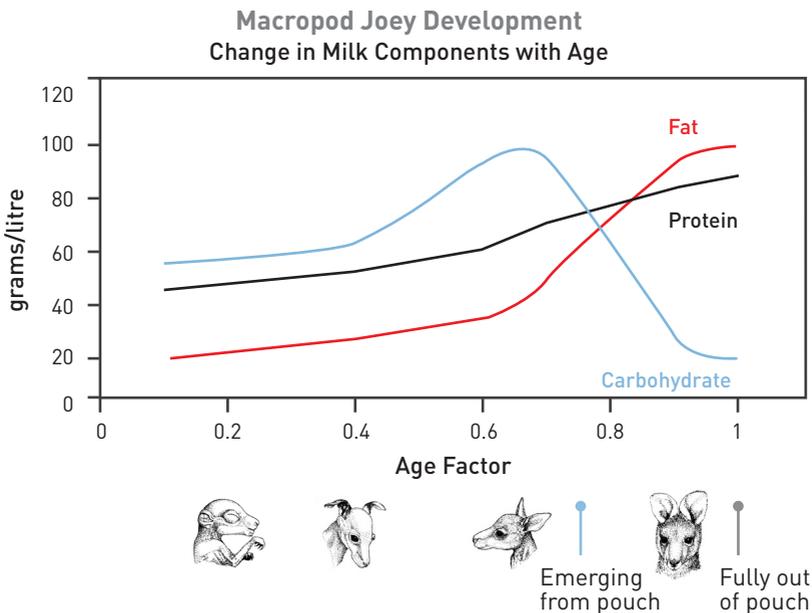


ABOUT MARSUPIAL MILK

Milk provides the essential nutrients for growth and development of juvenile marsupials. Information on the nutritional composition of milks from a range of different species is sourced 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. The chart below shows the changes in milk components for a typical macropod (kangaroo) joey. Different species of marsupials (possums, wombats, koalas) have different compositional changes during lactation and therefore have different developmental charts.



The 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 to provide additional energy. Protein levels also change to cater for the increased requirements for fur growth during mid lactation and the rapid growth rate seen around pouch emergence. For these reasons a single milk formula is not ideal for hand rearing any marsupial. Different Wombaroo milks are therefore formulated to provide the optimum nutrition at different stages of a joey's development.

The Wombaroo milk stages are related to the Age Factor (AF) of the joey, 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 320 days. Therefore a Grey Kangaroo joey at 160 days has an Age Factor of $160/320 = 0.5$. A joey at fully out of pouch age has completed 100% of its pouch life so it has an age factor of 1.0. By definition, a joey that spends any time in the pouch has an age factor of less than 1.0. Pouch emergence begins for most species of macropods at an Age Factor of around 0.7 to 0.8.

The concept of Age Factor helps us standardise the nutritional requirements for joeys from related species. Macropods develop at roughly the same rate when compared using Age Factor so that a Potoroo at 65 days, a Swamp Wallaby at 130 days, and a Grey Kangaroo at 160 days all have similar nutritional requirements (All have an Age Factor = 0.5).

The table below outlines the typical developmental "milestones" for macropods based on Age Factor (reproduced with permission from Helen George). This provides a useful guideline as to the expected development of a joey over time.

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. Limited 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.	Steadily increasing energy content of milk. Protein contains sufficient levels of sulphur-containing amino acids (cysteine & methionine) for the onset of hair & nail growth. Still limited gut flora.
0.4	Eyes still closed; ears still flat but starting to become upright; animal fully formed.	
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.	

Age Factor	Stage of Development	Nutritional Considerations
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.
0.8	Joey starting to emerge from the pouch; spends longer and longer periods outside the pouch; feeding, urinating, defecating outside the pouch.	Sharp fall in carbohydrate content of milk with decrease in associated gut enzymes.
0.9	First incisor teeth erupting through gum; full length fur growth.	Increasing levels of "body-building" proteins (caseins, α -globulins) to coincide with peak growth rate.
1.0	Joey fully emerged from the pouch; still drinking milk; solid food plays a large part in the diet.	Gut flora developed for digestion of solid food.

WHAT'S IN WOMBAROO

Wombaroo contains a blend of protein, carbohydrate, fat, vitamins and minerals formulated to match as closely as possible the composition of natural mother's milk.

PROTEIN is a recombination of bovine milk protein fractions to produce the optimum proportion of caseins and whey proteins, with a balanced amino acid profile. Essential amino acids have been fortified with extra lysine, cysteine & methionine the latter of which are particularly important for healthy hair growth.

CARBOHYDRATE is mainly in the form of glucose. Some formulations also contain maltodextrin made from the enzymatic digestion of starch, which is high in glucose-oligosaccharides and low in α -limit dextrin. Our research has shown this to be a well-digested form of energy, particularly for early lactation marsupials when carbohydrate accounts for up to 40% of the milk's energy (Rich BG, 1993. *Activities of intestinal disaccharidases in hand-reared macropods*. Wildlife Diseases Association of Australasia. Mallacoota). All marsupial formulae are low in lactose and free galactose to minimize digestive upset.

FAT is a mix of milk fat solids, vegetable oils and fatty acid esters prepared from fish oil. These ingredients are blended to produce the optimum mix of saturated, mono-unsaturated and polyunsaturated fats and include the essential omega-3 fatty acids α -linolenic acid (ALA), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

VITAMIN and MINERAL composition data in marsupial milk is sparse. The addition of these micro-nutrients is based on best estimates obtained from those milks that have been analysed. The nutrients well quantified in marsupial milk include vitamin A, vitamin E, calcium, phosphorous, potassium, sodium, iron and copper. Where values are unknown we have added the full complement of vitamins and minerals in quantities that are acceptable by recognised animal husbandry standards. This includes vitamin D₃, vitamin C, vitamin K₁, thiamine, riboflavin, pyridoxine, niacin, pantothenic acid, folic acid, biotin, cyanocobalamin, choline, inositol, magnesium, zinc, manganese, iodine and selenium. See **Appendix 4** for further discussion about calcium levels and the incidence of bone fractures in joeys.

HOW TO USE WOMBAROO

Use Wombaroo as a complete food for rearing orphaned joeys or as supporting nutrition for debilitated or convalescing animals. Maternal milk supplies immunoglobulins throughout much of a marsupial's lactation, providing immunity to diseases and intestinal protection due to its many antimicrobial properties

Success in hand rearing joeys may be improved if **Impact Colostrum Supplement** is added to Wombaroo milk to help boost the immune system.

Using Wombaroo milk for marsupials is a three-step process.

Step 1 Determine the Age Factor of the joey in care.

Step 2 Select the correct Wombaroo milk replacer for that age factor.

Step 3 Feed the correct volume of milk replacer based on the body weight of the animal.

Age Determination

Accurate age determination means that the correct formula for the stage of development can be fed. Joeys can be aged according to their physical characteristics (eg hair growth, body measurements, consistency of faeces). The developmental milestones outlined for macropods in the table on pages 2 and 3 may be a useful guide. This booklet provides growth charts for some of the common species that come into care, which can be used as a guideline for feeding joeys. Contact Wombaroo or visit www.wombaroo.com.au for growth information of any other species not listed in the booklet.

 **Body weight should not be used to estimate age as this can be highly misleading due to large variations between individuals, malnourishment or dehydration.**

Using the Growth Charts

It is important to note that the growth charts are only a guide and do not take into account differences due to sex, geographical variation and health condition of the joey. Estimate the animal's age from the body measurements given for that species (see **Appendix 5**). Where available, head length is the most accurate indicator of age, followed by foot and tail lengths. Often measurements do not exactly correlate, so use the average age indicated by the measurements on the chart.

 **The estimated age determines the stage of Wombaroo milk to feed.**

Based on the estimated age, the charts provide a typical body weight for that age. This is a guideline only and may be subject to a high degree of variation between individuals. However comparing the joey's actual weight to that presented on the chart may provide an indication as to the condition of the joey. For example in drought conditions it is not unusual for joeys to be up to 50% underweight compared to normal years.

 **The joey's actual body weight determines the daily feed volume.**

Feed according to the joey's actual body weight, as this gives the correct feed volume for your particular joey. Individual growth rates can vary substantially from the growth charts, so some animals won't match up with the charts. However if you are concerned that an animal is failing to thrive, underweight or malnourished it is always useful to seek veterinary advice. Further information on underweight or malnourished joeys is provided in **Appendix 2**.

Making Up Milk

Wombaroo should be made up according to the directions on the pack. Different formulae are made up at different concentrations of solids per litre of milk. For example Kangaroo Milk Replacer >0.7 formula is made up at 250g of powder per litre of prepared milk. This means that about 800mL of water is added to 250g of powder to make up 1 litre of formula. Do not simply add 1 litre of water to the 250g of powder as this will produce more than 1 litre of milk and result in a diluted formula.

► **Wombaroo milk powders have different densities and should be weighed when preparing milk.**

If weighing out milk powder is not possible then use the enclosed scoop to measure out small quantities of milk powder in accordance with the directions on the pack. Note that using the scoop is less accurate, so wherever possible we still recommend to weigh out the powder.



Even if only feeding small quantities, it is preferable to make up milk in larger volumes (i.e. a litre at a time) as this is more accurate to measure out and mix up. Once made up, milk can be stored frozen in smaller quantities (e.g. in ice cube trays or freezer bags). These smaller quantities can then be thawed, remixed and used as required with minimal wastage. Do not re-freeze thawed milk. Prepared milk can be stored in a refrigerator for a day or frozen for up to 2 weeks.



► **When making up milk use pre-boiled water, as this sterilises the water and reduces microbial contamination.**

Use warm water (about 50°C), too cold and the powder won't disperse properly and too hot can curdle the milk proteins and destroy some nutrients. Some formulae are particularly high in fat so are best mixed with an electric whisk to prevent separation. Milk may not make up properly if there are contaminants in water (eg tank water), or if the powder has been exposed to heat, moisture, light or is out of date. Refer to **Appendix 1** about storage of milk powders.

Feeding

Milk should be warmed to about 30°C and fed using a bottle and teat. Your Wombaroo stockist can supply 100ml graduated plastic bottles and a suitable latex teat from our range of shapes (see Bottles and Teats for the range of Wombaroo teats available).

Tables of suggested feed volumes are supplied with each packet of milk replacer. Feed volumes have been carefully calculated using a mathematical relationship between body weight and daily energy requirement. This relationship is not linear, so feeding a straight percentage of body weight is not accurate. Often new carers are told rules of thumb like "Feed 15% of body weight per day." This simple rule eventually produces feed volumes that are grossly inaccurate and can be detrimental to the health of the animal. Depending on the species and stage of lactation, the feed volume can range from 4% to 70% of body weight per day. Overfeeding may cause diarrhoea.

Do not concentrate or dilute Wombaroo milk replacers by making them up to volumes other than that indicated on the packet directions. This will change the osmolarity of the milk solution and may lead to malabsorption of nutrients from the gut. Avoid introducing additional nutrients to the milk (other than Impact Colostrum Supplement) as this may unbalance the nutrient profile of the Wombaroo.

Feeding Frequency

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. Husbandry guidelines for macropods are as follows:

Age Factor	Milk Feeds per day	Faecal Consistency	Housing Temperature
<0.4	12-8	Thin Custard	34-36°C
0.4	8-6	Thick Custard to Toothpaste	32-34°C
0.6	5-4	Toothpaste to Soft Pellets	28-30°C
>0.7	4-3	Soft to Firm Pellets	20-25°C
1.0 to weaning	2-1	Firm Pellets	Ambient

Source: Vogelnest, L & R Woods (Eds.). (2008). *Medicine of Australian mammals*. CSIRO PUBLISHING. p 22.

Feeding frequency is also dependent on the species' biology. For example, once left in the burrow, young wombats and echidnas are naturally fed larger volumes but less frequently. If unsure, consult an experienced carer about the husbandry requirements of the species in question.

Growth Rate

Weigh joeys regularly. Consistency in growth rate is a good measure of adequate nutrition. Animals have an optimum, or ideal, growth rate that allows development to occur in a controlled fashion. Overfeeding, leading to an excessive growth rate may lead to obesity and possible skeletal deformities. Underfeeding, causing sub-optimal growth rate may lead to poor development and a more disease prone animal. A continuing decline in growth rate could indicate the onset of disease or malnutrition in young animals. See **Appendix 2** for more information on treating underweight or malnourished joeys.

Transition of Milk

Milk transition refers to when a joey is changed from one Wombaroo milk stage to the next. This transition is necessary to cater for the changing nutritional requirements of joeys as they grow. It is important to transition joeys at the correct age to ensure they are getting the proper nutrition for their stage of development. We recommend to transition from one milk stage to the next gradually over a period of about 10 to 20 days (depending on species and age). This is outlined in the various growth charts presented for individual species. The gradual transition of milk formulas reduces the likelihood of digestive upset for the joey.

 **For example to transition a 950g Eastern Grey Kangaroo from 0.4 to 0.6 formula over a 10 day period:**

Start	100mL 0.4 Kangaroo Milk Replacer
Day 1-3	Mix 75mL 0.4 formula with 25mL of 0.6 formula
Day 4-6	Mix 50mL 0.4 formula with 50mL of 0.6 formula
Day 7-9	Mix 25mL 0.4 formula with 75mL of 0.6 formula
Finish	100mL 0.6 Kangaroo Milk Replacer

Note that the start and finish volumes are the same, and that simply the ratio of one milk to the other is changed throughout the transition. If an animal is not tolerating the transition well (e.g. diarrhoea), then go back to a higher proportion of the earlier stage milk, and progress through the transition more slowly.

Some developmental problems can be related to joeys not being transitioned at the correct age, or being left on a particular stage of milk for too long. For example the 0.6 Kangaroo stage only lasts for about 30 days for a Grey Kangaroo.

Even if a joey is significantly underweight for its age, it still needs to be transitioned to the next stage milk after the specified amount of time indicated in the growth chart. The reason for this is that changes in milk composition and digestive physiology still occur at the same age regardless of the joey's weight or body condition.

Drinking Water

When a joey first comes into care, it is important to provide sufficient rehydration fluids before feeding milk.

Pouch-bound Joeys: Having been properly rehydrated, the normal feed volume of Wombaroo milk adequately supplies the maintenance water requirements recommended for small mammals (see **Appendix 3**). Pouch-bound young with low activity levels, housed at the optimum temperature and humidity therefore do not usually require additional drinking water. However young joeys can dehydrate rapidly if not maintained under ideal conditions. If the joey is showing signs of dehydration (e.g. during hot weather, or due to diarrhoea), give extra drinks of water between feeds.

Emerging Joeys: Joeys begin to regulate their own water intake once they start to emerge from the pouch. Offer small drinks of water between feeds once they begin emerging and ensure drinking water is always easily accessible when joeys are fully out of pouch. Joeys should also have access to fresh grass and browse at this stage, and this can be sprayed with water to mimic dew that provides a natural source of moisture to grazing animals.

 **If providing drinking water, do not add large volumes of extra water into the milk, as this dilutes energy intake and may reduce absorption of nutrients. If possible, give drinking water separately, between milk feeds.**

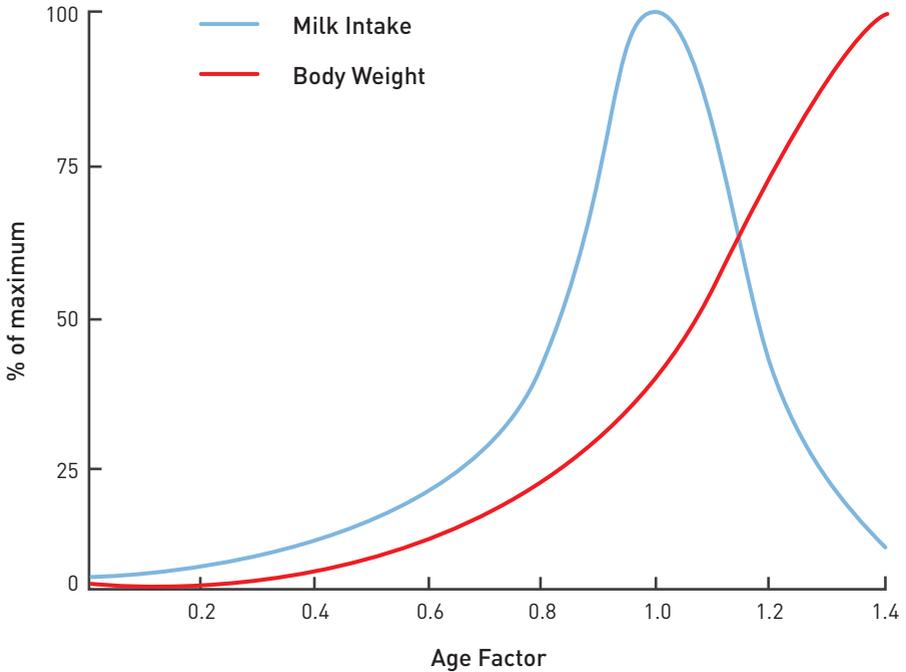
See **Appendix 3** for more detailed information on Dehydration & Drinking Water.

Weaning

Once a joey leaves the pouch it begins to eat more solid food and becomes less reliant on milk. The amount of milk fed until fully weaned depends on the amount and nutritional value of other food eaten.

A typical milk intake curve for the Tammar Wallaby is shown on the following page (Merchant 1989). It is expected that most marsupials would have a similar shaped milk production curve. The key points are:

1. Maximum milk intake occurs at full pouch emergence (Age Factor =1.0).
 2. Milk intake drops rapidly after pouch emergence, as the joey weans on to solid food.
 3. Joey is weaned at an age factor of about 1.4.
-



Using the above guideline, it is expected that joeys are usually weaned at an Age Factor of around 1.3 -1.5 times the joey's pouch life. For example a Grey Kangaroo with a pouch life of 320 days would be fully weaned by about $1.4 \times 320 = 450$ days. Sick or malnourished joeys may need to be weaned later than healthier ones. However the continued feeding of large volumes of milk after pouch emergence should be discouraged as this makes weaning a more difficult and prolonged process. Since sexual maturity and/or dispersal of young occurs shortly after weaning in many species, it is important that hand-reared animals are weaned at a similar time to mother-reared young.

Animals destined for release should be weaned on to solid foods that form part of their natural diet in the wild. For grazers and browsers maintained in captivity such as kangaroos, wallabies and wombats, **Wombaroo Kangaroo Pellets** (page 38) can be used as an ideal supplement for weaning joeys.

Reference

Merchant JC (1989). Lactation in macropodid marsupials. In *Kangaroos, Wallabies and Rat-Kangaroos* (eds G Grigg et al) p362.