Diet Formulation

Dr. Paul A. Iji
Production of nutritious and economic diets

To produce a diet that is nutritionally balanced and economically least-cost the producer must:

– understand the nutrient requirements of the animal;
– know the nutritive value of the feed ingredients, and of course,
– know the price of the ingredients.
Part 1

Understanding nutrient requirements and factors that affect them
Nutrient Requirements

- Animals require energy and all nutrients for maintenance, growth, production and reproduction.
- These include energy, amino acids, lipids, minerals and vitamins.
Energy

- Pigs and Poultry eat to satisfy their energy requirements
- Energy of feed is measured in Calories or Megajoules
  - $1 \text{ Cal} = 4.184 \text{J. or } 1 \text{MJ} = 239 \text{ kcal.}$
- Feed components contain different amounts of energy, i.e. Fat 39 MJ, Protein 23 MJ, and carbohydrates 18 MJ per kg dry matter.
Partitioning of dietary energy
monogastric animals

- Gross Energy
- Digestible Energy
- Metabolisable Energy
  - Faecal Energy
  - Urinary Energy
  - Heat increment
- Net Energy
ME and DE

- Determine digestible energy (DE) in pigs and metabolisable energy (ME) in poultry;
- DE and ME are done by measuring the amount of energy consumed and the amount of energy excreted by the animal in a feeding trial.
Calculation of DE or ME

\[
\text{DE} = \frac{(\text{Feed Intake} \times \text{GE of feed}) - (\text{Faeces excreted} \times \text{GE of faeces})}{\text{Feed Intake}}
\]
### ME and DE values of Common Feedstuffs for Poultry and Pigs

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>DE</th>
<th>ME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize (corn)</td>
<td>16.6</td>
<td>16.2</td>
</tr>
<tr>
<td>Sorghum</td>
<td>16.0</td>
<td>15.6</td>
</tr>
<tr>
<td>Wheat</td>
<td>15.9</td>
<td>14.5</td>
</tr>
<tr>
<td>Triticale</td>
<td>15.8</td>
<td>13.8</td>
</tr>
<tr>
<td>Barley</td>
<td>14.1</td>
<td>13.5</td>
</tr>
<tr>
<td>Rye</td>
<td>13.4</td>
<td>13.0</td>
</tr>
<tr>
<td>Oats</td>
<td>13.3</td>
<td>12.5</td>
</tr>
</tbody>
</table>
Energy Evaluation Systems

- **AME (apparent metabolisable energy):** also called the classic ME, or just simply ME, is the current default system used for poultry.

- **TME (true metabolisable energy):** corrected for endogenous energy losses (EEL); done by force-feeding fasted (24-48 h) adult cockerels with 40-60 g feed. Few people use it today.
Energy Evaluation Systems

- N-corrected ME: it is argued that body nitrogen, when catabolised, is excreted as energy containing products and that it is desirable to bring AME data to a basis of nitrogen equilibrium, $\text{AME}_n$, $\text{TME}_n$, etc.
Factors affecting energy utilisation in monogastrics

- **Environmental factors:**
  - Temperature
  - Relative humidity
  - Wind velocity

- **Intrinsic factors:**
  - Age: affects DE in pigs and ME in poultry
  - Strain: little effect in pigs, some effects in poultry
  - Feather cover in birds
  - Feed constituents, such as antinutrients
  - Feed storage, e.g., new season grain phenomenon.
Factors affecting energy utilisation: **Temperature**

- Evaporative heat loss by individual chickens (1 kg) held at six temperatures (Farrell and Swain 1977).

**Graph:**
- **Y-axis:** Evaporative heat loss (% of total)
- **X-axis:** Ambient Temperature (°C)

- At 35°C: 90%
- At 30°C: 60%
- At 22°C: 40%
- At 16°C: 20%
- At 9°C: 10%
- At 2°C: 5%

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**Footnotes and References:**

Factors affecting energy utilisation: Temperature

![Diagram of temperature zones and stress levels]

- **ZONE OF SURVIVAL**
- **ZONE OF HOMEOTHERMY**
- **TNZ** (Zone of Thermal Neutral)
- **ZONE OF THERMAL COMFORT**
- **ZONE OF THERMAL HYPERTHERMY**
- **ZONE OF THERMAL HYPOTHERMY**
- **DEATH FROM COLD**
- **DEATH FROM HEAT**

- **Core Temp**
- **Heat production**

**Cold stress**

**Heat stress**

**Environmental Temperature**

---

**A**

**B**

**C**

**D**

**E**

**F**

**G**

**H**
Factors affecting energy utilisation: Air Temperature and speed

Effects of air temperature and velocity on ME intake of a 2-kg hen (KJ/day).

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Air speed (m/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td>5</td>
<td>286</td>
</tr>
<tr>
<td>15</td>
<td>202</td>
</tr>
<tr>
<td>25</td>
<td>118</td>
</tr>
<tr>
<td>35</td>
<td>33</td>
</tr>
</tbody>
</table>

McDonald 1978.
Protein

- Animals require amino acids, rather than protein
- Concept of essential and non-essential aa.
- Digestible aa concept.
Protein Requirements

- Protein requirements in reality are requirements for amino acids (AA), which are the building blocks for proteins;
- Some AA are not synthesized within the body and they must be supplied by the feed. These AA are called ESSENTIAL AMINO ACIDS. There are 10 essential AA for monogastrics.
Amino Acids = building blocks of proteins

Each protein has a unique structure and combination of AA.
Limitations in protein synthesis due to the lack of an Essential Amino Acids

The “Liebig Barrel”: Protein synthesis is limited by the lack of an essential aa until all needs are met.
Minerals and Vitamins

- Minerals are required for formation of skeleton, components of functional compounds in the body, activators of enzymes, production of eggs, etc.;
- Vitamins are essential for normal growth and many bodily functions.
Part 2

Knowing your ingredients
Refer to individual ingredients in previous section.
Part 3

Formulating diets
Considering nutrient requirements

- Species, age, production status, breeds/strains, environmental conditions;
- NRC, ARC vs SCA;
- Production objectives, e.g., max growth, max feed conversion, lean growth, restricted growth, etc.
Considering your ingredients

- Your knowledge about the ingredients: availability and price, nutritive value, anti-nutrients, inclusion levels;

- Your understanding of the end product: palatability, pellet/crumble quality, effect on meat/milk/egg quality, threshold level of anti-nutrients, etc.
Formulating diets

- Manual formulations (Pearson’s square, Algebraic equations);
- Formulations using spreadsheet programs such as Excel, Lotus;
- Formulations using least-cost Diet Formulation Packages such as Format, Agridata, Feedmania, Take-Away, Winfeed, etc.
Pearson’s Squares

- Suitable for diets with few ingredients

- \( X \) = Desired dietary nutrient content, e.g. protein content
- \( A \) = Level of nutrient in ingredient A
- \( B \) = Level of nutrient in ingredient B
- \( C = \text{Difference between } B \text{ and } X \)
- \( D = \text{Difference between } A \text{ and } X \)
- \( E = \text{Sum of } C \text{ and } D \text{ or difference between } A \text{ and } B. \)
Example: Pearson’s Square

- Check for CP requirements:
- In 100 kg diet:
  - CSM constitutes 27 kg
  - CP from CSM = 0.4 x 27 = 10.8 kg or %
  - Maize constitutes 73 kg
  - CP from maize = 0.1 x 73 = 7.3 kg or %
  - Total CP = 18.1 kg or %
Example: Algebraic Equation

- Equation 1: $0.1x + 0.4y = 18$
- Equation 2: $x + y = 100$
- Equation 3: $0.1x + 0.1y = 10$
- Subtract 3 from 1: $0.3y = 8$
- $y = 8/0.3 = 26.67$
- $:. x = 100 - 26.67 = 73.33$
- **Check CP:**
  - CP from maize = $0.1 \times 73.33 = 7.333$
  - CP from CSM = $0.4 \times 26.67 = 10.668$
  - Total = 18.001 % CP (adequate).
Evaluating the diet

- Proximate analyses: DM, CP, and NDF/ADF for ruminants;
- Energy: for monogastrics, usually require DE/ME trials;
- Protein: amino acid profiles or in vitro protein tests;
- Field trials for performance.
Nutritive Value and Feed Evaluation
Introduction

- Provision of appropriate quality and quantity of nutrients for growth, development and production - proper feeding;
- Determinant of the above-said - feed evaluation.
The Australian feed industry

- Highly concentrated ownership, e.g., two companies (Ridley and Millmaster) share 60% of the market.
- Feed costs fluctuate due to imports, crop yield for the year, etc.
Part 1

Assessing nutritive value of feed from physical characteristics and chemical composition
Evaluating feeds using physical characteristics

- **Bushel weight** for grains is related to fullness of the grain and thus the higher the bushel weight, the more nutrients per volume.
Bushel weights

The recommended minimum bushel weights for grains used in pigs and poultry

<table>
<thead>
<tr>
<th>Grain</th>
<th>Bushel Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard</td>
</tr>
<tr>
<td>Barley</td>
<td>48</td>
</tr>
<tr>
<td>Corn</td>
<td>56</td>
</tr>
<tr>
<td>Wheat</td>
<td>60</td>
</tr>
</tbody>
</table>

The “bushel weight” is not an accurate measure of nutritive value of grains.

1 UK bushel = 36.368 L
1 US bushel = 35.238 L

The universal measure is now “Hectolitre weight”. 1 hL = 100 L
Evaluating feeds using chemical composition

- Using “Proximate analyses”
- Detailed analyses
Chemical Composition
- Proximate analyses

<table>
<thead>
<tr>
<th>Chemical Component</th>
<th>Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td></td>
</tr>
<tr>
<td>Nitrogen Free Extract</td>
<td></td>
</tr>
<tr>
<td>Crude Fibre</td>
<td></td>
</tr>
<tr>
<td>Crude Protein</td>
<td></td>
</tr>
<tr>
<td>Ether Extract</td>
<td></td>
</tr>
<tr>
<td>Total Ash</td>
<td></td>
</tr>
</tbody>
</table>

- Starch
- NSP + Lignin
- Amino acids
- Lipids
- Minerals
Chemical Composition
- Detailed analyses

- **Detailed composition:**
  - Amino acids, non-starch polysaccharides (NSP), fatty acids, minerals.
  - Accurate, but expensive. More and more feed manufacturers are demanding it.
Chemical Composition

- Summary

- Essential for all nutritional work and basis for modern feeding programs;
- Chemical composition of all ingredients varies depending on their sources (growing conditions, processing procedures, etc.) and need updating all the time;
- Chemical composition ≠ nutritive value.
Part 2

Determining nutritive value using bioassays
Bioassays

- Bioassays refer to “feeding trials” where the test feed is fed to the target animal and the total amount or a specific nutrient digested from that feed is measured.
- This is the most important measure of “nutritive value”.

Bioassays
Bioassays
Total tract digestibility

- The ultimate assessment of the nutritive quality of feed ingredients is to feed it to the animal and measure the amount of nutrients digested.
- Digestibility trials differ depending on the animal species and the purpose of the trial.
Pig Digestive Tract
Total tract digestibility
- DE trial in pigs

- 6-8 pigs in metabolism cages;
- Adaptation period of 10-14 d;
- Collection period of 5-7 d;

During collection, feed intake is held constant and faeces dried and weight recorded.
Chicken Digestive Tract

- Oesophagus
- Gall Bladder
- Liver
- Crop
- Proventriculus
- Gizzard
- Pancreas
- Duodenum
- Jejunum
- Ileum
- Caeca
- Colon
- Cloaca
- Kidneys
Total tract digestibility
- ME trial in poultry

- 4-6 reps of 4 birds each in metabolism cages;
- Adaptation period of 3 d;
- Collection period of 4 d;

During collection, *ad lib* feed intake is recorded and excreta collected quantitatively.
Total tract digestibility

- Summary

- Accurate for energy and dry matter digestibility measurements;
- Used widely as the industry standard throughout the world;
- Total tract digestibility data for nutrients such as amino acids, starch and lipids are not accurate due to effects of gut microflora and endogenous secretions.
Bioassays
- Within-Tract Digestibility

- Use of markers
- Calculations
- Advantages of measuring digestibility in the tract
Measuring digestibility in the gut
- characteristics of markers

- Should be inert and not absorbed or metabolised;
- mix intimately with the food or feed and remain uniformly distributed in the digesta;
- have no influence on gut physiology, ecology and motility;
- have quantities that allow ready, precise measurements.
Measuring digestibility in the gut
- types of markers commonly used

- **Solid-phase markers:**
  - Chromic Oxide (Cr$_2$O$_3$): commonly 0.2-0.5% of the diet. Fairly easy to determine.
  - Acid-insoluble ash (SiO$_2$): very common for monogastric studies. 1-2% in the diet. Easy to determine;
  - Long-chain hydrocarbons: excellent markers. 0.02% in the diets. Easy to determine.
  - Titanium dioxide (TiO$_2$): Easy to determine.

- **Liquid phase markers:**
  - Polyethylene glycol (PEG): Easy to determine. Affected by feed components.
  - Cr-EDTA: Widely used soluble marker.
Measuring digestibility in the gut

- Calculation

\[
D = 1 - \left( \frac{\% \text{ Nutrient in Digesta}}{\% \text{ Marker in Digesta}} \right) \div \left( \frac{\% \text{ Nutrient in Diet}}{\% \text{ Marker in Diet}} \right)
\]

\[
D = \text{digestibility coefficient}
\]
Measuring digestibility in the gut
- Advantages and disadvantages

- To obtain digestibility in specific parts of the gut and without hindgut microbial interference;
- For total tract digestibility trials, do not need to collect all the excreta;
- Marker separation in solid and liquid phases can lead to erroneous digestibility values;
- Some markers themselves can be hazardous to handle.
Bioassays

- True digestibility

True digestibility takes into account of:

- Endogenous losses of nutrients
- Microbial interference with measurement.

Used for energy and amino acids.
True digestibility
- Techniques used

- **Nitrogen-free diet:** Use fasted animals. Not physiological. Not very reliable.
- **Slope ratio assay:** Abnormal diets. Not widely used now.
- **Isotope markers:** Good, but expensive and tedious
- **Homoarginine method:** Good technique.
- **Peptide alimentation ultrafiltration technique (Hydrolysed casein technique):** Good technique.
True digestibility
- Advantages and disadvantages

- Consistent measures of nutrients truly digested;
- Values more accurate for least cost feed formulations;
- Values obtained on individual ingredients are not always additive when mixed together;
- Whatever is lost in the animal is charged against the producer, thus why bother?!
Bioassays

- Factors affecting digestibility

- Feed constituents
- Diet composition
- Animal factor (Species, physiological status, etc)
- Level of intake
- Age of the animal
Predicting nutritive value
Predicting Digestibility

- Near Infrared Reflectance Spectroscopy

- Simple, rapid and non-destructive technique;
- Popular in QC labs;
- Cannot be used for all nutrients;
- Limited to the chemical data on which it is calibrated.
Predicting Digestibility

- *In vitro* methods

- **Rationale:** to simulate digestion in a test tube;
- **Advantages:** cheap, rapid and do not use animals;
- **Disadvantages:** limited accuracy and reliability depending on the type of nutrient to be predicted, conditions *in vitro* vs *in vivo*.
Predicting Digestibility

- Summary

- Assays such as NIR and Available Lysine Assay are widely used, but not for feed formulations;

- Nutritive value is not a sole characteristic of the feed. Therefore a prediction equation must take into account both the animal and the feed factors.
Part 4

Nutritive value of individual ingredients
Ingredient Classification

Feed ingredients fall into the following categories:

- **Energy sources**: cereal grains; fats and oils, isolated starch;
- **Protein sources**: grain legumes and oilseeds, animal by-products such as meat and bone meal, offal meal, etc;
- **Mineral sources**: Minerals such as limestone, marine by-products, e.g., oyster shell, animal by-products, bone meal, etc.
Individual Ingredients:
- cereal grains

- Mainly used as energy sources;
- Nutritive value of the same cereal can differ widely in different animals;
- Used for both ruminants and monogastrics.
## Cereal grains

- Nutrient composition

<table>
<thead>
<tr>
<th>Grain</th>
<th>Starch</th>
<th>Protein</th>
<th>Lipids</th>
<th>NSP</th>
<th>Minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>750</td>
<td>90</td>
<td>35</td>
<td>85</td>
<td>20</td>
</tr>
<tr>
<td>Sorghum</td>
<td>680</td>
<td>100</td>
<td>35</td>
<td>30</td>
<td>17</td>
</tr>
<tr>
<td>Wheat</td>
<td>650</td>
<td>130</td>
<td>25</td>
<td>100</td>
<td>20</td>
</tr>
<tr>
<td>Triticale</td>
<td>630</td>
<td>120</td>
<td>24</td>
<td>120</td>
<td>20</td>
</tr>
<tr>
<td>Barley</td>
<td>630</td>
<td>130</td>
<td>23</td>
<td>167</td>
<td>22</td>
</tr>
<tr>
<td>Oats</td>
<td>600</td>
<td>130</td>
<td>60</td>
<td>235</td>
<td>30</td>
</tr>
<tr>
<td>Rye</td>
<td>600</td>
<td>110</td>
<td>18</td>
<td>150</td>
<td>20</td>
</tr>
</tbody>
</table>
## Cereal grains

- Energy values (monogastrics)

<table>
<thead>
<tr>
<th>Cereals</th>
<th>ME (Mj/kg)</th>
<th>DE (Mj/kg)</th>
<th>Sol NSP (%)</th>
<th>Insol NSP (%)</th>
<th>Total NSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>16.2</td>
<td>16.6</td>
<td>0.4</td>
<td>9.5</td>
<td>9.9</td>
</tr>
<tr>
<td>Sorghum</td>
<td>15.6</td>
<td>16.0</td>
<td>0.2</td>
<td>5.2</td>
<td>5.4</td>
</tr>
<tr>
<td>Wheat</td>
<td>14.5</td>
<td>15.9</td>
<td>2.4</td>
<td>9.0</td>
<td>11.4</td>
</tr>
<tr>
<td>Triticale</td>
<td>13.8</td>
<td>15.8</td>
<td>2.0</td>
<td>13.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Barley</td>
<td>13.5</td>
<td>14.1</td>
<td>4.5</td>
<td>12.2</td>
<td>16.7</td>
</tr>
<tr>
<td>Rye</td>
<td>13.4</td>
<td>13.0</td>
<td>4.6</td>
<td>8.6</td>
<td>13.2</td>
</tr>
<tr>
<td>Oats</td>
<td>12.5</td>
<td>13.3</td>
<td>4.5</td>
<td>19.0</td>
<td>23.5</td>
</tr>
</tbody>
</table>
Cereal grains
- Corn and sorghum

- High in energy
- Low in NSP
- No limitation in inclusion levels
- Possible constraints:
  - Poor/average pelleting quality
  - Potential mycotoxin contamination
  - Skin/egg yolk colour
  - Some sorghums have high levels of tannins.
Cereal grains
- Wheat and triticale

- Highly variable in ME, especially at harvest
- Excellent pelleting quality
- Constraints:
  - Wet litter with some wheats due to elevated levels of soluble NSP
  - Beak impaction with birds
  - Increased dirty eggs in laying hens
  - <50% inclusion.
Cereal grains
- Barley, oats and rye

- Highly variable in quality
- High soluble NSP
- Poor pelleting quality
- Constraints:
  - Wet litter problem due to soluble NSPs
  - Beak impaction with birds
  - Increased dirty eggs in laying hens
  - <20% without enzymes for barley and oats
  - <10% without enzymes for rye.
Individual Ingredients
- grain legumes

- Monogastrics: Use mainly as protein sources;
- Ruminants: both protein and energy;
- High in anti-nutrients.
Individual Ingredients
- Soybean

- High in protein (48% or 44%) and essential amino acids;
- High in NSP;
- Possible anti-nutrients such as trypsin inhibitors, amylase inhibitors, phytate and saponin.
Individual Ingredients

- Field peas and faba beans

- High energy legumes containing starch and protein;
- Field peas contain saponins and tannins; faba beans contain tannins and vicine/convicine.
Individual Ingredients

- Lupins

- Two major types of lupins - sweet lupin (*angustifolius*) and white lupin (*albus*);
- High in NSP, low in sulphur amino acids;
- Presence of anti-nutritive factor: alkaloid.
- Angustifolius: <10% in poultry, <15% in pigs;
- Albus: <15% in poultry, not used in pigs.
## Differences between lupin species

<table>
<thead>
<tr>
<th>L. angustifolius</th>
<th>L. albus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein: 32%</td>
<td>Protein: 36%</td>
</tr>
<tr>
<td>Fat: 5.9%</td>
<td>Fat: 9.4%</td>
</tr>
<tr>
<td>NSP: 36%</td>
<td>NSP: 34%</td>
</tr>
<tr>
<td>Whole seed: 25% hull</td>
<td>Whole seed: 18% hull</td>
</tr>
<tr>
<td>AME: 10 MJ/KG DM</td>
<td>AME: 13.2 MJ/kg DM</td>
</tr>
<tr>
<td>Australian origin</td>
<td>European origin</td>
</tr>
<tr>
<td>90% of lupin production</td>
<td>not accepted by pigs</td>
</tr>
</tbody>
</table>
Individual Ingredients

- Canola

- 36-38 % protein; gaining popularity;
- Levels up to 8% in poultry diets; 10% in pig diets;
- Possible constraints:
  - Anti-nutrient glucosinolate;
  - Dark colour on egg yolk colour;
  - Fishy taint in eggs;
  - Unidentified factors for turkey and breeders.
Individual Ingredients

- Cottonseed

- 40-41% protein; not usually used for poultry;

- Constraints:
  - high in fibre (unless decorticated)
  - anti-nutrient gossypol
  - poor lysine availability
  - yolk discoloration.
Individual Ingredients
- Sunflower and safflower

- 42-44% protein;
- Safflower is a hybrid between sunflower and saffron (a wildflower used widely in Eastern medicine);
- High in fibre and low in energy;
- Poor lysine availability.
### Levels of NSP present in legumes (%)

<table>
<thead>
<tr>
<th>Legume</th>
<th>Soluble</th>
<th>Insoluble</th>
<th>Total</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean</td>
<td>2.7</td>
<td>16.5</td>
<td>19.2</td>
<td>Irish and Balnave, 93</td>
</tr>
<tr>
<td>Canola (defatted)</td>
<td>3.2</td>
<td>10.9</td>
<td>14.1</td>
<td>Slominski et al. 94</td>
</tr>
<tr>
<td>L. angustifolius</td>
<td>3.1</td>
<td>33.4</td>
<td>36.5</td>
<td>Kocher, unpublished</td>
</tr>
<tr>
<td>L. albus</td>
<td>1.4</td>
<td>32.9</td>
<td>34.3</td>
<td>Kocher, unpublished</td>
</tr>
<tr>
<td>Sunflower</td>
<td>4.4</td>
<td>23.1</td>
<td>27.6</td>
<td>Irish and Balnave, 93</td>
</tr>
<tr>
<td>Pea</td>
<td>2.5</td>
<td>32.2</td>
<td>34.7</td>
<td>Graham and Aman, 87</td>
</tr>
<tr>
<td>Sorghum</td>
<td>0.6</td>
<td>6.3</td>
<td>7.0</td>
<td>Kocher, unpublished</td>
</tr>
</tbody>
</table>
Individual Ingredients
- Roots and tubers

- Roots and tubers are produced in large quantities - 710 million tonnes in 2004;
- Important feed sources for both ruminants and monogastrics.
By-products

- Crop by-products: high in NSP (fibre), vitamins, minerals, lipids. Widely used.
- Animal by-products: high in amino acids and minerals. Widely used in feed industry.
Crop by-products

- Commonly available cereal by-products include: millrun (mixture of bran, shorts and screening from wheat), rice pollard/bran;
- All high in fibre and low in energy. Levels up to 10% used in pig and poultry diets.
Animal by-products

- Animal by-products are generally high in protein.
- Commonly used ones include:
  - Meat meal*, meat and bone meal, fish meal, feather meal, poultry by-product meal, blood meal, dried whey, casein.
- Constraints: variable protein levels, disease issues, biogenic amines, rancidity.

* Not permitted for ruminant feeding
Animal by-products
- Fats and oils

- Fats and oils of animal origin:
  - Tallow and lard: high in saturates; poorly used by young birds;
  - Fish oil: possible promotion of lean growth; fishy taint problem in laying hens.

- Fats and oils of plant origin:
  - Vegetable oil: high in unsaturates; rancidity problem;
  - Coconut oil: high in saturates; 50% <C12:0; poorly digested;
  - Palm oil: High in saturates; variable; poorly digested.
Alternatives to Antibiotics

Compiled by: Mingan Choct
Modified by: Paul A. Iji
Why Use Antibiotics in Feed?

- Treat sick animals.
- Promote growth and feed efficiency.
- Australia imports 700t antibiotics, 2/3 goes to feed for prophylactic purpose.
- 72% of the time antibiotics improved growth and feed efficiency over the past 50 years (Rosen, 1997).
Why withdraw antibiotics then?

Antibiotics selectively eliminate bacteria.

Persistent, long term use will lead to some microbes developing resistance.
The Emergence of “Superbugs”

http://www.hhmi.org/grants/lectures/biointeractive/Antibiotics_Attack/r_3a.html
Evidence of Resistance

- Who is to blame? The livestock industry or the hospitals?
The European Ban

- Sweden banned AGP in 1986.
- EU banned virginiamycin, spiramycin, tylosin, and zinc bacitracin in 1999. Most European countries are now AGP free. Currently only two AGP’s are allowed (avilamycin and salinomycin?)
- Avoparcin and other glycopeptides were withdrawn from the market in Australia in 1999.
- An increasing number of countries demanding meat imports that have not had AGP at least for the finisher period.
The cost of the ban

- Cost of pig production up 8-15%, feed up US$9.5-12.5/t in EU (Best, 1997).
- A similar ban in the US would cost US$1.2-2.5 billion/yr (NRC Committee).
The reason for high costs

- Increased mortality and morbidity of animals, plus loss in FCR.
- Better, low density housing.
- Extra labour for more meticulous management of feeding, manure, and day to day care.
- In pigs, increase in weaning age.
The Focus of the Research

Gut microflora

The Good

Bifidobacteria
Lactobacilli

The Bad

Salmonella
Campylobacter
E.Coli

Poor Health
and Disease

Normal and
Healthy
Factors affecting gut microbial balance

- Approximately 60% of pig and poultry excreta is made up of microbial mass.
- CHO reaching the large intestine determine the type and activity of the gut microflora.
- Environment: high pathogen load.
- Stress: change of sheds, diet, misformulation of diet, poor management.
- Diet: anti-nutrients and NSP, storage problems, etc.
The Alternatives

Overview
Alternatives to AGP

- Organic acids
- Competitive exclusion
- Enzymes
- Immunostimulants
- Herbs, spices, essential oils
- Minerals
- Plasma products
- Milk products
- Prebiotics (oligosaccharides)
- Probiotics
- Synbiotics (Prebiotics + Probiotics)
- Siliceous earths
- Fermented liquid feeds
- Lectins
- Dietary fibre/protein sources
- Management
- Etc
The Alternatives

Organic Acids
The use

- To increase gut acidity to control proliferation of harmful bugs.
- Formic and propionic acids are commonly used in the pig and poultry industries, especially in Europe.
Mechanism of Action

- Effective in pigs, not obvious in poultry.
- $\text{RCOOH}$ exists as $\text{RCOO}^- + \text{H}^+$
- Inside bacterial cells, $\text{H}^+$ lowers pH, disturbs the acid base balance, causing the organism to waste energy for restoring pH balance, $\text{RCOO}^-$ disrupts DNA and protein synthesis.

$\downarrow$

Decreased replication.
How do organic acids exert their effects?

Acids pass into bacterial cells, dissociate into $H^+$ and $RCOO^-$, which limit replication and disrupt DNA and protein synthesis.

$H^+$ becomes high, pH lowers, cells lyse, or unable to replicate rapidly.
How effective are organic acids?

- In pigs, usually quite effective, reducing scours and increasing performance.
- Effects in poultry have been highly variable.
- Some logistical problems must be considered such as erosion of equipment, silos, feed troughs, etc.
### Effect of organic acids: example

*(Quoted by Collette and Dawson, 2001)*.

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</table>
The Alternatives

Probiotics
Definition of Probiotics

- Live organisms to replace depleted gut microflora to benefit the host;
- Defined and undefined cultures: microbial types and numbers are “known” vs. only the effects are known.
Probiotics

- Also known as direct-fed microbials.
- Two types: defined and non-defined.
- Competitive exclusion.
The Alternatives

Prebiotics
Prebiotics

- Substances that encourage development of microflora beneficial to the host.
- Fructo-oligosaccharides: encourage growth of *lactobacillus*, *bifidobacterium*, thus suppress growth of *salmonella*?
- Manno-oligosaccharides: adsorb enteric pathogens; immunomodulation?
Oligosaccharides:
- Prebiotic effect

Ability of mannan to displace E.Coli from epithelial cells (Ofek and Beacheyk, 1987).
Oligosaccharides:
- Prebiotic effect

The Alternatives

Enzymes
Enzymes are Biocatalysts

Enzyme + Substrate → Reaction Complex → Product A + Product B
Enzymes to Substrates are like Keys to Locks

Substrates:
Specific molecules, e.g., cellulose, arabinoxylan, amylose, trypsin, Phytic acid, etc.
Use and Definition

- Enzymes are commonly used in monogastric feeds, i.e., >95% broilers and >60% layers, >50% pigs;
- Enzymes are produced from microbes, e.g., bacteria and fungi or GMO (genetically modified microorganisms). Enzyme premixes for a tonne of feed $3-5 depending on the manufacturers.
Type of Enzymes

- Commonly used enzymes:
  Carbohydrases (xylanase, β-glucanase, cellulase, amylase, pectinase etc.);
  Phytase and protease.

- Used predominantly for monogastric feeds.
How Produced?

- Glycanase = carbohydrazes; include xylanase, beta-glucanase, cellulase, pectinase and amylase;
- All enzymes are produced from thermostable microbial sources and can stand up to at least 85°C and some up to 100°C.
Enzymes on dry matter digestibility - example

- Maize control
- Low-ME wheat
- Low-ME + E
- Normal wheat
- Normal + E

%
NSP and Enzymes on AME of Broiler Diets

Control NSP NSP+E

MJ/kg dry matter

9 11 13 15

Control NSP NSP+E

*
Increased precision and flexibility in least-cost feed formulation - Barley

Kocher, Hughes and Bar (1996)

AME in MJ/kg DM

with Enzyme

without Enzyme

Barley variety

Skiff, Chebec, Mundah, Franklin, Schooner, Yagan, Forrest, Arapilies, WI2868, QLD TG, WI2875
Feed Enzymes:

- phytase data

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<td>52.4</td>
<td>26.5</td>
<td>25.3</td>
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Release of Oligomers in Chickens

Release of free sugars in birds fed wheat based diets with xylanase
Avoparcin or xylanase on some microbes inhabiting the small intestine of 21-d old broilers (Bedford and Apajalahti, 2001)
Effect of NSP:

Interaction with gut microflora

NSP characteristic and caecal *C. perfringens* in broilers fed high NSP wheat +/- xylanase.

Summary

- We can only find “alternatives” to antibiotics in terms of certain effects of AGPs.
- These alternatives should be: **SEEC** (safe, effective, easy, cheap to use).
- There are promising alternatives, but change in management practice is imperative for a successful post AGP era.
End