Annotated Engineering Research Report (Stage 1)

Contents
1. Annotated example of an Engineering Research Report based on an individual research project.
2. Guidelines about report writing, with examples from the Engineering Research Report.

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Here, the writer included two figures that were illustrative of the focus of his research. The figures are not included in this version of the report for copyright reasons. Note that each Figure has a title to describe it. Titles for figures are placed below each figure.

As this example shows, the title of an engineering report should be concise and informative so that the reader can quickly discover what the report is about (Silyn-Roberts, 2012).

Note the inclusion of the author’s name and the date of submission right at the beginning of the report. This information together with the title and the course name is placed on the title page.

PROTEIN SOURCES IN NEW ZEALAND

COURSE NAME Research Report

Student name and ID
Abstract

With New Zealand’s population expected to reach 6.5 million by 2068, the sustainability, efficiency and ethical acceptability of chicken as a protein source in New Zealand is in question. This report evaluates the suitability of soybean farms as an alternative source of protein production in New Zealand to broiler farms. The information required was obtained through a literature search. To facilitate the comparison of farms, resource use per kilogram of digestible protein of a typical chicken farm and an equivalent soybean farm were considered. Results show that soybean farms require 81.2MJ/kg less energy per annum (p.a.) than typical chicken farms and 0.563L/kg less water p.a. Also, soybean farms produce 7.49kg/kg less CO2 equivalent gases p.a. but use 3.98x10^-4 Ha/kg more land area. Despite their greater efficiency, and ethical acceptability, New Zealand’s temperate climate makes it not economically viable to completely replace broiler farms in New Zealand. Soybean plants, however, could still be used in a crop rotation from November to March in the North Island.
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If a report has equations a description of each equation should be included after the List of Figures and List of Tables.
1.0 INTRODUCTION

With New Zealand’s population expected to reach 6.5 million by 2068 (Statistics New Zealand, 2017), it is important that domestic food production remains efficient, sustainable and ethically acceptable. Also, with the average New Zealander consuming 37.5kg of chicken each year, chickens are the most greatly consumed poultry in New Zealand (PIANZ, 2018). It is thus important that the poultry industry is efficient with its use of resources, or a more efficient protein-alternative is found.

Animal, plant and insect-based sources, as well as lab-grown sources are some of the alternative protein sources under investigation. Soybean farms have already proven successful in other countries, with 77.5 million acres being planted in the USA in 2009 (Ash, 2017). Additionally, soybeans have a similar nutritional composition to chicken (Johnson, White, & Galloway, 2008), so may serve as a more humane alternative.

The objective of this report is to evaluate soybean farms as an alternative form of protein production to broiler farms. The scope includes an analysis of the benefits and challenges arising from energy, water and land usage and the CO₂ equivalent production.
of both types of farm. Consideration is
given to consumer satisfaction, the
efficiency of production of chicken and
soybeans, and adopting an ethical
approach. Limitations include reliance on
secondary data, the two month time-
frame allocated and difficulty finding
New Zealand-based data.

1.1 Definitions

Typical Chicken Farm – These farms
produce 402,500 chickens/year,
assuming the average chicken
production per farm is the same as in
Kentucky (from where reliable
information is most easily accessible)
(University of Kentucky, 2018).

Equivalent Soybean Farm – The total
digestible protein production of all
equivalent soybean farms is equivalent to
the total digestible protein production of
all typical broiler farms in New Zealand.
Dividing the total protein production
amongst soybean farms of the land area
205.4 Ha – the mean land area of grain
farms in New Zealand (Land Information
New Zealand, 2012) – gives an
‘equivalent soybean farm’. Table 1
summarises the key characteristics of
each type of farm:
Table 1 – Key characteristics of a typical chicken farm and an equivalent soybean farm

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Typical Chicken Farm</th>
<th>Equivalent Soybean Farm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of farms required to meet demand of New Zealand consumers</td>
<td>180 (Appendix B ii)^a</td>
<td>65 (Appendix D ii)^f</td>
</tr>
<tr>
<td>Digestible protein production per annum (kg)</td>
<td>175,000 (Appendix B iii)</td>
<td>488,000 (Appendix D iii)</td>
</tr>
<tr>
<td>Energy usage per annum (MJ)</td>
<td>15,100,000 (Appendix C i)^b</td>
<td>2,340,000 (Appendix E i)^g</td>
</tr>
<tr>
<td>Water usage per annum (L)</td>
<td>98,400 (Appendix C iii)^c</td>
<td>0 (Appendix E iii)^h</td>
</tr>
<tr>
<td>Land area (Ha)</td>
<td>3.98 (Appendix C iv)^d</td>
<td>205.4 (Appendix E iv)</td>
</tr>
<tr>
<td>CO₂ equivalent production per annum (kg)</td>
<td>1,400,000 (Appendix C ii)^e</td>
<td>270,000 (Appendix E ii)</td>
</tr>
</tbody>
</table>

Key assumptions for each calculation:

- ^a^ The average production of chickens per farm, per year is the same in New Zealand as in Kentucky (University of Kentucky, 2018).
- ^b^ The energy requirements to produce broiler chickens is the same as in 2008 (Pelletier, 2008).
- ^c^ The average water consumption is **244.375L per 1000 birds per annum** (University of Arkansas Division of Agriculture, 2009).
- ^d^ All farms adopt the minimum best practice recommendations of 30 kg live chicken mass/m² (Ministry for Primary Industries, 2018), the proportion of chicken produced on free-range farms in New Zealand is the same as Australia (Australian Chicken Meat Federation Inc., 2013), all free range

Note that for each of the key assumptions, the writer provides a reference to the literature from where the information came. Doing this is essential for ensuring the credibility of any literature-based research. APA referencing style is used in this report.
chickens have access to a range of 1.5x the floor area of the barn as required for SPCA accreditation (PIANZ, 2018) and each farm is only comprised of the land area available for the chickens to roam.

e The CO₂ equivalent production per tonne of broiler poultry is the same as in 2008 (Pelletier, 2008).

f Soybean productivity is maintained at the highest observed productivity in New Zealand of six tonnes/hectare (Millner & Roskruge, 2012).

g The average energy required to produce soybean plants is the same as in 2008 (Pelletier, N.; Arsenault, N.; Tyedmers, P., 2008).

h Assuming optimal irrigation levels are less than those in central Iowa, USA (Iowa is closer to the equator than New Zealand), soybean farms would require a maximum of 317mm of rainfall over a season (Dietzel, et al., 2015). As soybean plants take roughly five months to mature (Kowalski, 2018), and the lowest average rainfall over five months in New Zealand is 343mm (in Masterton) (NIWA, 2010), soybean farms should require no irrigation on average.

The above assumptions were made to allow the use of outdated and international data where no recent data was available for New Zealand.
2.0 Discussion

2.1 Benefits

2.1.1 Energy consumption, water consumption and carbon dioxide equivalent production

Table 2: Resource use of a typical chicken farm and an equivalent soybean farm per kg of digestible protein production

<table>
<thead>
<tr>
<th>Resource</th>
<th>Chicken Farm</th>
<th>Soybean Farm</th>
<th>Chicken Farm – Soybean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy usage per annum (MJ/kg)</td>
<td>86.2 (Appendix C i)</td>
<td>5.00 (Appendix E i)</td>
<td>81.2</td>
</tr>
<tr>
<td>Water usage per annum (L/kg)</td>
<td>0.563 (Appendix C iii)</td>
<td>0 (Appendix E iii)</td>
<td>0.563</td>
</tr>
<tr>
<td>Land area (Ha/kg)</td>
<td>$2.27 \times 10^{-1}$ (Appendix C iv)</td>
<td>$4.21 \times 10^{-1}$ (Appendix E iv)</td>
<td>-3.98x10^{-4}</td>
</tr>
<tr>
<td>CO2 equivalent production per annum (kg(CO2)/kg(digestible protein))</td>
<td>8.04 (Appendix C ii)</td>
<td>0.553 (Appendix E ii)</td>
<td>7.49</td>
</tr>
</tbody>
</table>

The key assumptions are identical to the corresponding assumptions in Table 1.

Soybean farms use 81.2MJ less energy, 0.563L less water and produce 7.49kg less CO₂ equivalent gas per kg of digestible protein, per annum as seen in Table 2. As a result, soybean farms are more economical and environmentally-friendly to run than broiler farms.

2.1.2 Ethics and morality

The ethical acceptability of raising broiler chickens for slaughter is the subject of an ongoing debate. Although chicken farmers claim "Animal health, welfare and..."
well-being are given the highest priority” (PIANZ, 2018), many people believe the “wrongful mistreatment of animals” (Chignell, Cuneo, & Halteman, 2016) to be commonplace in animal farms. Regardless of the conditions broiler chickens are raised in, the consumption of chicken remains a non-permissible moral issue to some (Chignell, Cuneo, & Halteman, 2016).

As soybeans are sourced from plants, the ethical issues associated with their consumption are reduced; genetic modification of soybean plants may present an ethical issue for some, however (Bawa & Anilakumar, 2013). The use of plants rather than animals increases the likelihood that New Zealand consumers will overall be more morally satisfied.

### 2.1.1 Consumption efficiency

Soybeans have a greater nutritional input per unit consumed than chicken. The average person consumes 21kg of chicken per annum (Appendix A iii) while only 16.4kg of soybeans must be consumed per annum to receive an equivalent amount of digestible protein (Appendix D i). This is due to the high protein content of soybeans (40% of dry mass as seen in Figure 3) compared to chicken (31.0%) (Smetana, Mathys, Knoch, & Heinz, 2015).
Figures provide a pictorial representation of what is being described (in this case, the composition of soybeans). Figures enable the writer to present their findings concisely and clearly.

Figure 3: Nutrient composition of soybeans (Preece, Hooshyar, & Zuidam, 2017)

Soybean production wastes less nutrients than chicken production. As seen in Figure 4 below, approximately 10% of energy is passed to the next trophic level (Drayer, 2016).

Figure 4: Comparison of energy efficiency of soybean and chicken consumption

Removing chickens from the energy equation would result in humans receiving 1% of the total energy input, rather than 0.1% currently. As 98% of soybeans produced are used in animal feed (Johnson, White, & Galloway, 2008), direct consumption would significantly decrease the effort put into producing chemical-potential energy that would otherwise be effectively wasted.

See how the writer uses the 'boosters' or 'intensifiers' "significantly" and "effectively" to make much stronger claims about the benefits of soybean farming.

Note that each Figure has a title to describe it. In APA style, titles for figures are placed below where figures appear, whereas titles for tables are placed above.
2.2 Challenges

2.2.1 Land area requirements

Soybean farms require $3.98\times10^{-4}$ Ha more land area than broiler farms per kilogram of digestible protein produced, as seen in Table 2. A total of 13,400 Ha (Appendix E iv) is required to make all 65 (Table 1) required soybean farms. It will be a challenge to find, purchase and maintain such a significant portion of land.

2.2.2 New Zealand Climate

New Zealand’s climate presents the greatest challenge to the viability of soybean farms. Most varieties of soybean plants have an optimum temperature range of 20 – 25°C (Martin, 1988).

The only five-month period (average time to maturity of soybean crops) (Kowalski, 2018) within which New Zealand experiences mean maximum temperatures in this range is from November to March (with minimum temperatures fluctuating between 9 - 14°C) (NIWA, 2010). Furthermore, these temperatures only occur in the North Island (NIWA, 2010). These findings mean that soybeans could only be grown near their optimum rate in the central North Island for a period of five months, which means that they are not economically viable for most of the year (Millner & Roskruge, 2012).

2.2.3 Consumer satisfaction

Soybean-based meat substitutes frequently aim to replicate the taste and texture of meat (Porter, 2003), and consumers are often dissatisfied when this aim is not met. Although soybeans can be extruded with high moisture, giving a texture similar to chicken (MacDonald, Pryzbyszewski, & Hsieh, 2009), the current negative perceptions held by some consumers about soy-based substitutes will need to be overcome to ensure successful uptake (Simon, 2016).

Also of concern is the reality that soybeans are considered one of the “Big 8” most allergenic foods (Ustunol, 2014). Consequently, a large proportion of the population will be unable to consume soy-based foods.
3.0 Conclusions

Equivalent soybean farms use 81.2MJ/kg less energy and 0.563L/kg less water than typical chicken farms. Also, they produce 7.49kg/kg less CO₂ equivalent gases than comparable chicken farms. Additionally, soybeans are considered to be more ethically acceptable for consumption. Overall, 10x more input energy is received by the human consumer, and only 16.4kg of soybeans must be consumed for every 21kg of chicken meat to receive an equivalent quantity of protein. However, soybean farms require 3.98x10⁻⁴ Ha/kg more area than chicken farms, and many people are allergic to soybean-based foods, while others perceive soy substitutes negatively.

New Zealand’s temperate climate provides the greatest barrier to the success of soybean farms. The lack of economic viability for most of the year makes it unlikely that soybean farms can completely replace broiler farms in New Zealand. However, North Island farmers could grow soybean crops during the summer season, rotating to other crops during colder seasons. In this way, soybean farms could partially replace broiler farms in New Zealand.
4.0 References


The References list contains references to all the sources (e.g., books, journal articles, online papers) referred to in this report. In this report the APA referencing style is used.


University of Kentucky. (2018, January 17). *Kentucky poultry energy efficient project*. Retrieved from University of Kentucky - College of Agriculture, Food and Environment: http://www2.ca.uky.edu/poultryprofitability/Production_manual/Chapter2_Broiler_production_facts_and_figures/Chapter2_size.html#Table6

5.0 APPENDICES

Appendix A: Total chicken protein consumed by New Zealanders

i) Total mass of chicken meat consumed in New Zealand
- Live mass of chicken consumed by the average New Zealander per annum = 37.5kg/year (PIANZ, 2018).
- Population of New Zealand = 4,831,000 persons (Statistics New Zealand, 2018).

\[
\text{Total live weight chicken consumption per annum} = \frac{\text{kg}}{\text{person} \times \text{year}} \times 4,831,000 \text{ persons}.
\]

\[
= \frac{37.5}{\text{kg}} \times 4,831,000 \text{ kg}.
\]

\[
= 181,162,500 \text{ kg/year}.
\]

ii) Total digestible protein consumed by New Zealanders from chicken
- Total live weight chicken consumption per annum = 181,162,500 kg/year (Appendix A).
- On average, 56.0% of live weight chicken is edible (Pellettier, 2008).
- Protein content of live chicken weight is 31.0% (Smetana, Mathys, Knoch, & Heinz, 2015).
- The Protein Digestibility Corrected Amino Acid Score (PDCAAS) for chicken is 1.00 (Smetana, Mathys, Knoch, & Heinz, 2015).

\[
\text{Total digestible protein consumed by New Zealanders from chicken per annum}
\]

\[
= \frac{\text{live weight chicken consumption per annum} \times \text{edible \% of live weight} \times \text{protein \% of live weight} \times \text{PDCAAS for chicken}}{\text{kg/year}}.
\]

\[
= \frac{181,162,500 \text{ kg/year}}{100\%} \times \frac{56\%}{100\%} \times \frac{31\%}{100\%} \times 1
\]

\[
= 31,449,810 \text{ kg/year}.
\]

\[
= 31,400,000 \text{ kg/year (3sf)}.
\]

Assuming no protein content is lost during processing.

iii) Mass of chicken consumed by average New Zealander per annum
- Live mass of chicken consumed by the average New Zealander per annum = 37.5kg/year (PIANZ, 2018).
- On average, 56.0% of live weight chicken is edible (Pellettier, 2008).

\[
\text{Average consumption of chicken mass per person per annum} = \frac{\text{live weight chicken consumption per person per annum} \times \text{edible \% of live weight}}{\text{kg/person \times year}}.
\]

\[
= \frac{37.5 \text{ kg/year}}{100\%} \times \frac{56\%}{100\%}
\]

\[
= 21 \text{ kg/person \times year}.
\]
Appendix B: Characteristics of a typical chicken farm

i) Total yearly consumption of chickens

- Total live weight chicken consumption per annum = 181,162,500 kg/year (Appendix A i).
- Average chicken mass = 2.5 kg (Bartov, 2010).

\[
\text{Total number of chickens consumed in NZ per annum} = \frac{\text{total live weight chicken consumption per annum}}{\text{average chicken mass}}
\]
\[
= \frac{181,162,500 \text{ kg}}{2.5 \text{ kg/chicken}}
\]
\[
= 72,465,000 \text{ chickens/year}
\]

ii) Number of typical chicken farms required

- Total number of chickens consumed in NZ per annum = 72,465,000 chickens (Appendix B i).
- Assume the average production of chickens per farm, per year is the same in New Zealand as in Kentucky (from where reliable information is most available) = 402,500 chickens/farm/year (University of Kentucky, 2018).

\[
\text{Number of 'typical' chicken farms required} = \frac{\text{total number of chickens consumed in NZ per annum}}{\text{number of chickens per farm per annum}}
\]
\[
= \frac{72,465,000 \text{ chickens/year}}{402,500 \text{ chickens/farm \times year}}
\]
\[
= 180.037 \text{ farms}
\]
\[
= 180 \text{ farms (3sf)}
\]

As New Zealand has around 180 farms (PIANZ, 2018), this estimation is reasonable.

iii) Digestible protein production by each typical chicken farm

- Total digestible protein consumption per annum = 31,449,810 kg/year (Appendix A ii).
- Number of typical chicken farms = 180.037 (Appendix B ii).

\[
\text{Digestible protein production by each farm per annum} = \frac{\text{total digestible protein consumption per annum}}{\text{number of typical chicken farms}}
\]
\[
= \frac{31,449,810 \text{ kg}}{180.037 \text{ farms}}
\]
\[
= 174,685.26 \frac{\text{ kg}}{\text{farm \times year}}
\]
\[
= 175,000 \frac{\text{ kg}}{\text{farm \times year (3sf)}}
\]

Assuming domestic chicken production = chicken consumption so as to meet domestic demand.
Appendix C: Resource usage of a typical farm

i) Energy use
   - 14,959 MJ used to produce 1 tonne of broiler poultry (Pelletier, 2008).
   - Total live weight chicken consumption per annum = 181,162,500 kg/year (Appendix A i).
   - Number of typical chicken farms = 180.037 farms (Appendix B ii).
   - Digestible chicken produced by a typical chicken farm per annum = 174,685.26 kg (farm x year) (Appendix B iii).

   Energy consumption of a typical chicken farm per annum
   \[ = \frac{\text{energy consumption per mass of chicken produced}}{\text{total live weight chicken consumption per annum}} \times \frac{\text{number of typical chicken farms}}{} \]
   \[ = \frac{14,959 \, MJ}{t} \times \frac{181,162,500 \, kg \, \text{year}}{180.037 \, \text{farms}} \times \frac{1 \, t}{1,000 \, kg} \]
   \[ = 15,052,493.75 \, \frac{MJ}{\text{farm} \times \text{year}} \]
   \[ = 15,100,000 \, \frac{MJ}{\text{farm} \times \text{year}} \quad (3sf) \]

   Energy consumption of a typical chicken farm per kg of digestible protein
   \[ = \frac{\text{energy consumption of a typical chicken farm per annum}}{\text{digestible chicken produced by a typical chicken farm per annum}} \]
   \[ = \frac{15,052,493.75 \, MJ}{174,685.26 \, kg \, \text{year}} \]
   \[ = 86.2 \, \frac{MJ}{kg} \quad (3sf) \]

ii) Carbon dioxide production
   - 1395 kg of CO₂ equivalent per tonne of broiler poultry (Pelletier, 2008).
   - Total live weight chicken consumption per annum = 181,162,500 kg (Appendix A i).
   - Number of typical chicken farms = 180.037 (Appendix B ii).
   - Digestible chicken produced by a typical chicken farm per annum = 174,685.26 kg (farm x year) (Appendix B iii).

   \[ \text{CO₂ equivalent production of a typical chicken farm per annum} \]
   \[ = \frac{\text{CO₂ equivalent production per mass of chicken produced}}{\text{total live weight chicken consumption per annum}} \times \frac{\text{number of typical chicken farms}}{} \]
   \[ = \frac{1,395 \, kg}{t} \times \frac{181,162,500 \, kg \, \text{year}}{180.037 \, \text{farms}} \times \frac{1 \, t}{1,000 \, kg} \]
   \[ = 1,403,718.75 \, \frac{kg}{\text{year} \times \text{farm}} \]
   \[ = 1,400,000 \, \frac{kg}{\text{year} \times \text{farm}} \quad (3sf) \]
\[
\text{\(CO_2\) equivalent production of a typical chicken farm per kg of digestible protein} = \frac{\text{\(CO_2\) equivalent production of a typical chicken farm per annum}}{\text{digestible chicken produced by a typical chicken farm per annum}} \\
= \frac{1,403,718.75 \text{ kg}(CO_2)\text{ year}^{-1}}{174,685.26 \text{ kg}(\text{digestible protein})\text{ year}^{-1}} \\
= 8.04 \frac{\text{kg}(CO_2)}{\text{kg}(\text{digestible protein})} \quad (3sf)
\]

**iii) Water usage**

- Water consumption varies based on age and time of year (Poultry Hub, 2018). Assume average water consumption is 244.375L per 1000 birds (University of Arkansas Division of Agriculture, 2009).
- Number of chickens per farm per annum = 402,500 chickens (University of Kentucky, 2018).
- Digestible chicken produced by a typical chicken farm per annum = 174,685.26 kg (farm x year) (Appendix B iii).

**Water usage of a typical chicken farm per annum**

\[
= \text{water usage per chicken} \times \text{number of chickens per farm per annum} \\
= \frac{244.375}{1000 \text{ chickens}} \times \frac{402,500}{\text{farm} \times \text{year}} \\
= \frac{98,360.9365}{\text{farm} \times \text{year}} \quad (3sf)
\]

**Water usage of a typical chicken farm per kg of digestible protein**

\[
= \frac{\text{water usage of a typical chicken farm per annum}}{\text{digestible chicken produced by a typical chicken farm per annum}} \\
= \frac{98,360.9365}{174,685.26 \text{ kg}} \\
= 0.563 \frac{L}{\text{kg}} \quad (3sf)
\]

**iv) Land usage**

- Assume all farms are adopting the minimum best practice recommendations of 30 kg live chicken mass/m² (Ministry for Primary Industries, 2018).
- Assume the proportion of chicken produced on free-range farms in New Zealand is the same as Australia (10.15%) and take the average of 12.5% as an estimate (Australian Chicken Meat Federation Inc., 2013).
- Assume proportion of chicken produced on organic farms is the same as Australia: <1% (Australian Chicken Meat Federation Inc., 2013), thus ignore additional land used by these farms as it is negligible.
- Assume all free range chickens have access to a range 1.5x floor area of the barn as required for SPCA accreditation (PIANZ, 2018).
- Total live weight chicken consumption per annum = 181,162,500 kgs (Appendix A i).
- Digestible chicken produced by a typical chicken farm per annum = 174,685.26 kg (farm x year) (Appendix B iii).

**Total barn land area used in the broiler industry**

\[
= \frac{\text{total live weight chicken consumption per annum}}{\text{chicken density in barn}} \\
= \frac{181,162,500 \text{ kg}}{30 \text{ kg/m}^2} \\
= 6,038,750 \text{ m}^2
\]
Run area used in free range chicken farms

\[ \text{run area used in free range chicken farms} = \text{total barn area used in farms} \times \% \text{ of free range farms} \times \text{run area as a proportion of barn area} \]

\[ = 6,038,750 \text{ m}^2 \times \frac{12.5\%}{100} \times 1.5 \]

\[ = 1,132,265.625 \text{ m}^2 \]

Total land area used in the broiler industry = barn area + run area

Total land area used in the broiler industry = \[6038750 \text{ m}^2 + 1132265.625 \text{ m}^2 = 7,171,015.625 \text{ m}^2\]

\[ \text{Land area used by an average chicken farm} = \frac{\text{total land area used}}{\text{number of typical chicken farms}} \]

\[ = \frac{7,171,015.625 \text{ m}^2}{180.037 \text{ farms}} \]

\[ = 39,830.79 \text{ m}^2 \text{ per farm} \]

\[ = 39,800 \text{ m}^2 \text{ per farm (3sf)} \]

Land area usage of a typical chicken farm per kg of digestible protein

\[ \text{land area used by an average chicken farm} = \frac{\text{digestible protein produced by a typical chicken farm per annum}}{3.98 \text{ Ha}} \]

\[ = \frac{174,685.26 \text{ kg \times year}}{3.98 \text{ Ha}} \]

\[ = 2.27 \times 10^{-5} \text{ Ha/kg \times year (3sf)} \]

As the land is reusable for each yearly batch of chickens, answer = \[2.27 \times 10^{-5} \text{ Ha/kg (3sf)} \]

Assuming the farm is only comprised of the land area available for the chickens to roam.

Appendix D: Characteristics of an equivalent soybean farm

i) Mass of soybeans required to be consumed

- 40% of a soybean’s mass is protein (Preece, Hooshyar, & Zuidam, 2017).
- Proteins in soybeans have a PDCAAS of 0.9 – 0.99 depending on the method of processing (Ustunol, 2014). Assume no protein content is lost in processing thus the PDCAAS is 0.99.
- Total digestible protein produced by broiler farms per annum = 31,449,810 kg/year (Appendix A ii).
- Population of New Zealand = 4,831,000 persons (Statistics New Zealand, 2018).

Let \( M \) be the total mass of soybeans required to get the same mass of digestible protein as is consumed, in the form of chicken, by New Zealanders per annum.

\[ \% \text{ of soybean mass that is protein} = \frac{M \times \text{PDCAAS}}{\text{total digestible protein production by broiler farms per annum}} \]
\[ M = \frac{31,449,810}{0.396} \frac{kg}{year} \]
\[ M = 79,418,712.12 \frac{kg}{year} \]

Assuming no soybean mass is lost during harvesting, thus production of soybeans = consumption of soybeans.

**Average required consumption of soybean mass per person per annum**

\[ \frac{\text{total mass of soybeans to be consumed per annum}}{\text{number of people in New Zealand}} = \frac{79,418,712.12}{4,831,000} \frac{kg}{year} = 16.4 \frac{kg}{person \times year} \text{ (3sf)} \]

**ii) Number of equivalent soybean farms required**

- Assume soybean productivity is maintained at the highest observed productivity in New Zealand of 6 tonnes/hectare (Milner & Roskruge, 2012).
- Total mass of soybeans to be produced = 79,418,712.12 kg/year (Appendix D i).
- Assume the size of each farm is that of the average grain farm in New Zealand: 205.4 Ha (Land Information New Zealand, 2012).

**Total land required for soybean farms**

\[ \frac{\text{total mass of soybeans to be produced}}{\text{mass production of soybean farms per hectare}} = \frac{79,418,712.12}{6 \frac{t}{ha}} \times \frac{1t}{1000 \ kg} = 13,236,452 \ ha \]

**Number of typical soybean farms required**

\[ \frac{\text{total land area required for soybean farms}}{\text{land area per soybean farm}} = \frac{13,236,452 \ ha}{205.4 \ \frac{ha}{farm}} = 64A \ \text{farms} \ (3sf) \]

= 65 farms

(round up to ensure enough protein production to meet demand)
### Appendix E: Resource use of an equivalent soybean farm

#### i) Energy use

- 1.5 – 2.3 MJ/kg of soy produced (Pelletier, N.; Arsenault, N.; Tyedmers, P., 2008). Assume energy use is the average of this range: 1.9 MJ/kg.
- Total mass of soybeans to be produced = 79,418,712.12 kg/year (Appendix D i).
- Number of equivalent soybean farms = 64.4 farms (Appendix D ii).
- Mass of digestible protein production per soybean farm per annum = 488,351.087 kg/farm/year (Appendix D iii).

Energy consumption of an equivalent soybean farm per annum

\[
\text{energy consumption of an equivalent soybean farm per annum} = \frac{\text{energy consumption per mass of soybeans produced}}{\text{total mass of soybeans produced per annum}} \times \frac{\text{number of soybeans produced per annum}}{\text{total mass of soybeans produced per annum}}
\]

\[
= \frac{1.9 \text{ MJ/kg}}{\text{kg}} \times \frac{79,418,712.12 \text{ kg/year}}{64.4 \text{ farms}}
\]

\[
= 2,343,098.65 \text{ MJ/farm/year}
\]

\[
= 2,340,000 \text{ MJ/farm/year (3sf)}
\]

**Energy consumption of an equivalent soybean farm per kg of digestible protein**

\[
\text{energy consumption of an equivalent soybean farm per kg of digestible protein} = \frac{\text{energy consumption of an equivalent soybean farm per annum}}{\text{mass of digestible protein produced per soybean farm per annum}}
\]

\[
= \frac{2,343,098.65 \text{ MJ/farm/year}}{488,351.087 \text{ kg/farm/year}}
\]

\[
= 5.00 \text{ MJ/kg (3sf)}
\]


**ii) Carbon dioxide production**

- $190.3 - 247.7 \text{ g of CO}_2$ equivalent is produced per kg of soy. Assume CO$_2$ production is the average of this range: $219 \text{ g/kg}$.
- Total mass of soybeans to be produced = $79,418,712.12 \text{ kg/year}$ (Appendix D i).
- Number of equivalent soybean farms = 64.4 farms (Appendix D ii).
- Mass of digestible protein production per soybean farm per annum = $488,351.087 \text{ kg/farm/year}$ (Appendix D iii).

\[
\text{CO}_2 \text{ production of an equivalent soybean farm per annum} = \frac{\text{CO}_2 \text{ production per mass of soybeans produced}}{\text{total mass of soybeans produced per annum}} \times \frac{\text{number of soybean farms}}{64.4 \text{ farms}}
\]

\[
= 219 \frac{\text{g}}{\text{kg}} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{79,418,712.12 \frac{\text{kg}}{\text{year}}}{64.4 \text{ farms}}
\]

\[
= 270,072.95 \frac{\text{kg}}{\text{farm \times year}}
\]

\[
= 270,000 \frac{\text{kg}}{\text{farm \times year}} \quad (3sf)
\]

\[
\text{CO}_2 \text{ production of an equivalent soybean farm per kg of digestible protein}
\]

\[
= \frac{\text{CO}_2 \text{ production of an equivalent soybean farm per annum}}{\text{mass of digestible protein produced by an equivalent soybean farm per annum}} \times \frac{\text{kg(CO}_2)}{\text{kg(CO}_2)}
\]

\[
= \frac{270,072.95 \frac{\text{kg}}{\text{farm \times year}}}{488,351.087 \frac{\text{kg(digestible protein)}}{\text{farm \times year}}}
\]

\[
= 0.553 \frac{\text{kg(digestible protein)}}{\text{kg(CO}_2)} \quad (3sf)
\]

**iii) Water use**

- Water use varies depending on growth stage, soil water holding capacity, and climate (primarily temperature and humidity). Assume optimal irrigation levels are the same as those in central Iowa, USA: 317mm over a season (Dietzel, et al., 2015).
- Soybean plants take roughly 5 months to mature (Kowalski, 2018).
- The only time New Zealand experiences mean max temperatures within the optimal 20 – 25°C range is from November – March and they only occur from the central North Island, north (NIWA, 2010). During this time period, the central North Island experiences a mean of 400 mm of rain (NIWA, 2010). As this is above the optimal water requirements, natural precipitation should be sufficient for the growth of soybeans in New Zealand.
Engineering Reports

Background to this engineering report

The above engineering report was written by a first year engineering student at the University of Auckland based on a literature search completed for a Research Report.

Sections of an Engineering Report

There are many different ways to structure an engineering report; the structure chosen depends on the type of report (e.g., general report, design report) (Silyn-Roberts, 2012).

Students writing this research report were required to include the following main sections in the format given: Title page, Abstract, Table of Contents, 1.0 Introduction, 2.0 Discussion, 2.1 Benefits, 2.2 Challenges, 3.0 Conclusions, 4.0 Reference list in APA style, 5.0 Optional Appendices. They were also asked to include at least one figure or table, and calculations with the values and any assumptions used explained.

Because there are several different types of engineering reports, it is vital that you follow the course guidelines about the sections that need to be included. In addition, you need to use the correct referencing style and keep within the word limit. Below is a brief overview of each section of a research report like this one based on a literature search:

Title page

The Title page takes up the first page of an engineering research report. Information placed on this page includes the title of the report, the course name, the writer’s name, and the date (month, year).

Abstract

The purpose of the Abstract is to explain what the report is about, why it was written, how information was obtained, and what was found.

Table of Contents

The Table of Contents enables the reader to get an immediate overview of what is included in the report and where each part is located.

List of Figures, Tables, and Equations

The List of Figures, Tables and Equations follows the Contents page. The List of Figures is always placed first. Each Figure is numbered sequentially with a brief title and listed with its page number.

Introduction

The Introduction gives the reader the opportunity to understand the background to the report and what it is about, why it was written, and how the information was found. This section may also include the definition of key terms and the assumptions behind the data collected and calculations made.

Discussion

The Discussion of this report interprets the data identified through the literature search and outlines the benefits and challenges of what is proposed in the report (in this case, a switch to soybean farms from broiler farms). Key data are presented in tables and figures; for example, in pie and flow charts.
Conclusions
This section gives the writer the chance to sum up the main findings of the research.

References
This section comprises a list of all references referred to in the research paper.

Appendices
It is usual practice to put non-essential information, which provides further clarification of a point in an Appendix. Appendices are sequentially labelled with letters of the alphabet. Placing the information here means that unnecessary space is not used within the body of a paper (Bates College, 2011).

Distinctive language features of engineering research reports
Engineering reports have a number of distinctive language features, which are outlined below:

Parallelism
One distinctive feature of well-written engineering reports is the use of parallelism, which means that the same grammatical pattern is used in lists or comparisons. The writer sometimes uses parallelism in this report, which makes it easier for the reader to follow the argument; e.g.,

(1) The total digestible protein production of all equivalent soybean farms is equivalent to the total digestible protein production of all typical broiler farms in New Zealand.

Noun phrase   preposition    noun phrase
The total digestible protein production of all equivalent soybean farms.
the total digestible protein production of all typical broiler farms in New Zealand.

(2) Animal, plant and insect-based sources, as well as lab-grown sources ...

Pre-modifiers    Head noun
Animal, plant and insect-based    sources
lab-grown    sources

Pronoun usage
A further feature of research reports is related to the use of personal pronouns (e.g., I, he, we). Check with your lecturer whether it is appropriate to use these because in some cases they can be used. No pronouns, however, are used in this report. Rather, the writer uses passive voice to avoid any need of mentioning their role in carrying out the study; e.g.,

(1) The above assumptions were made to allow the use of outdated and international data where no recent data was available for New Zealand.

(2) The information required was obtained through a literature search.

Specialised vocabulary
Another feature of well-written research reports is that specialised vocabulary is correctly used. As you can see in the following two sentences, the writer has correctly used equations and commonly accepted abbreviations:

Results show that soybean farms require 81.2MJ/kg less energy per annum (p.a.) than typical chicken farms and 0.563L/kg less water p.a..

Indeed, the writer has first written the expression "per annum" in full and subsequently just written the abbreviated form "p.a.".
Given the importance of correctly using specialised vocabulary, you may find it useful to build a
glossary and focus on learning these words so that you are familiar with their meaning, the words
they collocate with, and the various forms of the word, including abbreviations.

Expressing an opinion or the author’s “voice”

As you can see in the above report, it is possible for the writer to position themselves and express
their opinion through their choice of language even though it is written entirely in the third person
and no use of “I” is made. Indeed, as this report shows, it is possible to express your views by
using words that express certainty (thus making a strong claim) or uncertainty (thus making a
weak or tentative claim).

**Strong claims**

Strong claims are made using adverbs that have a strong meaning (e.g., significantly). These
adverbs along with the adjective counterparts (e.g., significant, greatest) are sometimes referred
to as “boosters” or “intensifiers”. As the following example shows, when making such a claim in
the report, the writer first provides evidence for the claim being made:

As 98% of soybeans produced are used in animal feed (Johnson, White, & Galloway,
2008), direct consumption would **significantly** decrease the effort put into producing
chemical-potential energy that would otherwise be **effectively** wasted.

**Tentative claims**

Weak or tentative claims are made by using “hedging” devices such as “perhaps” or “may”.
Hedging is a way that writers can express uncertainty, avoid drawing unjustified conclusions and
acknowledge that they are not experts. The following example illustrates the writer using the
modal verb “may” to indicate that there is a possibility that there could be ethical issues around
the use of soybean plants which have been genetically modified:

As soybeans are soured from plants, the ethical issues associated with their consumption
are reduced; genetic modification of soybean plants **may** present an ethical issue for
some, however (Bawa & Anilakumar, 2013).

The extent to which strong or weak claims are made in reports often depends on the topic and the
room for interpretation within this.

Another way to express the writer’s voice

Although not done in this report, it is possible for writers to make subjective comments when
interpreting the data in the Discussion by using words (e.g., obvious[ly], surprising[ly], ideal[ly])
and phrases (e.g., it is useful to note, in particular).

Verb usage

This engineering report is almost entirely written in the present tense. A switch is made to the
past tense is to report on the methodology used (see Abstract), and to sum up the rationale for
each assumption (see Introduction).

Verb tenses

**Abstract**
The present tense is used to:

(1) Describe the problem the report is exploring

   With New Zealand’s population expected to reach 6.5 million by 2068, the
   sustainability, efficiency and ethical acceptability of chicken as a protein source in New
   Zealand is in question.
(2) Outline the purpose of the report and what it is seeking to achieve
   This report evaluates the suitability of soybean farms as an alternative source of
   protein production in New Zealand to broiler farms.

(3) Summarise the results
   Results show that soybean farms require 81.2MJ/kg less energy per annum (p.a.) than
   typical chicken farms and 0.563L/kg less water p.a.

(4) Outline the conclusions
   Despite their greater efficiency, and ethical acceptability, New Zealand’s temperate
   climate makes it not economically viable to completely replace broiler farms in New
   Zealand.

The past tense is used to:

(1) Report on the methodology used
   The information required was obtained through a literature search.

Introduction
The present tense is used throughout the introduction (apart from the last sentence) to:

(1) Give a broad introduction to the topic
   With New Zealand’s population expected to reach 6.5 million by 2068 (Statistics New
   Zealand, 2017), it is important that domestic food production remains efficient,
   sustainable and ethically acceptable.

(2) Highlight the need for the current research
   It is thus important that the poultry industry is efficient with its use of resources, or a
   more efficient protein-alternative is found.

(3) State the purpose of the current research
   The objective of this report is to evaluate soybean farms as an alternative form of
   protein production to broiler farms.

(4) Outline the scope of the research
   The scope includes an analysis of the benefits and challenges arising from energy,
   water and land usage and the CO2 equivalent production.

(5) Give definitions of key terms
   These farms produce 402,500 chickens/year assuming the average chicken production
   per farm is the same as in Kentucky (from where reliable information is most easily
   accessible) (University of Kentucky, 2018).

(6) Outline key assumptions
   The average production of chickens per farm, per year is the same in New Zealand as
   in Kentucky (University of Kentucky, 2018).

The past tense is only used in the last sentence to sum up why each assumption was made

The above assumptions were made to allow the use of outdated and international data
where no recent data was available for New Zealand.

Discussion
The present tense is used throughout the Discussion. For example, the present tense is used to:

(1) Describe the Table and the Figures
   The key assumptions are identical to the corresponding assumptions in Table 1.
(2) Outline issues around ethics and morality
The ethical acceptability of raising broiler chickens for slaughter is the subject of an ongoing debate.

(3) Describe the challenges
New Zealand’s climate presents the greatest challenge to the viability of soybean farms.

Conclusions
The present tense is used throughout the Conclusions. For example, the present tense is used to:

(1) Refer to data that provide a summary of the research findings
Overall, 10x more input is received by the human consumer, and only 16.4kg of soybeans must be consumed for every 21 kg of chicken meat to receive an equivalent quantity of protein.

(2) Describe the challenges
New Zealand’s temperate climate provides the greatest barrier to the success of soybean farms.

Active and passive voice
Both the active and passive voice are used in this engineering report. The writer chooses whether to use the active or passive voice depending on what is being said and where the focus is to be.

When the active voice is used, the subject of the sentence is the doer or performer of the action, and the object is the receiver of the action. The active voice in the following example from the Abstract is used because the writer wants the focus to be on the performer of the action (i.e., “This report”):

This report evaluates the suitability of soybean farms as an alternative source of protein production in New Zealand to broiler farms.

In contrast, the passive voice is used in the Abstract where there writer wants to focus to be on the receiver of the action (i.e., 10x more input energy):

Overall, 10x more input energy is received by the human consumer ...

The passive voice in the past tense is used where the experimental procedure is referred to because the focus is on the result of the action that has been completed, rather than on who carried it out:

The information required was obtained through a literature search.

Aspect
The progressive aspect (e.g., It is starting) is not used at all in the report and the perfective aspect (e.g., It has started) is occasionally used when the writer wants to refer to an action which started in the past and is still of current relevance:

Soybean farms have already proven successful in other countries, with 77.5 million acres being planted in the USA in 2009 (Ash, 2017).

... all free range chickens have access to a range 1.5x the floor area of the barn as required for SPCA accreditation (PIANZ, 2018).
Reduced relative clauses
A further feature of engineering research reports is the use of reduced relative clauses. Use of such clauses helps make the writing concise. Reduced relative clauses are in the passive voice and should not be confused with the simple past tense as this example illustrates:

The information required was obtained through a literature search. [passive]

The verb "required" in the above example is the non-finite -ed participle. If this clause had been written as a full relative clause, it would say:

The information that was required was obtained through a literature search. [passive]

If this sentence had been written in the active voice, it would have placed unnecessary focus on the researcher carrying out the action:

The information that the researcher required was obtained through a literature search. [active]

Modal verbs
Modal verbs are used for a number of reasons which include:

(1) Expressing uncertainty
As soybeans are soured from plants, the ethical issues associated with their consumption are reduced; genetic modification of soybean plants may present an ethical issue for some, however (Bawa & Anilakumar, 2013).

(2) Making a stronger claim
The use of plants rather than animals increases the likelihood that New Zealand consumers will overall be more morally satisfied.

Removing chickens from the energy equation would result in humans receiving 1% of the total energy input, rather than 0.1% currently.

(3) Expressing possibility
Additionally, soybeans have a similar nutritional composition to chicken (Johnson, White, & Galloway, 2008), so may serve as a more humane alternative.

Soybean plants, however, could still be used in a crop rotation from November to March in the North Island.

Developing a coherent argument
An important feature of a well-written research report is that it is coherent and well-structured. A variety of strategies can be used to ensure that the ideas are logically connected to one-another. One is to use "transition signals" such as "however" and "In this way":

The lack of economic viability for most of the year makes it unlikely that soybean farms can completely replace broiler farms in New Zealand. However, North Island farmers could grow soybean crops during the summer season, rotating to other crops during colder seasons. In this way, soybean farms could partially replace broiler farms in New Zealand.

Another feature is to use a pronoun such as "it", "this", or "these". If using a pronoun, however, check that the meaning is clear as in the following example where the pronoun clearly represents. Otherwise, if the meaning of the pronoun is not clear, it is preferable to repeat the noun or noun phrase, or use a synonym or a noun phrase, as shown in this example where the phrase "this
range” points back to the previous paragraph in which “an optimum temperature range” was given:

New Zealand’s climate presents the greatest challenge to the viability of soybean farms. Most varieties of soybean plants have an optimum temperature range of 20 – 25°C (Martin, 1988).

The only five-month period (average time to maturity of soybean crops) (Kowalski, 2018) within which New Zealand experiences mean maximum temperatures in this range is from November to March (with minimum temperatures fluctuating between 9 - 14°C) (NIWA, 2018).

References

