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Optimum Sugar Concentration in Artificial Nectar Diets for Lorikeets

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Abstract

In the wild, lorikeets obtain much of their energy from nectar collected from native flowers, particularly *Eucalyptus*. In captivity or when supplementary feeding wild birds, it is desirable to provide an artificial diet that closely resembles the nutritional and physical properties of natural nectar. Artificial nectars are prone to microbial spoilage, but this problem can be mitigated by utilising high concentrations of simple sugars (sucrose, glucose and fructose), which have an antimicrobial preservative effect. However, excess sugar concentration increases solution osmolarity and viscosity, which can both negatively affect food intake and assimilation efficiency.

Observations of wild lorikeets feeding on *Eucalyptus cosmophylla* provided a baseline for the typical sugar concentration and osmolarity of nectar consumed. This information was combined with published data on the viscosity and antimicrobial effects of sugar concentration in nectar solutions. Based on optimising these factors, a sugar concentration of around 25-30% w/v in artificial nectar solutions was deemed appropriate for feeding lorikeets. Some practical recommendations for feeding of artificial nectars are also presented.

Introduction

The formulation of artificial diets for nectarivorous birds poses some specific challenges. In captivity liquid diets are prone to microbial spoilage, which may lead to bacterial or yeast infections (Gelis, 2012). Highly concentrated nectars draw water osmotically from the body into the gut (Nicolson, 1998) and may exacerbate dehydration and renal disease. For wild birds it is desirable that artificial diets provide similar nutritional and physical properties to that of naturally-occurring nectar. This applies when supplementary feeding free-flying birds and also for sick or injured birds during rehabilitation. Foraging birds are limited by high viscosity nectars, as these reduce the speed of nectar extraction, which in turn make birds more susceptible to predation and competitor aggression (Kim et al., 2011). This has implications on survivability of wild populations that are support-fed, such as the endangered Helmeted Honeyeater (*Lichenostomus melanops cassidix*) in Victoria.

Sugar Content in Naturally-occurring Nectar

In the wild, lorikeets derive a significant proportion of their energy from nectar obtained from native flowers, particularly *Eucalyptus* (Cannon, 1984). Large numbers of Rainbow (*Trichoglossus haematodus*), Musk (*Glossopitta concinna*) and Purple-crowned (*G. porphyrocephala*) Lorikeets regularly feed on flowering Cup Gum (*Eucalyptus cosmophylla*) in the Adelaide region (pers. obs.). *E. cosmophylla* is also reported as a common food plant for these Lorikeet species by other observers (HANZAB, 1999).

From a nutritional viewpoint, floral nectar is essentially a solution of simple sugars dissolved in water. The main sugars are the disaccharide sucrose and its component monosaccharides glucose and fructose (Figure 1).

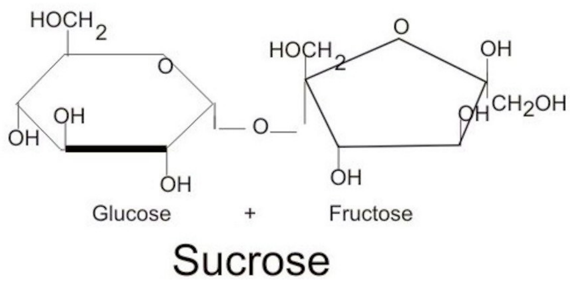

Figure 1. Sucrose is a disaccharide made up of one part glucose and one part fructose.

The normal range of sugar concentration of *E. cosmophylla* nectar is reported as 16 to 37 w/v% (Davis, 1997). The proportion of sugars in the nectar of *E. cosmophylla* is variable depending on the age of the flower, but is approximately 35% glucose, 35% fructose and 30% sucrose at peak nectar flows. As monosaccharides, the glucose and fructose components are rapidly absorbed directly in the gut of birds. However to break down sucrose, birds require the intestinal enzyme *sucrase* to liberate the component monosaccharides prior to digestion. Rainbow lorikeets are reported to have a digestive assimilation efficiency of >99% for sucrose, indicating relatively high levels of intestinal sucrase activity (Fleming et al., 2008). From a nutritional point of view it therefore seems to matter little whether the sugars are present as the disaccharide or as the monosaccharides, since lorikeets can assimilate them both efficiently. From an osmotic point of view however, sucrose exerts about half the osmotic pressure in solution (on a w/v% basis) as the monosaccharides, due to its higher molecular weight. Practically, this results in birds having a preference for sucrose-dominated nectars as solutions become more concentrated (Fleming et al., 2008), probably to offset the increased osmotic effect of monosaccharide solutions.

Antimicrobial Preservative Effect

Sugar solutions above 30 w/v% have a significant inhibitive effect on microorganisms, and are therefore considered to have a preservative effect (Tarkow et al., 1942). This is the basis for the long-standing practice of preserving foods such as jams. The primary mechanism for this preservative action is extracellular osmosis of water which dehydrates the microorganisms. The result is a reduction of *water activity* (a_w), a measure of unbound, free water molecules available for microbial survival and growth.

However, dilute sugar solutions have higher water activities and tend to promote microbial growth. For example Arafeh et al., (1998) reported significant bacterial contamination of a 10% sucrose solution occurring 24 hours after preparation. Harrison et al. (2007) investigated 33% w/w solutions of sucrose stored in capped bottles that were accessed frequently in a medical institution. They found either no bacterial contamination or only small numbers of common skin organisms after 28 days. Results were similar for both refrigerated and unrefrigerated samples. The bacteria found were of low pathogenic potential and were not consistently isolated from all the solutions. No Gram-negative bacteria were isolated from the solutions.

Osmotic Concentration of Solutions

It is clearly desirable to maximise the concentration of sugar solutions to enhance their preservative effect. This is particularly the case when feeding captive lorikeets, as we want to minimise the risk of microbial contamination of solutions fed out at ambient conditions. However, by increasing sugar concentration, one will eventually run into problems of excessive solution osmolarity. This may impact on digestibility and exacerbate dehydration, as hypertonic solutions act to draw moisture from the body. According to Nicolson (1998) animals which utilise nectar as a food source may have osmoregulatory problems when nectar concentrations do not match their water requirements. Since clinical conditions such as renal failure and gout are commonly reported in avian patients, then it is not prudent to use sugar solution osmolarities beyond that which is found in nature.

To calculate the osmolarity of a nectar solution we need to account for the molar contributions of each sugar component:

Sugar Concentration (g.L^{-1})/Molecular Weight (g.mol^{-1}) = Molarity (mol.L^{-1}).

Since sugars do not dissociate, this is equivalent to the solution osmolarity.

If we take the upper limit of naturally-occurring nectar solutions to be equivalent to a 37% w/v (370g/L) nectar of *E. cosmophylla* at peak flow (Davis 1997), we can calculate the osmolarity as:

0.35 x 370/180 (glucose component) + 0.35 x 370/180 (fructose component) + 0.30 x 370/342 (sucrose component) = 1.76 mol.L^{-1}

A pure glucose or fructose solution with the same osmolarity would have a concentration of 1.76 x 180 = 317g.L^{-1} or 31.7% w/v.

A pure sucrose solution with the same osmolarity would have a concentration of 1.76 x 342 = 602g/L or 60.2% w/v.

So from an osmotic point of view, the upper limit of concentration of pure glucose/fructose or pure sucrose solutions would be around 32% w/v and 60% w/v respectively. This clearly demonstrates how sucrose can have a much higher concentration than glucose/fructose solutions to produce the same osmotic effect.

Viscosity of Solutions

Another limitation to consuming nectar solutions is that the viscosity rises exponentially with sugar concentration. It has been theorised that this places a physical limit on the ability of an animal to quickly and efficiently harvest nectar (Kim et al, 2011). Avian nectarivores, which utilise *capillary suction* through their brush-tipped tongues, tend to favour lower concentration nectars compared to insects and bats that use a *viscous dipping* mechanism. The optimal sugar concentration for capillary suction feeders such as honeyeaters has been calculated to be 33% (Kim et al, 2011) although it is not clear how well this applies to lorikeets. However, given the brush-like papillae on their tongues, it is unlikely that lorikeets would be able to tolerate much higher viscosity sugar solutions than honeyeaters. From a captive management situation, highly viscous nectars also pose more problems in terms of feather maintenance and cleanliness, particularly around the beak and face.

Conclusions

Determining the appropriate sugar concentration for artificial nectars is an optimisation of three factors:

1. Maximising the antimicrobial preservative effect.
2. Minimising osmotic effects.
3. Minimising viscosity effects.

Observations of wild birds feeding on *Eucalyptus cosmophylla* indicate that nectar taken by lorikeets range in sugar concentration from 16 to 37% w/v. To maximize the preservative effect, artificial nectars should be at the higher end of this range. However, osmotic constraints may limit the use of solutions to about 32% w/v for pure glucose/fructose solutions. Due to viscosity constraints, it is prudent to limit the sugar concentration to around the optimum level preferred by capillary suction feeders, which is 33% w/v.

Furthermore, the necessary addition of other nutritional components to artificial nectars such as electrolytes and amino acids will also exacerbate these osmotic and viscosity constraints.

On this basis, an optimum nectar sugar concentration of around 25-30% w/v would seem appropriate for feeding captive lorikeets.

Practical Recommendations for Feeding Artificial Nectar

- When feeding artificial nectar aim for a total solids concentration of around 30% w/v (i.e., 300g/litre).
- Utilise carbohydrates with a high proportion of soluble sugars (sucrose, glucose and fructose) - this binds water in solution, making it unavailable for microbial growth, thus providing a preservative effect.
- Do not dilute artificial nectars - this increases water activity, and increases the rate of spoilage.
- Diets that contain insoluble starch (e.g., cereal grains such as rice or wheat flour) do not have a preservative effect. These quickly separate out of solution, leaving a dilute sugar solution on top (supernatant) and a thick, sludgy residue on the bottom. This situation leads to a separation of nutrients and exacerbates microbial spoilage.
- Always provide access to fresh water when feeding nectar diets. Even though the liquid food contains moisture, the solution is still hypertonic, and can exacerbate dehydration in captive birds.
- Feed according to the energy requirements of the bird. Not only will this reduce the incidence of obesity in captive birds, but it decreases the likelihood of microbial contamination by reducing the amount of uneaten excess food.
- In hot weather, offer the nectar diet in the early morning and evening. Cooler temperatures at these times reduce the rate of microbial growth. This also mimics the peaks in nectar flows of flowering plants and the normal foraging times of nectarivorous birds.

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