 Baron-Hay Court
South Perth
Western Australia 6151

P: +61 (08) 6168 9900
E: admin@aegic.org.au

Sydney

1 Rivett Road
Riverside Corporate Park
North Ryde
New South Wales 2113

PO Box 711
North Ryde
NSW 1670, Australia

P: +61 (02) 8025 3200

aegic.org.au

AEGIC

Department of Primary Industries and Regional Development
GOVERNMENT OF WESTERN AUSTRALIA

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

AEGIC is an initiative of the Western Australian State Government and Grains Research & Development Corporation

Grain Growers

aegic Australian Export Grains Innovation Centre