NUTRITIONAL REQUIREMENTS OF JUVENILE MARSUPIALS

Gordon Rich

Wombaroo Food Products

10 Oborn Rd, Mount Barker, SA 5251

Email: wombaroo@adelaide.on.net

ABOUT MARSUPIAL MILK

Mother's milk provides the essential nutrients for the growth and development of juvenile marsupials. Information on the nutritional composition of milks from a range of different species is now available from both published data as well as private research undertaken by Wombaroo. This research shows that marsupial milk undergoes significant changes in composition (fat, protein & carbohydrate) over the period of lactation, as demonstrated for macropods in Figure 1.

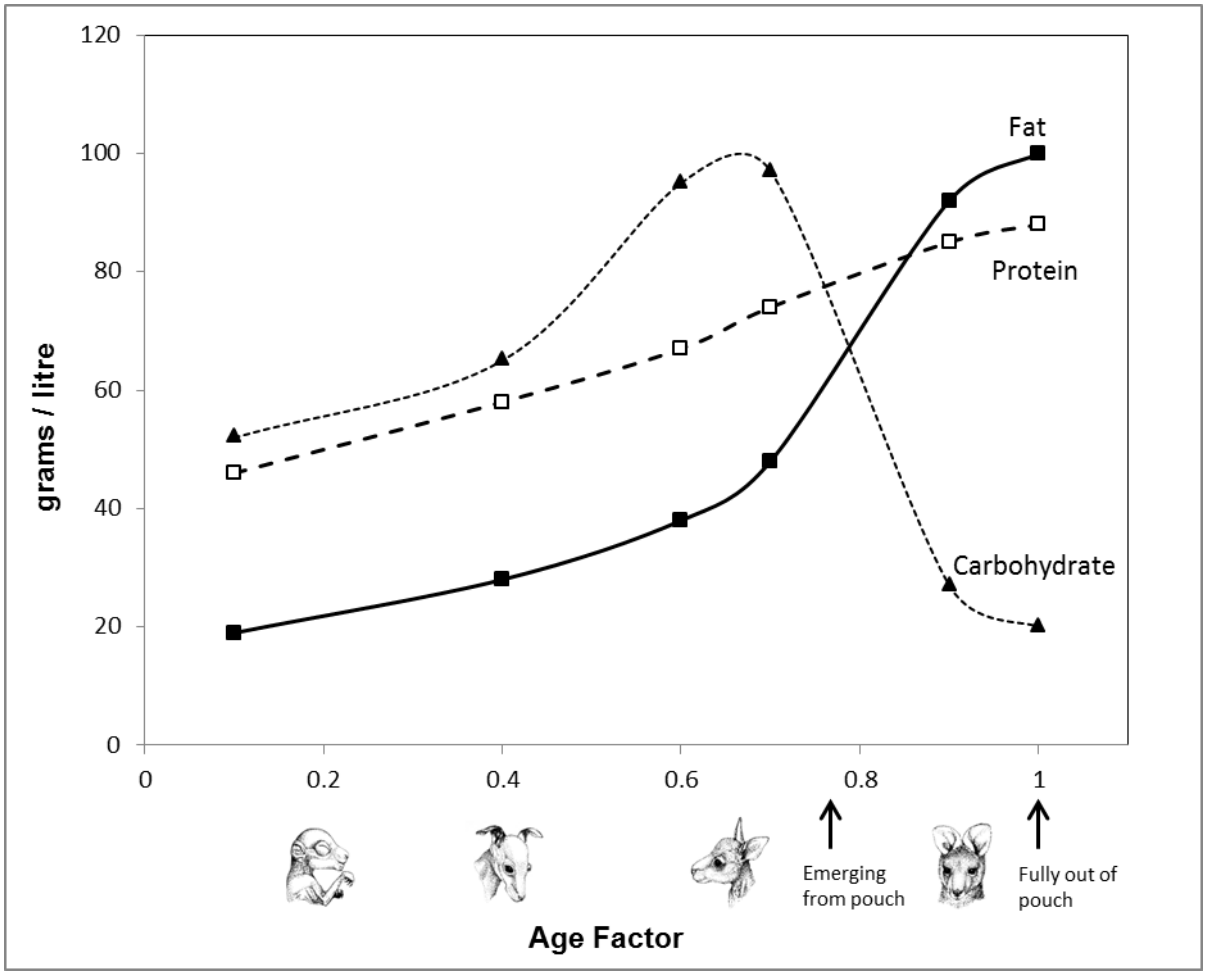

Figure 1. Changes in milk composition with age for a typical macropod joey.

These changes in milk composition cater for the widely differing nutritional requirements of the developing joey from furless “pinkie” to fully out-of-pouch. For example, early lactation macropods obtain much of their energy from carbohydrate and cannot tolerate high fat levels. However later in lactation this situation is reversed, with milk becoming heavily concentrated with fat. Since fat contains about twice the kilojoules per gram than does carbohydrate, the later lactation milk provides much higher levels of energy to the active out-of-pouch joey.

Even within the broad nutrient categories of fat, protein & carbohydrate there are also significant variation in the make-up of these components over the course of lactation. For example the fat in early lactation milk is rich in saturated palmitic acid, whereas in later lactation there are higher levels of mono-unsaturated oleic acid[4]. Protein content also varies between whey and casein fractions, with levels of specific proteins changing according to functional requirements such as establishment of immune system (*immunoglobulins*), hair growth (*cysteine*) and facilitation of iron transport (*transferrin*). Carbohydrates are mainly composed of galacto-oligosaccharides in early lactation, but these virtually disappear later on when there is a loss of the galactose-metabolising enzymes in the gut[5]. Lactose is only a minor carbohydrate constituent (<3% of volume) and is not well tolerated at higher levels[6].

The changes in nutrient composition observed in marsupial milk explain why a single artificial milk formula is not ideal for hand rearing any marsupial. Figure 1 shows the milk composition for a “model” macropod joey – this is pooled data from a number of different species ranging in size from the Long-nosed Potoroo (*Potorous tridactylus*)[1] to the Red Kangaroo (*Macropus rufus*)[2]. It is important to note that the various families of marsupials (eg Possums, Wombats, Koalas, Dasyurids) show different compositional changes in their milk during lactation and therefore have different developmental models.

AGE FACTOR

It is useful to relate the stage of development of a joey to its Age Factor (AF), which is the age of a joey as a proportion of its total pouch life:

$$\text{Age Factor (AF)} = \frac{\text{Age of Joey}}{\text{Age when fully out of Pouch}}$$

For example a Grey Kangaroo is normally fully out of the pouch at about 310 days. Therefore a joey of this species at 155 days has an age factor of 155÷310 = 0.5 (or 50% of its pouch life). A joey at fully out of pouch age has completed 100% of its pouch life so it has an age factor of 1. By definition a joey that spends any time in the pouch has an age factor of less than 1. First pouch emergence begins for most macropods at an age factor of around 0.7 to 0.8.

The concept of Age Factor helps us standardize the nutritional requirements for joeys from the same family of species. Macropods develop at roughly the same rate when compared using Age Factor so that a Potoroo at 75 days, a Swamp Wallaby at 130 days, and a Grey Kangaroo at 155 days all have similar nutritional requirements (All have an Age Factor =0.5).

JOEY DEVELOPMENT WITH AGE

The physical changes in a developing joey occur at set times over the course of lactation. Developmental milestones such as eyes opening, first hair growth and complete emergence from the pouch can all therefore be related to the Age Factor. These stages of development have associated nutritional considerations which are outlined for a typical macropod in Table 1 below.

Table 1. Developmental milestones for macropods (reproduced in part with permission from Helen George)

Age Factor	Stage of Development	Nutritional Considerations
0 (birth)	Eyes closed; front legs developed; buds for hind legs.	Low energy milk, with a low fat content. Digestive system is not well developed - milk contains easily digested carbohydrates and proteins. Immunoglobulins to boost immune system. No gut flora
0.2	Eyes closed; ears folded flat on top of head; ear-canal closed; membrane joining lip; small hole at front of mouth for teat; hind legs formed.	
0.3	Membrane between lips has disappeared; whiskers growing. Runny yellow faeces.	
0.4	Eyes still closed; ears still flat but starting to become upright; animal fully formed; can see down ear canal; fully developed whiskers.	Steadily increasing energy content of milk. Protein contains sufficient levels of sulphur-containing amino acids (eg *cysteine & methionine*) for the onset of hair & claw growth. Still no gut flora.
0.5	Eyes now open; dark colouring on back of hands, bridge of nose, tips of ears; fur about to come through skin; poking head out from pouch occasionally; Faeces yellow custard to toothpaste consistency.	
0.56	Fur colour visible under skin on entire body; Fur forming on bridge of nose and head.	
0.6	Fur lengthening rapidly all over the body; fur appears last on belly/chest; leaning from mother's pouch and eating dirt to establish gut flora, starting to thermoregulate .Faeces darkening and forming.	Peak carbohydrate content in milk with high levels of associated digestive enzymes. Able to handle higher fat levels in milk.
0.7	Joey grazing from pouch making use of green feed; secondary coat appearing, the animal looks like a miniature adult. Faeces soft to firm green pellets.	High energy milk with a high fat content - coincides with increased activity levels of joey. Sharp fall in carbohydrate content of milk with decrease in associated gut enzymes. Increasing levels of "body-building" proteins (eg *caseins, α-globulins*) to coincide with peak growth rate. Gut flora developed for digestion of solid food.
0.8	Joey starting to emerge from the pouch; spends longer and longer periods outside the pouch; feeding, urinating, defecating outside the pouch	
0.9	First incisor teeth erupting through gum; full length fur growth	
1.00	Joey fully emerged from the pouch; still drinking milk; solid food plays a large part in the diet	

HAND REARING

When hand-rearing an orphaned marsupial it is important to mimic as closely as possible the nutrition received by a mother-reared animal. Getting the nutrition right is basically a 3-step process:

1. Determine the age of the joey
2. Select a suitable milk replacer for the age
3. Feed the correct volume based on the body weight of the joey

Age Determination

Accurate age determination allows the carer to provide correct nutrition for the stage of development. Joeys can be aged according to their physical characteristics (eg hair growth, body measurements, consistency of faeces). The developmental milestones outlined in Table 1 may be a useful guide for age determination. Typical growth charts are also available for a range of species which contain body measurement data which may help to estimate age. Body weight should not be used to estimate age as this can be misleading especially in mal-nourished, dehydrated or overweight individuals. There may also be regional differences in size or variations due to sex.

Milk Replacer

Wombaroo has recognized the importance of changing milk composition with age and has developed staged milk replacers for various species (Kangaroos, Wombats, Possums, Koala & Echidna). The selection of milk replacer stage is important in providing the correct nutrition for the joey's stage of development. For example mid lactation marsupials (AF ≈ 0.5) require the correct proteins in their milk in order to support healthy hair growth. Later lactation animals (AF >0.7) require high levels of fat to provide additional energy to support increased activity once they leave the pouch. Joeys should be transitioned from one stage of milk formula to the next in order to match the changes in milk composition seen in mother's milk. This transition must occur at the correct time for optimum growth. For example in macropods there is a significant drop in the carbohydrate-metabolising enzymes at around AF = 0.7, so animals older than this should be on a low-carbohydrate milk.

Some developmental problems can be related to joeys not being transitioned at the right age, or being left on a particular stage of milk for too long. For example the 0.6 Kangaroo milk stage only lasts for about 30 days for a Grey Kangaroo. It is important to transition on to the next stage milk after this amount of time, even if a joey is underweight for its age. The reason for this is that the internal changes to digestive physiology still occur in the joey at specified times during lactation regardless of body weight.

Feeding

Feed volume is a function of:

- Energy content in the milk, which varies throughout lactation, and
- Metabolic energy requirements of the joey.

A joey's energy needs can be calculated using the following mathematical relationship[3] which accounts for body surface area, body weight and activity level of the joey:

$$\text{Energy Requirement} = C \times w^{0.75}$$

C = a factor based on the activity level (lower for pouch-bound joeys, higher for out of pouch animals)

w = body weight (kg)

This relationship of energy requirement (and therefore food intake) to body weight is not linear. Often carers are told *"Feed 10-20% of body weight per day"* however this simple rule eventually produces feed volumes that are grossly inaccurate and can be detrimental to the health of the animal. Actual feed volumes can range anywhere from 4% to 100% of body weight, depending on the species and stage of lactation.

- **Always feed volumes according to body weight and not based on age or body measurements.**

Young joeys suckle small volumes of milk frequently and can only cope with large, infrequent feeds as they become older. As a rule, it is preferable to feed a little often rather than a lot infrequently. Feeding frequency is also dependent on the species' biology. For example, once left in the burrow, young wombats and echidnas are fed larger volumes less frequently.

It is important to weigh joeys regularly. Consistency in growth rate is a good measure of correct nutrition. Animals have an optimum, or ideal, growth rate that allows development to occur in a controlled fashion. A growth rate in excess of this optimum may lead to obesity and possible skeletal deformities. A sub-optimal growth rate may lead to poor development and a more disease prone animal. A continuing decline in growth rate could herald the onset of disease or indicate dehydration in small animals.

Drinking

Young animals will drink water when thirsty. It is important to give drinks of water during periods of hot weather or if the joey is showing signs of dehydration. Also provide joeys with small drinks of water between feeds once they begin to emerge from the pouch. Ensure drinking water is available when joey is fully out of pouch.

If providing drinking water, do not add extra water to the milk, as this will dilute the milk and can lead to poor absorption of nutrients.

Weaning

Once a joey leaves the pouch it begins to eat more solid food and becomes less reliant on milk. The amount of milk consumed until fully weaned will depend on the amount and nutritional value of other food eaten. The length of time taken to wean a joey depends on the species. As a guide, joeys are weaned at about 1.3-1.5 times the joey's pouch life. For example a grey kangaroo joey's pouch life is about 310 days and should be fully weaned by about 450 days.

Husbandry Aspects for Hand-Reaing

Even with suitable nutrition, good animal husbandry plays a critical role in successful hand-rearing of marsupials. Some important husbandry considerations include:

Disease Prevention: Good hygeine is important to minimise the spread of disease. This includes proper sterilisation of feeding utensils, maintenance of joey cleanliness and freshness of milk formula fed.

Dehydration: Joeys kept at too high a temperature, especially during warm weather, can dehydrate quickly. Animals can also lose water through excessive respiration which may occur due to stress, over-handling or excess activity levels for their stage of

development. Carers need to be able to monitor dehydration levels and minimise the risk factors.

Bone Fractures: Bone development in marsupial joeys relies on adequate calcium levels, balanced with phosphorus and vitamin D_3 intake. Bone mineralisation progresses when the joey leaves the pouch and load bearing occurs. Joeys need to gradually increase the level of load bearing to strengthen bones. Pouch bound joeys are prone to fractures, even with suitable dietary calcium levels, due to their low level of bone mineralisation. Problems are exacerbated if husbandry practices induce premature load bearing eg over-activity of young, excess movement in the artificial pouch or falls from an unsecured pouch opening. In the wild the mother tightly controls movement and level of activity in the pouch-bound young and captive husbandry needs to mimic this as closely as possible to minimise the incidence of fractures.

References

1. Crowley H.M, Woodward D.R & Rose R.W. (1988). Changes in milk composition during lactation in the potoroo, *Potorous tridactylus*. Aust J Biol Sci. 1988;41(3):289-96.
2. Muths E. (1996). Milk Composition in a Field Population of Red Kangaroos, *Macropus Rufus*. Australian Journal of Zoology 44(2) 165 – 175.
3. Peters R.H. (1983). The Ecological Implications of Body Size. Cambridge University Press.
4. Tyndale-Biscoe H. (1973). Life of Marsupials. Edward Arnold Australia.
5. Vernon J.K, Messer, M & Green B. (1981). Enzymes of Galactose Metabolism in Livers of Suckling and Adult Tammar Wallabies (*Macropus eugenii*) and Other Marsupials. Aust J Biol Sci, 34, 401-9
6. Vickery K & Walker D.M. (1982). Threshold for glucose and lactose in the diet of young kangaroos. Proc Nutr Soc Aust. 7:141

Gordon Rich: Gordon graduated as a Chemical Engineer from the University of Adelaide in 1996, and has worked around the world in the production and manufacturing industry. In 2005 he joined the family business, Wombaroo, and is involved in product research & development. He has a keen interest in birds and animals and has experience with a range of native and domestic species.