Energy...

Energy

I. Definition

A. The energy content of feedstuffs

1. **In animal nutrition, we are interested in the chemical (molecular) energy of feedstuffs**
2. **Heat energy can be determined by bomb calorimetry**
3. **One calorie raises the temperature of 1 g of water 1°C (i.e., 14.5 to 15.5 °C); a kilo-calorie (kcal) raises 1000 g or water 1 °C**

Bomb calorimetry

Energy

- IUPAC has adopted the Joule:
  1 Joule is 107 ergs (0.239 calories),
  and 1 kcal = 4.185 kJoules
- In nonruminant diet formulation, we will deal largely with the kcal
- In ruminant nutrition, we will deal primarily with the Mcal

Energy

II. From gross energy to net energy

A. All materials containing carbon and hydrogen that can be oxidized to CO_2 and water represent *potential energy* for animals. We refer to this energy value as the gross energy content of a feedstuff.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6H_2O + 686 \text{ kcal/mole (heat)}$$

B. Not all of the gross energy is available to the animal for use.

Energy...

Gross Energy
in feed consumed

Fecal energy — **Digestible energy**

Urinary energy — **Metabolizable energy**

Heat of nutrient metabolism — **Net energy**

Maintenance
a. Basal metabolism
b. involuntary activity
c. Body heat (warmth)
d. Heat loss (cooling)

Production
a. Tissue growth
b. Reproduction
c. Eggs
d. Milk
e. Work

Nutrient Requirements

→ Digestibility:

$$\frac{(\text{input} - \textit{fecal}\ \text{output})}{\text{input}} \times 100\%$$

Energy

C. The chemical composition of ingredients dictate the digestible and metabolizable energy content of a feed.

1. Carbohydrates
   a. Monosaccharides, disaccharides, polysaccharides
   b. Cellulose, hemicellulose
   c. Lignin
2. Fats
   a. Degree of saturation
   b. Mono, di and triglycerides; fatty acid location on the glycerol backbone
3. Amino Acids (glucogenic and ketogenic)

Energy

D. Carbohydrates as Energy Sources

1. Polysaccharides from cereal grains, and grain products such as wheat middlings

   A. Starch: amylose (straight chain polymer) and amylopectin (branched chain polymer)

   B. Nonstarch polysaccharides (NSP) (Fiber): cellulose, hemicellulose, lignin. Much of the dietary fiber is indigestible.

Energy

2. Starch Digestion

   A. Enzyme dependent: metabolic pathways utilize monosaccharides to generate ATP

   1. Amylase (salivary, pancreatic)
   2. Oligo-1,6-glucosidase
   3. Disaccharidases
      a. lactase: glucose and galactose
      b. maltase: glucose and glucose
      c. sucrase: glucose and fructose

Digestive enzymes convert complex CHO into monosaccharides that can be metabolized by the animal to generate chemical energy.

Amylose:
- •Soluble in hot water
- •Glucose units linked through α-1-4 linkages; straight chain

Amylose is digested by **salivary and pancreatic amylase** to yield the disaccharide, maltose.

Maltose is digested by **maltase** (α-glucosidase) into the individual glucose units that are readily absorbed by the intestinal epithelial cell.

Digestive enzymes convert complex CHO into monosaccharides that can be metabolized by the animal to generate chemical energy.

Amylopectin:
- •Insoluble in hot water
- •Glucose units linked through α-1-4 linkages; but, contains branches due to α-1-6 linkages.

The α-1-6 linkages are digested by **intestinal** oligo -1,6-glucosidase to yield simple glucose for absorption.

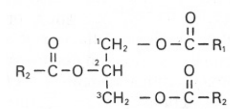
Energy

E. Lipids (Fats and Oils) as Energy Sources

1. Fats: choice white grease, animal fat, beef tallow, lard, restaurant grease, vegetable oils

   a. Digestion and absorption are critical
      1. *Lingual* lipase
      2. Triglycerides are emulsified by *bile salts* and then attacked by *pancreatic* lipase.
      3. Products are free fatty acids and monoacylglycerol.

Dietary fats contain glycerides and free fatty acids.



TRI	DI	DI	MONO
^{1}C-FA FA-^{2}C ^{3}C-FA	C- FA-C C-FA	C-FA FA-C C-	C- FA-C C-

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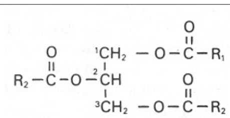
Pancreatic lipase is specific for the 1 and 3 positions of the triglyceride, and results in a <u>2</u>-monoacyl glycerol + free fatty acids.



^{1}C-FA
FA-^{2}C $\xrightarrow{\text{Lipase}}$ C- / FA-C / C- + 2 FA
^{3}C-FA

TRI MONO

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TRI MONO

If the FA at positions 1/3 are <u>saturated</u>, the ME value of the fat is lower because saturated FA are less readily absorbed than unsaturated FA, and unsaturated FA are more readily absorbed as the 2-monoacylglycerol.

Lard

^{1}C-FA(unsaturated)
FA-^{2}C
^{3}C-FA(unsaturated)

Absorbability: 92%

Beef Tallow

^{1}C-FA(saturated)
FA-^{2}C
^{3}C-FA(saturated)

Absorbability: 70%

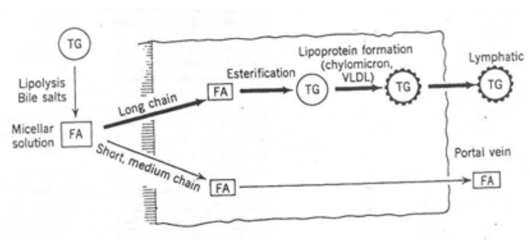
Energy

4. Fatty acids and monoacylglycerol are incorporated into *micelles*

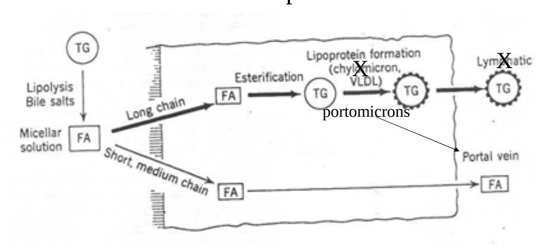
5. *Micelles are passively absorbed*

6. Passage to *lymphatic system* (triglycerides) or the *portal blood* (medium and short chain fatty acids.

Mammals



Avian Species



Energy

b. Absorption of fats depends on:

1. Chain length
2. Degree of saturation
3. Arrangement of saturated and unsaturated fatty acids on the glycerol molecule.

Energy

III. Dietary fatty acid profiles influence metabolic events

A. Fatty acids from dietary fats/oils are incorporated into cellular lipids.

1. Fatty acids are incorporated into cells and tissues.

Feeding linoleic acid will load tissues with linoleic acid.

Energy

Soybean oil is high in linoleic acid...

Fat Source[1]	Diet[2]	Adipose Tissue[2]	Skeletal Muscle[2]
Beef Tallow	11.71	9.06	10.47
Fish Oil	14.85	9.37	7.08
Soybean Oil	69.45	46.58	32.00

1 Each diet contained 10% of the indicated fat source.
2 Linoleic acid as a percentage of the total fatty acid content in the diets and tissues.

Energy

Fish oil is high in omega-3 fatty acids...

Fat Source[1]	Diet[2]	Adipose Tissue[2]	Skeletal Muscle[2]
Beef Tallow	< 0.10	< 0.10	< 0.10
Soybean Oil	< 0.10	< 0.10	< 0.10
Fish Oil	6.90	3.46	4.55

1 Each diet contained 10% of the indicated fat source.
2 Eicosapentaenoic acid as a percentage of the total fatty acid content in the diets and tissues.

What about beef tallow and stearic acid (18:0)?

Fat Source[1]	Diet[2]	Adipose Tissue[2]	Skeletal Muscle[2]
Beef Tallow	17.09	11.31	11.16
Soybean Oil	2.92	8.43	11.22
Fish Oil	3.81	11.07	11.39

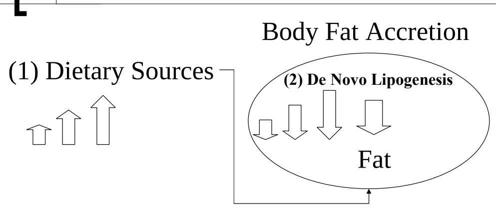
1 Each diet contained 10% of the indicated fat source.
2 Stearic acid as a percentage of the total fatty acid content in the diets and tissues.

Energy

III. Dietary fatty acid profiles influence metabolic events

A. Fatty acids from dietary fats/oils are incorporated into cellular lipids.

B. Feeding dietary fat diminishes the need for lipogenesis, in vivo.



Because dietary fatty acids are incorporated into tissues, and because dietary fat reduces the need for de novo lipogenesis, the fatty acid profiles of cells/tissues can be modified.

Energy

III. Dietary fatty acid profiles influence metabolic events

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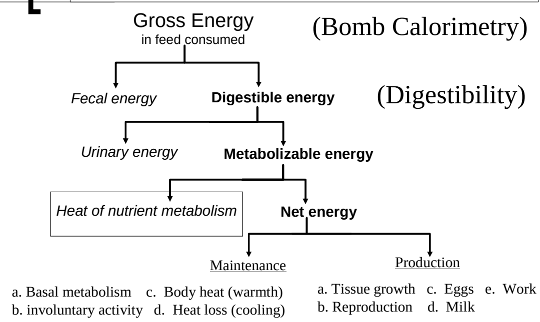
B. Feeding dietary fat diminishes the need for lipogenesis, in vivo.

C. Why important?

1. Meat quality
    a. Body composition
    b. Cutability
    c. “Off flavors”
    d. Shelf life
2. Consumer Appeal
    a. heart healthy eggs, meat
3. Therapeutic nutritional intervention
4. Energetic efficiency

Energy



IV. The Heat Increment and Fat

A. An energy (heat) loss to the animal, but NOT a waste.
1. Can be used for maintenance heat.
2. Fats have a lower heat increment
    a. Substitution of fat for CHO increases gain and efficiency

IV. The Heat Increment and Fat

A. An energy (heat) loss to the animal, but NOT a waste.
1. Can be used for maintenance heat.
2. Fats have a lower heat increment
    a. Substitution of fat for CHO increases gain and efficiency
3. May improve overall energy intake during periods of heat stress.

V. The Extra-caloric Effect of Fat

A. Fat slows the passage rate of digesta.
1. Digestibility of other nutrients increased.
    a. proteins/amino acids

Dietary Fat: 3.2 to 12.2%

Ileal Digestibility: 80.7 to 83.3%