Introduction to Nutrition

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Intended learning outcomes

At the end of this session you should be able to:

- Identify the different types of feed, & their source, required by different animal species, in order to compare their importance in diets for different animals.
- Compare & contrast the nutritional requirements & methods of obtaining nutrients from feed of herbivores, carnivores, & omnivores; in order to assess the appropriateness of different diets and feedstuffs for different groups of animals.

Keywords

Nutrition, Nutrient, Digestion, Feed, Ruminant, Carnivore, Omnivore, Herbivore

Part 1: Feed function, constituents and sources

Definitions

Nutrition: the science of feeds as they relate to the requirements, production and health of animals (and people!)

Feed: a substance fed to animals to sustain them (e.g. wheat, raw bones)

Feedstuff: any product (natural or artificial) with nutritional value when properly prepared (e.g. vitamin A)

Nutrients: the portions of feeds that animals can use when made available (usually after digestion) to their cells, organs & tissues. Nutrients include carbohydrates (simple to complex saccharide molecules), amino acids, fats, fibre (polysaccharides like cellulose that are components of plant cell walls, indigestible to mammalian enzymes), minerals & vitamins; although not strictly a nutrient, do not forget that feeds also contain water in variable quantities (little to lots)

(Nutritional) Quality: how well a feed meets animal requirements due to the amount of nutrients it contains or how well the relative nutrient proportions in it match up with animal requirements.

Ration: a combination of feedstuffs prepared by humans and fed to animals. Rations and foods may supply all or only some of an animal's dietary needs, in which case they are termed **complete/full/total or incomplete**, respectively.

As the old saying goes, we (and all other animals) are what we eat! Nutrition is fundamental to animal well-being. An understanding of animal nutrition is vital to maintaining animal health and correcting nutritional diseases. In a world of every-increasing competition for resources, as we use animals for food, fibre and work, nutrients must be utilised efficiently if we are to live sustainably and farms are to remain economically viable.

Feed types & sources for animals

Animals have evolved to have different nutritional requirements according to the ecological niche they occupy. Food universally provides nutrients that are:

- building blocks for body tissues
- burnt to provide energy
- essential components to bodily functions, e.g. vitamins, enzymes and hormones

To achieve these three functions, we are interested in feeds' content of some basic things, namely:

- energy, which can be derived from carbohydrates, fats & amino acids
- protein (from amino acids)
- vitamins & minerals
- water

These functional components of feeds are discussed in much greater detail in later lectures.

The components of feeds are classified in slightly different ways according to the animal species in question, but we can still use a rough overall classification, based on the feedstuff source, that also helps identify the nutrients therein.

1. **Meat & fish** are animal tissues, from muscles ('meat') to organs ('offal'); good providers of protein and energy (metabolised from fats and/or protein).

2. **Dairy & eggs** generally contain higher quality protein than meats, suitable for nourishing the growing animals they were evolved to feed.

    Because they are derived from animals, meats, dairy products and eggs often contain nutrients in roughly the correct proportions required by animals and are easily digested. Animal tissues are also nutrient-dense.

3. **Cereals & vegetables** are derived from plants and can be further subdivided into:

a) **Forages**: fresh, dried or ensiled[1] vegetable matter, such as grass. They tend to be bulky, have a high fibre, low energy but variable protein content, and are harder to digest. Forages include

pasture, hay and silage/haylage. Herbivores have evolved mechanisms to obtain more nutrients from forages than omnivores or carnivores, especially utilising plant structural carbohydrates as an energy source.

b) **Concentrates** have a higher energy (from digestible starches), relatively low fibre, and variable protein content. They include cereal grains (e.g. wheat, corn), and high-protein or -nitrogen concentrates (e.g. lucerne hay, nuts).

4. **Fats & oils** can be derived from vegetable (e.g. oil seeds such as canola) or animal sources. They are energy dense, containing about twice the energy of concentrates.

As alluded to above, we can classify animals according to their principal feed source too. Many animals overlap categories more than we might think. **Carnivores** eat meat and other animal tissues. Obligate carnivores are dependent on certain nutrients only present in animal tissues, such as essential amino acids, fatty acids or vitamins. **Herbivores** consume plants (but can or have been fed animal-derived products at times) and omnivores naturally consume a bit of both (e.g. pigs, chickens, humans, dogs). Further specialisations can be described. For example, birds might be seed-eaters (e.g. finches, canaries, parakeets, many parrots), nectar-drinkers (e.g. lorikeets; also some marsupials) or insectivores.

An animal's environment also affects its nutrition, especially for domesticated species. Animals in artificial or highly controlled environments might have all their food manufactured and/or supplied by humans (e.g. the carnivorous cat eating tinned cat food, the housed dairy cow or the zoo elephant). Animals, such as grazing livestock, may eat their own food directly from the environment, which might vary from a human-sown, mono-species 'improved' pasture grazed for precise amounts of time at specific stocking densities, to opportunistic grazing of native scrubland (although it might not be native for the animal!). Humans might provide specific nutritional supplements to correct deficiencies (e.g. a slow-release selenium injection or a high-protein feed to meet growing animals' needs). At the far end of the scale, an animal may be largely at the nutritional mercy of nature (e.g. wild animals or the livestock owned by nomads).

Part 2: Pasture, forages and concentrates

- Plants and pastures (either cultivated or uncultivated) provide energy, fibre and protein.

An ideal pasture is:

- Nutritious
- Meets nutritional requirements year round (there may be large seasonal variation)
- Persists under grazing and out-competes weeds
- Maintains ground cover (prevents erosion)
- Doesn't cause health problems

Forage:

- The plant components
- Fresh; preserved (e.g. ensiled); dry (e.g. hay)
- High in fibre; lower in energy; variable protein

Concentrates (the seeds and fruits from plants and pastures - concentrated energy):

- Seeds and/or fruits – cereal grains such as wheat, barley, oats, rye, triticale, corn, legume grains (lupins, peas, beans)
- High in energy; lower in fibre; variable protein

Part 3: Feed utilisation by animals

The previous section showed us there is a very wide variety of foods available to animals. Somehow these must be obtained by the animal and broken down ('digested') to small enough components for absorption and utilisation within the body. Animals have specialisations from nose to tail that help them do this; conversely, these specialisations and evolutionary adaptations to plentiful and limiting dietary components dictate an animals' feed requirements. This is covered in much more detail in anatomy & physiology subjects.

The gastrointestinal tract obviously plays a central role in nutrition:

The mouth is important for collecting food (think of a giraffe with a prehensile tongue that lets it browse the highest tree branches or a hyena's teeth that can crush bones to extract the marrow) and breaking it down mechanically. Carnivores' teeth are adapted to piercing skin, and tearing and cutting flesh, whereas herbivores have nibbling and cropping teeth suited to *harvesting* food over a wide area or a long time, and grinding down tough, fibrous forages. Omnivores have teeth that are a combination of both!

Specialist seed-eating birds have beaks suited to cracking and piercing seeds; of course beaks may also be adapted to tearing and ripping (raptors), sieving (spoonbills), trapping (pelicans), piercing (herons) or sipping (hummingbirds) — the list goes on. Birds, having no teeth, may grind food lower down the digestive tract in the ventriculus or 'gizzard'. This is the lower, muscular part of the stomach and often contains stones or grit swallowed by the bird that help with the grinding.

Arguably, even greater differences exist between carnivores, omnivores and herbivores in the stomach and lower parts of the gut. The stomach stores, mixes, and mechanically and chemically breaks down food. Monogastric (*mono*: one; *gastric*: of the stomach) animals have stomachs with a single compartment. Monogastrics include carnivores, omnivores and herbivores. The stomach empties into the small intestine, where chemical breakdown and nutrient absorption occurs. Further down, the large intestine helps regulate water and mineral absorption, and passes waste. It is also a site of digestion, although this is performed by bacteria that possess enzymes for breaking down nutrients indigestible by mammals themselves.

Herbivores invariably have a larger fore - or hindgut (before or somewhere after the stomach, respectively) than carnivores or omnivores. As discussed previously, the high fibre content of plant material makes it bulky and more must be consumed to achieve the same energy intake. Fibre is also much slower to digest than other nutrients.

Thus, a herbivore's gut must provide room and time for digestion. Although mammals cannot digest many of the components of plant cell walls, such as cellulose and pectin, many bacteria, protozoa and fungi can. Herbivores' specialised gut compartments house billions of these microorganisms and act as a 'fermentation vat' for microbial digestion of plants; the bugs get a home and the host gets the nutrients.

Foregut fermenters include the even-toed ungulates[1] (Order *Artiodactyla*;), as well as other, unrelated species (e.g. kangaroos). Artiodactyls include a very diverse range of **ruminant** (cattle, sheep, goats, deer, giraffes, antelopes) and **pseudoruminant** (camels, alpacas, llamas, etc) species. The non-secretory part of the stomach is greatly enlarged into two (camelids) or three (true ruminants have a *reticulum, rumen & omasum*) compartments where storage, mixing & bacterial fermentation occur. The last (i.e., third or fourth) stomach is equivalent to the normal, glandular stomach in monogastrics. These animals *ruminate*, or chew their food 'over again'. The bit chewed over again is the *cud*, which is ingested food regurgitated from the forestomachs[2]. Note that other forestomach fermenters like kangaroos don't ruminate.

Ruminants are very well suited to eating low-quality forages containing large amounts of fibre that cannot be directly digested by mammals or low-quality protein. Microbial fermentation of fibre in the rumen produces chemicals such as organic volatile fatty acids that the animal uses for energy. Additionally, microbes convert low-quality plant protein into high-quality microbial protein by digesting protein right down to nitrogen compounds that they then rebuild into the amino acids they (and, incidentally, the host) need. In fact, rumen microbes can utilise non-protein nitrogen-containing chemicals in the diet, such as urea, to create proteins where none existed in the diet. Much of the protein a ruminant actually absorbs is in the microbes flowing out of the forestomachs to be digested as if the animal had eaten it directly. Conversely, foregut fermenters are relatively inefficient utilisers of higher quality feeds, because nutrients are invariably wasted feeding the microbes in the rumen before the host.

Hindgut fermenters include the odd-toed ungulates (Order *Perissodactyla*, containing horses, tapirs and rhinos) and other species such as elephants. Bacterial fermentation of plant matter occurs in a greatly enlarged colon (large intestine) and caecum, from which volatile fatty acids are absorbed for energy. Because fermentation occurs below the true stomach and small intestine, where most host digestion and absorption occurs, microbial protein is lost to the host. Hindgut fermenters often make up for poorer digestion by eating large amounts of food and having high throughput through the gut. They also utilise higher quality feed more efficiently. This seems to have favoured their evolution to larger body sizes than the foregut fermenters. However, despite their smaller size, there are more than 50 genera of ruminant alive today; of the 158 known genera of perissodactyles, only six remain.

Carnivores do not require these adaptations to facilitate digestion of their animal-derived feeds and thus have much simpler, shorter guts. However, many omnivores have digestive tracts intermediate between carnivores and herbivores. For example, pigs have an enlarged hindgut and also a relatively large non-secretory section to their single stomach.

1 ungula = 'hoof'

2 Ruminating permits further mechanical digestion of food and is possible if the animal has enlarged stomachs. Imagine a hindgut fermenter trying to belch the contents of its large intestine the whole way back up its digestive tract. To increase their digestive efficiency, some hindgut fermenters like rabbits eat some of their own faeces instead.

Further Reading

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