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Title: Clinical review – Guinea pig Nutrition – what do we know?

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Key Learning Outcomes:

- Recognise that Guinea pigs are popular pets, but are not routinely presented for veterinary examination unlike other pet species
- Know what the current dietary recommendations are for pet Guinea pigs
- Recognise the importance of dietary vitamin C for pet Guinea pigs
- Know what potential adverse health effects may occur in pet guinea pigs associated with an incorrect diet

Introduction:

Guinea pigs are popular pets in the United Kingdom, with recent estimated numbers of approximately 0.4 million - 0.9 million being kept as pets (around 1.3-2% of the total pet

population), (The Pet Food Manufacturers' Association, 2022), (Harrup and Rooney, 2020), (Wills, 2020). This is only slightly lower than the estimated number of pet rabbits in the UK (0.6 million – 1 million), (The Pet Food Manufacturers' Association, 2022), (Wills, 2020).

Guinea pigs have been used historically for scientific research and consequently most of the referenced information available on husbandry and diet is based on laboratory animal work and conditions (NRC, 1995). This information may not be directly transferable to pet Guinea pigs since husbandry practices for pet animals are very different to laboratory conditions, the latter being carefully controlled for temperature, humidity, ventilation and pathogen exposure. Nutritional requirements may also vary according to breed, age, sex, season and husbandry aspects. Although there have been significant advances in recent years in our understanding of pet rabbit husbandry and nutrition, the documentation and understanding of pet Guinea pig nutritional requirements and associated welfare needs are more limited, with little or no research available (Meredith, 2015), (Wills, 2020). This is a current cause for concern amongst the veterinary profession, animal welfare organisations and pet food manufacturers (Veterinary Record, 2019), (Harrup and Rooney, 2020), (Wills, 2020), (RSPCA, 2011), (Burgess, 2022).

Aim:

This article will review what we do and do not know currently about pet guinea pig nutritional requirements. Wild guinea pig diets will be discussed and current pet guinea pig owner feeding habits outlined. The article will also look at the potential adverse effects of an incorrect diet on guinea pigs and their welfare. Some of this information is currently unknown, however whether extrapolations may be possible from other species, will be discussed. This article is a useful overview for all veterinary staff treating pet Guinea pigs, and giving dietary advice to owners, in veterinary practice.

What we do know about Guinea pig nutrition:

Guinea pigs are herbivorous rodents that originate from South America where they are widespread and inhabit a variety of habitats ranging from grassland, forests, dry rocky areas and even swamps. They are social animals, living in herds and communicating through vocalisation and body movements. Pet Guinea pigs should therefore always be kept in social groups (Figure 1). In the wild, Guinea pigs mainly eat grasses and are unspecialized grazers, consuming low-energy, high-fibre, abrasive food in large quantities (Reiter, 2008). Guinea pigs, similar to rabbits, have continuously erupting aradicular elodont dentition, requiring a high fibre diet for dental and gastrointestinal health (Meredith, 2015), (Reiter, 2008). Dental wear occurs secondary to the interaction between ingested food material and tooth occlusal surfaces during chewing. Diets containing high forage phytolith/silica content are more abrasive and increase enamel surface wear (Winkler and others, 2019). Compared to the more selective feeding practices of rabbits, Guinea pigs can digest fibre more efficiently and are faster at eating hay than rabbits, consuming more over time (Franz and others, 2011). Late afternoon / evening is the most popular feeding time for wild Guinea pigs.

Despite being common pets in the UK, the basic dietary requirements of pet Guinea pigs are largely unknown, based primarily on nutritional guidelines for laboratory animals and extrapolation from other species, such as rabbits, resulting in inconsistent dietary recommendations (NRC, 1995), (Wills, 2020).

Diets formulated to these guidelines, in particular muesli-type diets (Minarikova and others 2015), have been implicated by veterinarians as playing an important role in many disease processes in Guinea pigs, particularly when fed in the absence of hay (Wills, 2020).

Dietary advice to pet Guinea pig owners is often contradictory and conflicting, in particular with respect to whether fruit items should be offered or not, leading to confusion (Witkowska and others, 2017), (Wills, 2020). This makes it very hard for dedicated owners to ascertain exactly what to feed their pet Guinea pig, with considerable variation in the diet offered by UK Guinea pig owners being reported (Witkowska and others, 2017).

In captivity, pet Guinea pigs are typically fed good quality hay ad-lib, green vegetables, fresh grass and herbs, root vegetables and concentrates (box 1), (Figure 2 a., b. and c.), (Fawcett, 2011). They should also always be provided items to gnaw to encourage incisor tooth wear and food can be scatter fed to encourage foraging behaviour and provide environmental enrichment (RSPCA, 2011), (Figure 3). Fresh water should be offered daily from a bowl and bottle. Water uptake increases with increased dry matter of the diet. In rabbits water uptake increases when offered water from a bowl (Tschudin and others, 2011a). In guinea pigs however, the converse has been shown to be true, with increased water intake observed from nipple drinkers / water bottles. (Balsiger and others, 2017), (Figure 4). Balsiger and others, 2017 conducted a small study in 10 guinea pigs, which had been used to drinking from a bottle only before the study commenced. They allowed a 25 day adaption period, where water bowls and bottles were provided. This study found that water intake in guinea pigs varies considerably between individuals. One possible reason for water bottle preference proposed by the authors is that it acted as a behavioural enrichment encouraging increased oral manipulation (gnawing and chewing) opportunity. Average daily food intake is 60-70g/kg/day (2-3x in young and pregnant animals), with water intake 100-200ml/kg/day (Keeble and Meredith, 2009).

Box 1: Recommended dietary components for guinea pigs (RSPCA, 2011), (Keeble and Meredith, 2009), (Witkowska and others, 2017), (PDSA, 2022)

- Good quality meadow hay ad-lib scatter fed (own body size amount – 85-90% of the diet)

- Green vegetables – cabbage, kale, chicory, watercress, rocket, spring greens, pak choi, swiss chard, celery leaves, carrot tops (approx. 1 teacup per day)
- Fresh grass, herbs and wild plants such as dandelion leaves, groundsel, cow parsley, basil, sage, mint, coriander.
- Dried herbs
- Pelleted concentrates (1 tablespoonful per day)
- Occasional items as ‘treats’ – broccoli, cauliflower, spinach, celery, green beans, root vegetables – carrots, beetroot, parsnips

- Clean drinking water offered from a bottle and bowl daily

- Make any diet changes gradually as guinea pigs may be averse to change.

- Items to gnaw should always be provided to encourage incisor tooth wear.
- Scatter feed items to encourage foraging behaviour

A recent UK owner survey on pet Guinea pig diets concluded that 72.8% of animals were fed ad-lib hay, indicating that 27.2% of animals were not fed ad-lib hay. Ninety-nine percent of animals were fed concentrates in some form, either as a pelleted diet (76.7%) or as a muesli mix (27.3%). Fresh greens were fed daily to 69.9% of animals (Harrup and Rooney, 2020), again indicating that 30.1% did not receive these items daily in their diet.

Muesli diets have been associated in pet rabbits with obesity, inactivity, selective feeding leading to an unbalanced diet, dental disease, uneaten caecotrophs and poor gastrointestinal health (Prebble and others, 2015a), (Prebble and others, 2015b), (Prebble and Meredith, 2014), (Meredith and Prebble, 2017), (Meredith and others, 2015) and it is postulated that the same dietary associations may occur in pet Guinea pigs.

Research by Harrup and Rooney (2020) suggests that approximately 1 in 4 pet Guinea pigs in the UK are fed an inappropriate diet (no ad-lib hay, no fresh greens or feeding a muesli based diet), which is a welfare concern. In mainland Europe muesli only diets are widely available to purchase and marketed as complete diets for pet Guinea pigs, despite strong peer-reviewed scientific evidence that these diets are detrimental to rabbits. In the UK concentrate diets (pelleted and muesli) are marketed as supplemental feeds together with ad-lib good quality

hay and leafy greens. These dietary recommendations should help reduce the incidence of diet-associated health issues in pet guinea pigs, although there is still a potential for selective feeding associated with muesli-based diets.

Guinea pig specific nutritional requirements:

Guinea pig nutritional needs differ markedly to other companion animals. In particular, they require an exogenous source of Vitamin C in their diet (10mg/kg/day), due to the absence of the enzyme L-gulonolactone oxidase, required to convert L-gulonolactone to L-ascorbic acid, a need that has been well-researched (Frikke-Schmidt and others, 2016). This increases 2-3 fold during pregnancy. Vitamin C supplementation can be via the diet (most commercial concentrate diets have added vitamin C), or feed vitamin C rich fresh food items (box 2)) or via water intake (box 3) (Witkowska and others 2017).

Box 2: Vitamin C rich food items for Guinea pigs (PDSA, 2022)

- Root vegetables – carrots, beetroot
- Leafy greens – dandelions, cabbage, kale, spring greens, spinach, parsley
- Peppers
- Tomato
- Asparagus

Box 3: Important information on vitamin C supplementation (Witkowska and others, 2017)

- Vitamin C breaks down quicker at higher temperatures
- Vitamin C degradation is concentration dependent in water
- Check the use by date on concentrates as vitamin C degrades with storage
- Exposure to UV light increases vitamin C degradation
- Never feed rabbit or other rodent concentrates to guinea pigs as these do not have appropriate vitamin C levels for guinea pigs.

Excess dietary vitamin C is voided in the urine. Diets with higher vitamin C content will result in elevated urinary vitamin C levels, indicating a high level of bodily tissue saturation with vitamin C. Vitamin C has been shown to be effective in the prevention of urinary tract infections, due to it acidifying the urine, resulting in limiting bacterial growth (Carlsson and others, 2001), (Figure 5). Dietary vitamin C supplementation does not increase the risk of urolith formation (Singh and others, 1993). However in the same study, in guinea pigs fed high calcium carbonate or sodium oxalate diets, the addition of vitamin C (at 10mg/100g body weight/day) increased the risk of renal calcification and urolith formation. This indicates that care should be taken with vitamin C supplementation in animals with pre-existing hypercalciuria and hyperoxaluria. The role of dietary vitamin C as a potential underlying cause or contributory factor in the development of urinary tract disease in pet Guinea pigs needs further investigation (Meredith, 2015).

Whilst much is known regarding dietary vitamin C in guinea pigs, our understanding of Guinea pigs' dietary fibre, calcium, phosphorus and Vitamin D requirements is less complete. Research suggests that calcium / phosphorus dietary imbalances, Vitamin D deficiencies or genetics could be more important in the development of acquired dental disease in Guinea pigs than simply the abrasive content of the diet (Muller and others, 2014). The results reported by Muller and others, 2014, should be interpreted carefully however, since the study period was short, allowing little time for dental occlusal changes associated with lack of an abrasive diet to develop (two weeks) and muesli diets were not included. Vitamin D uptake / synthesis and exposure to UVB light may also play a significant role in the development of dental disease in Guinea pigs (Norman and Wills, 2016), (Watson and others, 2014). It has been shown that Guinea pigs offered UVb lighting have higher blood levels of vitamin D3 and ionised calcium (Witkowska and others, 2017).

Laboratory animal research has shown that certain macronutrients are essential to Guinea pigs and these include n-6 fatty acids such as linoleic acid, amino acids, such as arginine and tryptophan and minerals such as calcium, phosphorus, magnesium and potassium. Diets high in cholesterol and fat have been associated with hepatic lipidosis (Witkowska and others, 2017).

Effects of diet on health and welfare in rabbits:

An 18-month controlled feeding trial was conducted on 32 Dutch rabbits to assess the effects on rabbit health and welfare of four diets: Hay only; Nugget and hay; Muesli only; and Muesli and hay. The key aims of this study were to investigate the effects of these diets on body weight and body condition score, food and water intake, faecal output, selective feeding, dental health and behaviour.

The study found statistically-significant evidence that feeding of muesli is associated with:

- Obesity (BCS>4) and inactivity - rabbits fed muesli only diet spent the least time feeding and the most time inactive (Prebble and others, 2015a), (Prebble and others, 2015b).
- Selective feeding, leading to intake of an unbalanced diet with low fibre intake. (Prebble and Meredith, 2014).
- Reduced water intake (Prebble and Meredith, 2014).
- Smaller droppings and low faecal output, indicating reduced gastrointestinal motility (Meredith and Prebble, 2017).
- Uneaten caecotrophs (Meredith and Prebble, 2017).
- Dental disease (Meredith et al, 2015).

Furthermore Prebble and others, (2015a), concluded that growing rabbits require additional supplementation to a hay only diet in order to reach breed standard adult weights, therefore a hay only diet in young rabbits is not recommended.

This research led to widespread removal of muesli-style diets from retail outlets and changes to feeding policy following the identification that they are detrimental to rabbit health.

It has however been shown that rabbits feed more selectively than Guinea pigs, having a lower capacity to digest fibre, but it is unclear what effect this would have on guinea pigs offered varying diets (Franz and others, 2011).

Nutritional advice for pet rabbits has improved since these feeding trials, based on the study findings, but unfortunately Guinea pigs are still largely neglected and are often fed poor diets, with resulting health and welfare issues (Harrup and Rooney, 2020), (Meredith 2015).

Similar studies are required in pet guinea pigs, although feeding trials will need ethical review approval and are likely to come under the Animal (Scientific Procedures) Act, 1986, given the adverse effects seen in the rabbit feeding trials.

Effects of diet on health and welfare in pet Guinea pigs:

Whereas companion animals such as dogs, cats and rabbits are routinely presented to veterinary practitioners for health examinations, vaccination and neutering, this is not common practice in Guinea pigs leading to concerns that health issues associated with poor husbandry and diet may go undetected resulting in pain and suffering (Harrup and Rooney, 2020), (Meredith, 2015), (Wills, 2020), (Figure 6).

Increased morbidity and mortality rates in pet Guinea pigs have been described associated with inadequate nutrition, which is a major welfare concern (Fawcett, 2011), (Harrup and

Rooney, 2020). Dental disease has been recognised as a significant health issue in Guinea pigs, being the most commonly diagnosed disorder in this species (Minarikova and others, 2015), (Jekl and others, 2008), (Legendre, 2016), (Crossley, 1995), (Figure 7). The exact pathophysiology of dental disease in this species is currently not fully understood, however the importance of a good quality diet to promote dental and gastrointestinal health is thought to be paramount (Meredith, 2015), (Reiter, 2008), (DeCubellis and Graham, 2013).

The Guinea pig dental formula is: 2x (I1/1, C0/0, P1/1, M3/3), with cheek teeth recorded as P4, M1, M2 and M3. Jekl and others, 2008 found that in Guinea pigs, the mandibular right P4 and both the mandibular left incisor and P4 were most often affected with dental disease.

Computed Tomography is the most valuable and sensitive diagnostic tool for the diagnosis of Guinea pig dental disease, being able to detect early cheek teeth changes (Brenner and others, 2005), (Schweda and others, 2014). Reported dental changes include; fractures, macrodontia, periapical disease, clinical crown elongation and dental spikes (Schweda and others, 2014), (Figure 8 a and b). In pet rabbits, muesli-style diets have been associated with a high occurrence of dental disease and this association is expected to be similar in pet Guinea pigs (Mäkitaipale et al, 2015), (Meredith et al, 2015).

Tibiofemoral osteoarthritis causes a significant health issue in pet guinea pigs (Minarikova and others, 2015), (Keeble, 2021), (Figure 9). Osteoarthritis may occur secondary to dietary and husbandry factors in pet guinea pigs such as obesity, ulcerative pododermatitis, vitamin C deficiency or excess, inadequate exercise, improper substrate or joint trauma (Pignon and Mayer, 2021). Low vitamin C levels have been associated with osteoarthrosis, but even with vitamin C supplementation, osteoarthrosis can still occur in guinea pigs indicating that other factors are likely to be involved in the aetiology of this condition, as is recognised in other companion animal species (Minarikova and others, 2015).

There is scientific evidence in guinea pigs that glucosamine and chondroitin sulfate oral supplements are protective and prevent against the development of osteoarthritis when given from an early age (Taniguchi and others, 2012). Dietary supplements, such as glucosamine and chondroitin sulfate (given orally at 200 mg/kg once a day), may be beneficial in the prevention and treatment of this disease in pet guinea pigs if given early on in the disease course (Keeble, 2021). It is unknown however, whether this same beneficial effect would occur in chronic cases of osteoarthritis, which is often the stage that pet guinea pigs are presented to veterinarians.

Hypovitaminosis C ('scurvy') causes lameness and swollen joints after 2-3 weeks of dietary deficiency due to intra-articular haemorrhage. Animals are also often anorexic, with weight loss, rough hair coat, lethargy, delayed wound healing and occasionally diarrhoea (Figure 10). Animals may also show signs of pain such as teeth grinding and increased vocalisation. Severely affected Guinea pigs may die. Subclinical cases can occur resulting in immunosuppression and secondary issues such as respiratory, skin and gastrointestinal infections (box 4), (Witkowska and others, 2017).

Box 4: Clinical signs associated with Hypovitaminosis C ('scurvy') in pet Guinea pigs

- Lameness and swollen joints due to intra-articular haemorrhage
- Anorexia
- Weight loss
- Rough coat
- Lethargy
- Delayed wound healing
- Evidence of pain – teeth grinding and vocalisation
- Diarrhoea
- Death
- Increased incidence of respiratory, skin and gastrointestinal infections

Guinea pigs are prone to calculi formation (usually calcium carbonate) and there are several suggested predisposing factors, but it is thought that diets high in calcium, together with reduced water intake increase the likelihood of stone formation, since excess calcium is renal excreted, similar to rabbits (Witkowska and others, 2017) (Figure 11).

Guinea pig social interactions, with both positive and negative behaviours, have been reported (Harrup and Rooney, 2020) and Guinea pig behavioural ethograms proposed (Gut and others, 2018), (Dunbar and others, 2016). A potential behavioural relationship associated with diet fed has not been investigated. In pet rabbits fed a muesli only diet, animals spent the least time feeding and the most time inactive (Prebble et al, 2015b) and it is postulated that this could be similar for pet Guinea pigs (box 5).

Box 5: Possible health issues associated with poor nutrition in pet guinea pigs

- Increased morbidity and mortality rates
- Reduced urinary tract health and increased calculi formation
- Dental disease
- Poor gastrointestinal mobility
- Osteoarthritis
- Hypovitaminosis C ('scurvy')
- Reduced environmental enrichment and foraging behaviour

Summary:

By increasing our understanding of the basic nutritional requirements of pet Guinea pigs, positive contributions can be made to improving their overall health and welfare. Currently, however, we lack scientifically robust studies determining the nutritional requirements of pet Guinea pigs in the UK. Feeding trials similar to those conducted in rabbits would help further our understanding of pet Guinea pig nutrition, providing evidence-based recommendations for veterinary staff and educational information for owners, thus significantly improving the welfare of Guinea pigs.

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In Practice Review Article: Guinea pig nutrition

Figure Headings

Box 1: Recommended dietary components for guinea pigs (RSPCA, 2011), (Keeble and Meredith, 2009), (Witkowska and others, 2017), (PDSA, 2022)

Box 2: Vitamin C rich food items for Guinea pigs (PDSA, 2022)

Box 3: Important information on vitamin C supplementation (Witkowska and others, 2017)

Box 4: Clinical signs associated with Hypovitaminosis C ('scurvy') in pet Guinea pigs

Box 5: Possible health issues associated with poor nutrition in pet guinea pigs

Figure 1: **a)** Guinea pigs are social animals and should be kept with companions (photo courtesy of Leah Muirhead). **b)** Group feeding can make it difficult to ascertain individual appetite and animals should be observed daily for any changes in food intake, chewing issues or reluctance to eat.

Figure 2: **a)** Good quality meadow hay should be offered ad-lib daily to Guinea pigs and can be presented scattered, in hay boxes, or racks, or stuffed into cardboard rolls as environmental enrichment. **b)** Fresh grass is a good source of dietary fibre for Guinea pigs. **C)** Leafy greens can be added to the diet daily (approx. 1 teacup per animal per day) and are a good source of vitamin C.

Figure 3: Scatter feeding encourages foraging behaviour in pet Guinea pigs

Figure 4: Fresh water should be offered from a sipper bottle and bowl daily

Figure 5: Urine staining of the perineum can be associated with several factors such as urinary tract infections, urinary calculi and inability to posture due to osteoarthritis. Appropriate vitamin C supplementation may help reduce the incidence of urinary tract infections in Guinea pigs.

Figure 6: Guinea pigs are rarely presented for routine health checks, unlike other pets.

Figure 7: Excessive salivation is a sign of dental disease in the Guinea pig, which can be attributable to lack of abrasive feed in the diet.

Figure 8: a) Severe dental disease in an anaesthetised Guinea pig that presented with inappetance, weight loss and hypersalivation. This animal has incisor malocclusion, with bridging over the tongue of the overgrown mandibular cheek teeth arcades which lead to anorexia. The crowns of the left maxillary cheek teeth are also visible and elongated. **B)** Leafy greens can be hand fed to ill animals and are often preferentially eaten in these cases than concentrates or hay.

Figure 9: Right lateral radiograph in an aged male guinea pig with moderate gastric tympany. Degenerative changes are evident in both stifle joints as a secondary observation, despite some superimposition. These changes were palpable on clinical examination, but had not been noticed by the owner.

Figure 10: Weight loss and lethargy in an aged Guinea pig. One differential diagnosis is hypovitaminosis C.

Figure 11: Left lateral abdominal radiograph in a pet guinea pig that presented with stranguria. A radiodense urolith is evident caudoventral to the pelvis within the urethra. There is also calcification of the meniscal stifle cartilage indicating degenerative joint disease and gas accumulation within the intestines secondary to ileus.

MCQ CPD quiz Guinea pig nutrition

Qu.1: What do Guinea pigs eat in the wild?

- A) High-energy, high fibre, abrasive food
- B) low-energy, high-fibre, abrasive food
- C) High-energy, low-fibre, abrasive food
- D) Low-energy, high-fibre, non-abrasive food

Answer – B) low-energy, high-fibre, abrasive food

Qu.2: What should the bulk of a pet Guinea pig's diet consist of?

- A) Concentrates
- B) Green vegetables
- C) Good quality hay
- D) Dried herbs

Answer C) Good quality hay

Qu 3: What is the daily recommended vitamin C intake for a pregnant Guinea pig?

- A) 5mg/kg/day
- B) 10 mg/kg/day
- C) 15mg/kg/day
- D) 20mg/kg/day

Answer D) 20mg/kg/day

Qu 4: Which of the following is a clinical sign of hypovitaminosis C in the Guinea pig?

- A) Lameness
- B) Pruritus
- C) Ataxia
- D) Excess salivation

Answer A) Lameness

Qu 5: Which of the following may be associated with poor nutrition in pet Guinea pigs?

- A) Melaena
- B) Neoplasia
- C) Dental disease
- D) *Head tilt*

Answer C) Dental disease