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Food Preference and Demand in a Ramp Task in Guinea Pigs (*Cavia porcellus*)

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Guinea pigs (*Cavia porcellus*) are popular pets and used as laboratory animals, however, their dietary preferences are under-studied. It is important for guinea pig owners and carers to increase the opportunity for good animal welfare by providing personalized and enriching dietary options. Thus, this study aimed to assess the use of paired-stimulus and multiple-stimulus-without-replacement preference assessments to determine the food preferences of seven male guinea pigs and test the validity of the methods by testing the demand for the most- and least preferred foods as reinforcers for climbing an elevated ramp. Generally, the preference assessments identified the same foods as the most preferred for each guinea pig, but not the least preferred foods. Guinea pigs climbed up to the steepest angle for both most and least preferred foods, but a non-linear least squares regression and demand analysis indicated faster climbing and inelastic demand for most preferred foods compared to slower climbing and elastic demand for least preferred foods. Both preference assessment methods were valid in identifying a preferred food, however, the multiple-stimulus-without-replacement assessment was more efficient to conduct. High-preference foods such as parsley and dandelion are recommended as future training reinforcers for guinea pigs and as foods to consider using as enrichment in captive guinea pig systems to encourage good welfare.

Keywords: behavioral economics, guinea pig, preference assessment

傾斜課題におけるモルモットの食物の嗜好性と需要

モルモット（*Cavia porcellus*）はペットとして人気があり，実験動物としても利用されているが，その食物嗜好性については十分に研究されていない．モルモットの飼い主や 飼育者は，個体に合った充実した餌を提供することで，動物福祉を向上させる機会を増やすことが重要である．そこで本研究では，対刺激提示法と多刺激非置換提示法を利用して 7 匹の雄モルモットの食物嗜好性を評価し，最も嗜好性の高い食品と最も嗜好性の低い食品を，高架スロープを登る際の強化子として用い，需要をテストすることで，これらの方法の妥当性を検証することを目的とした．全般的に嗜好性評価では，各モルモットが最も好む餌料は同じであったが，最も好まない食餌料は異なった．モルモットは，最も嗜好性の高い餌と最も嗜好性の低い餌の両方において最も急な角度まで登ったが，非線形最小二乗回帰と需要分析によると，最も嗜好性の高い餌は登るのが速く，非弾力的需要であるのに対し，最も嗜好性の低い餌は登るのが遅く，弾力的需要であった．どちらの嗜好性評価法も好みの餌を特定するのに有効であったが，多刺激非置換提示法の方がより効率的に評価することができた．パセリやタンポポのような嗜好性の高い餌料は今後，モルモットの訓練強化子，およびモルモットの飼育においてエンリッチメントに使用することを検討すべき餌料として推奨される．

キーワード：行動経済学，モルモット，嗜好性評価

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Preferencia y Demanda de Alimentos en una Tarea de Rampa en Conejillos de Indias (*Cavia porcellus*)

Los conejillos de Indias (*Cavia porcellus*) son mascotas populares y se utilizan como animales de laboratorio, sin embargo, sus preferencias dietéticas están poco estudiadas. Es importante que los dueños y cuidadores de conejillos de Indias aumenten las oportunidades de lograr un buen bienestar animal proporcionando opciones dietéticas personalizadas y enriquecedoras. Por lo tanto, este estudio tuvo como objetivo evaluar el uso de evaluaciones de preferencias con estímulos pareados y estímulos múltiples sin reemplazo para determinar las preferencias alimentarias de siete conejillos de Indias machos y probar la validez de los métodos probando la demanda de los alimentos más y menos preferidos como reforzadores para subir una rampa elevada. En general, las evaluaciones de preferencias identificaron los mismos alimentos como los más preferidos por cada conejillo de Indias, pero no los alimentos menos preferidos. Los conejillos de indias treparon hasta el ángulo más pronunciado tanto para los alimentos más preferidos como para los menos preferidos, pero una regresión de mínimos cuadrados no lineal y un análisis de demanda indicaron un ascenso más rápido y una demanda inelástica para los alimentos más preferidos en comparación con un ascenso más lento y una demanda elástica para los alimentos menos preferidos. Ambos métodos de evaluación de preferencias fueron válidos para identificar un alimento preferido, sin embargo, la evaluación con estímulos múltiples sin reemplazo fue más eficiente de realizar. Se recomiendan alimentos de alta preferencia como el perejil y el diente de león como futuros reforzadores del entrenamiento para conejillos de Indias y como alimentos a considerar para usar como enriquecimiento en sistemas de conejillos de Indias en cautiverio para fomentar un buen bienestar.

Palabras clave: economía de conducta, conejillo de Indias, evaluación de preferencias

Guinea pigs (GPs; *Cavia porcellus)* are a popular species of household pet due to their calm disposition, small size, and low-maintenance requirements (Sachser et al., 2007). While their dietary requirements have been identified (Lykkesfeldt et al., 2007; O'Dell et al., 1957; Witkowska et al., 2017), studies on their food preferences are sparse (Begum-Diamond et al., 2022). Knowledge of these preferences is essential in providing optimal husbandry, as providing highly-valued foods has been shown to have implications for both mental state and nutritional health (Alegría-Morán et al., 2019; Hewson-Hughes et al., 2011). As there is currently no standard of care, or guide to feeding or using food types as enrichment for GPs, this study aims to compare the accuracy of two preference assessment methods and relative demand for valued foods in GPs. This information will contribute to the body of knowledge and facilitate methods for providing opportunities for improved welfare, and to potentially inform their future care standards for the 38,000 GP owners in New Zealand (Companion Animals New Zealand, 2020).

Under the New Zealand Animal Welfare Act 1999, animal caregivers have an obligation to attend to their animals' welfare and behavioral needs. To meet these behavioral needs, Amdam and Hovland (2011) state that caregivers should provide animals with choice opportunities that align with their natural foods. Ultimately, offering animals choice and control within their environment encourages good animal welfare (Amdam & Hovland, 2011; Englund & Cronin, 2023; Martin-Wintle et al., 2015). Browning and Veit (2021) describe how choice can allow for natural behavioral expression and can enhance an animal's ability to cope within its environment. Amdam and Hovland (2011) also state that choice provision can provide owners and carers with insight into requirements and resources that are important for animal welfare. By offering captive animals' different foods as enrichment items, individual preferences and species behavioral needs can develop, which can inform ethical animal management adjustments.

Conversely, a lack of choice and control within the environment has been shown to be detrimental to captive animals. For example, Birkett and Newton-Fisher (2011) showed how the deprivation of choice in captive chimpanzees (*Pan troglodytes*) led to greater frustration, abnormal behaviors such as rocking, and increased stress. The study described how providing greater autonomy and choice can improve well-being and even reproductive success. On the other hand, too much choice within captivity, such as excess food or unhealthy options, might lead to illness (Browning & Veit, 2021), as observed in captive possums (*Trichosurus vulpecula,* Cameron et al., 2021).

Preference Assessments

Preference assessments are instrumental for veterinarians, researchers, and animal caregivers in identifying animal preferences (Dawkins, 2004). Therefore, the accuracy and efficiency of these methods is vital in order to utilize the results in training or husbandry practices or to facilitate therapeutic practices between human and non-human animals (Boughton & Abramson, 2023). Cameron et al. (2021) identified that context can be an important factor in the use of preference assessments. This was because the outcome, in their case determining a preferred reinforcer for use in dog (*Canis lupus familiaris*) training, was dependent on the preference assessment used in reinforcer identification, and that use of the resultant reinforcer might only work in a similar context to how it was measured.

A common preference assessment method used in animals due to simplicity is the paired stimulus (PS) preference assessment. This method measures preference between two simultaneously provided foods, while recording which is selected or consumed. To determine a rank order of preference each commodity is paired with every other commodity and offered to the participant. Thus, depending on the number of test items, it can require many sessions to formulate a rank order (Hall et al., 2017; Martin et al., 2018). PS has been used to identify hierarchies of preferences for various species, including dogs (Cameron et al., 2019, 2021; Waite & Kodak, 2023), and possums (Cameron et al., 2013), and can help determine commodities to assist in reinforcing behavior (Fisher et al., 1992).

The multiple-stimulus-without-replacement (MSWO) method compares multiple objects simultaneously (DeLeon & Iwata, 1996). All test commodities are presented together, with each item removed (or consumed) after each selection, providing a simple order of preference (DeLeon & Iwata, 1996). MSWO has been shown to be accurate and efficient for preference assessment in both humans and non-human animals (Cameron et al., 2021; Tobie et al., 2015). MSWO is less time-consuming than PS due to the requirement for fewer trials (Martin et al., 2018) as more item comparisons are performed simultaneously, MSWO may be less demanding on the individual (Cameron et al., 2021). However, MSWO could be impractical within an already stressed environment, such as an animal shelter (Fulgencio, 2018), or may be awkward if the animal cannot be restrained, such as for wild possums. These issues were not considered problematic for testing GPs.

Ramp Climbing and Demand

Demand is a concept that describes the value of a commodity to an individual and indicates how their behavior might change depending on this internal value (Hursh, 1980). Demand can be measured using different methods, such as elasticity, which describes how much effort or price an individual will exert or pay as it increases in cost. Examples of price or response requirements include the number of responses on a key (e.g., Foster et al., 2009), or the elevation of a ramp (Begum-Diamond et al., 2022), illustrating an increase in effort required to obtain a commodity. The quality of elastic demand is when the effort exerted by an animal reduces proportionally to its increase in cost, whereas inelastic demand is when the effort exerted is not proportional to its increase in cost, and quantity or quality of effortful behavior is flexible to increases in price (Hursh & Silberberg, 2008). Elastic demand, in the case of animal preference, indicates an item is not worth the increased effort to obtain, whereas inelastic demand means the item is highly valued and an individual will continue to increase effort to attain it, despite increased cost. The change in response behavior to obtain a commodity of changing price is often termed ‘essential value’ where a smaller alpha value indicates a small change in consumption as response requirement increases (i.e., inelastic demand); versus a larger alpha value indicating a bigger change in consumption as response requirement increases (i.e., elastic demand).

Begum-Diamond et al.'s (2022) study on measuring ramp use in GPs provided proof-of-concept in the use of ramps of different gradients as a way to measure the effort an animal would exert to obtain a resource. The study identified that GPs would climb the ramp to different gradients depending on the schedule of increases (each day or after each climb) and that the operanda could be used to measure the relative demand for different commodities using break point and climbing duration as dependent variables. The same ramp used in Begum-Diamond et al. (2022) was utilised for the current study with the only equipment change being the addition of a mirror, to ensure that the test foods were visible from the bottom of the ramp at all angles.

The Six Study Foods

Textbooks on cavy biology suggest commercial pellets (infused with vitamin C), hay, vegetables, and fruit such as carrot and apple, and high-protein foods such as oats, corn and wheat as regular dietary items for foods (Warren, 2015). However, they do not discuss dietary preferences and how to measure them in GPs. Thus, in the selection of test foods for the current experiment research, discussions with experienced GP owners were conducted to ensure a robust but varied selection. The test foods were chosen as potential high-value items for training reinforcers or enrichment opportunities, except for pellets, which were chosen as a staple option common for all GPs. The test foods were apple, broccoli, carrot, dandelion, parsley, and commercial pellets. Pellets are a staple dietary component providing fibre and nutrients (Mancinelli, 2016). Broccoli and carrots reportedly wear down continuously growing teeth (Bligh, 2021; Garner-Richardson, 2012) and broccoli provides a source of β-carotene (Calloway et al., 1963), and other nutrients (Bligh, 2021). Dandelion leaves were suggested by an experienced GP owner and researcher (K. Cameron, personal communication, April 25, 2023) and contain healthy sources of vitamin C (Mancinelli, 2016), but will be given in small amounts to avoid high calcium oxalate levels (Garner-Richardson, 2012). Apple should be given sparingly, as although it provides vitamin C (Purdue University College of Veterinary Medicine, n.d.), dietary fibre, and antioxidants, excessive consumption can cause acidity or high sugar levels (Garner-Richardson, 2012).

The aim of this study is to measure the preferences for foods in GPs using PS and MSWO methods and to evaluate the validity of these methods by measuring demand for the most- and least-preferred foods as reinforcers for climbing behavior in an elevated ramp. It is expected that most preferred foods will show higher demand with faster movement in the ramp than least preferred foods.

Method

Guinea Pigs and Husbandry

Seven male GPs (approximately seven months old) participated in this experiment named A (Adam), B (Bernard), C (Chip), G (Gus), H (Hammond), I (Ivan), and J (Jake; Table 1). The GPs were sourced from Auckland Cavy Care and fostered at Te Puna Kararehe (Animal behaviour and husbandry unit) at Unitec in Auckland New Zealand from February to October 2023. Of the original 10 animals used for a prior experiment, three GPs were rehomed early due to incompatibility with their housing pair. All GPs were adopted to their forever homes after the study. They were housed in their original bonded pairs in C&C cages (indoor cage systems) of 1.4 m long by 0.70 m width and 0.35 m wall height, which included appropriate hides, hay, and tunnels. The GPs were also used for animal management and veterinary nursing handling practise by students. Each GP was weighed prior to each experimental session, received a distance exam each day, and a health check every week. The GPs were young and still growing, so a record of their growth each weighing was monitored. Ethics for this experiment were approved by the AgResearch Animal Ethics committee: protocol 487.

Table 1

Details of the Weight Range and Average Biweekly Browth of Each Guinea Pig.

Guinea pig	Weight range (grams) (Average biweekly weight growth (grams))	Preference assessment order	Demand assessment order (Most or least preferred food determined by PS or MSWO)
A	690 – 1001 (3.8)	PS, MSWO	Most (both PS/MSWO) then Least (PS) then Most (MSWO)
B	640 – 966 (4.1)	PS, MSWO	Most (both PS/MSWO) then Least (both PS/MSWO) then *Grass
C	470 – 782 (4.2)	PS, MSWO	Most (both PS/MSWO) then Least (PS) then Most (MSWO)
G	810 – 970 (1.6)	PS, MSWO	Most (both PS/MSWO) then Least (MSWO), then **Most (PS/MSWO 1 session) then Least (PS)
H	860 – 1122 (3.0)	MSWO, PS	Most (both PS/MSWO) then Least (MSWO) then **Most (both PS/MSWO 1 session) then Least (PS)
I	700 – 960 (3.2)	MSWO, PS	Most (MSWO) then Least (MSWO) then Most (PS) then Least (PS)
J	560 – 786 (2.9)	MSWO, PS	Most (MSWO) then Least (MSWO) then Most (PS) then Least (PS)

Note. * GP B did not respond to least preferred food, thus grass was tested. ** As the same food was previously tested, one session was run to ensure no carry-over effects using the least preferred food. The animals were approximately 4 months old and weight gain was expected. Preference assessment (PS – paired stimulus, MSWO – multiple stimulus without replacement) and demand assessment presentation order of foods based on determination of most or least preferred foods by the preference assessment.

After researching appropriate rations and discussions with experienced cavy owners, five foods (i.e., carrot, parsley, broccoli, apple and pellets (Burgess Excel®)) were supplied by the unit, and dandelion (*Taraxacum aequilobum*) was sourced from locations around the Unitec Mount Albert campus, among other locations around West Auckland, New Zealand. The technicians at the unit provided small amounts of each food in the GP enclosures in the weeks leading up to the experiment to ensure that the GPs were familiar with the foods.

In the preference assessments, a large pinch of parsley, dandelion and pellets and a piece of 1 cm^3 apple, broccoli and carrot were considered equal presentation of each food due to widely varied size, texture, and shape. It was more important that each food sample was obvious to the GP.

Apparatus

All experiments were carried out in the same research room attached to an ectotherm room. The room was secluded and had an air conditioner that kept the room between 20-21°C during the experiment. There was a single window that provided light but was not in direct sunlight when the experiment was carried out. A carry cage was used to move the pairs of GPs from their home cage to the research room. For the preference assessments, a 60 cm × 60 cm box with a towel covering the bottom was used. The test foods were placed about 5 cm apart at one end of the box. During the trials, a GP was placed about 5 cm from the middle point between the foods. For the MSWO assessments, the GPs were placed into the same box as the PS assessments, with all six foods placed in a semi-circle around where the animal would be placed—about 2 cm apart.

The demand experiment was conducted using a custom-built ramp made from untreated plywood and painted white with non-toxic paint (Figure 1). It was 17 cm wide and 120 cm long, with rungs cut into the wood 2 cm apart. The angle of the ramp could be manipulated by lifting the ramp in 3 cm increments and placing two bolts through a conduit to hold the ramp in place. The start and finish boxes (17 cm by 30 cm) remained horizontal and were lined with newspaper. Safety latches held the start and finish boxes in place at the set angle.

Procedure

Each GP experienced three sessions of PS preference assessment over three days consisting of 30 trials total, and three sessions of MSWO preference assessment consisting of three assessments per session as was also used in Cameron et al (2021). Each assessment consisted of five trials. GPs A, B, C, and D experienced the PS first, whilst GPs G, H, I, and J experienced the MSWO first, then the alternative assessment. Sessions were performed in the morning between 8:00 a.m. and 10:00 a.m., before typical daily rations were delivered to ensure adequate food drive to climb the ramp. Daily rations consisted of fresh greens (such as grass [*Dactylis glomerata*], meadow grass [*Poa annua*], clover [*Trifolium repens*], and dandelion with constant access to hay and water). At 2:00 p.m., food was presented to each pair made up to consist of 30 g pellets, 30 g vegetables (e.g., carrot, beans, tomato) and 20 g of fresh greens.

A choice was defined as the GP consuming a mouthful of the test food, which took approximately 3-5 s to consume. A session consisted of thirty trials, with each food paired with every other food and offered on the left and right side of the pair. If a food was not chosen within 2 min, the conditions were reset, and the next trial of two new foods was presented. Between trials, the GP was removed to set up the next pair. The foods selected were recorded, with the food chosen the most out of 10 presentations ranked as the most preferred. These ranks were tallied over all three PS sessions to provide an overall ranking, which determined the most and least preferred foods for each GP. A food needed to be selected at least once, rather than never, to be considered the least preferred food. If a food was never selected in the preference assessment it was not tested in the experiment as it would not promote any behavior and would not allow comparison of climbing behavior as the dependent variable (see Cameron et al., 2015).

For the MSWO assessments, the first food chosen by the GP was recorded as the first choice. The GP was removed, and the test foods were moved one space to the right (with the right-most returning to the left-most position). This continued until all foods were chosen. To work out the rank order of foods, a point system was used. If a food was chosen first, it was assigned 5 points; if second, it was assigned 4 points and so on. These points were added up for the three sessions over three days with food with the most points ranking as most preferred.

A color-coded agreements table was created to compare these rankings between the PS and MSWO assessments and identify the most and the least (consumed) preferred food for testing as a reinforcer in the ramp.

Demand Testing

The GPs were experienced in climbing the ramp to receive grass due to participation in a prior study confirming the functionality of a mirror on the top of the finish box to ensure line-of-sight with the food at every angle.

The most and least preferred foods for the PS and MSWO for each GP were used as reinforcers for climbing the ramp. Each GP experienced a maximum of 12 sessions (one per day) climbing the ramp, with three consecutive sessions for each food. The foods tested were the most preferred food identified by the PS and MSWO and the least preferred as identified by the PS and MSWO assessments—making a maximum of four potential foods. The order of testing was randomized. If the same food was identified by multiple assessments, the GP was required to only climb the ramp for a single set of sessions, with a single session between the sessions for the least preferred foods to offset previous lower responsivity for a lower valued food which was not analyzed.

Prior to the first trial of the day, the GP was placed in the end box of the ramp to sample the test commodity of the session. The ramp height was set at 0 cm in the first trial of the session (horizontal). After each successful ramp run the height was increased by 6 cm using the Progressive Effort Condition (PEC) schedule in Begum-Diamond et al. (2022). The climb duration was recorded from when the whole body of the GP crossed a line drawn on the outside of the ramp at the point when the elevation started from the horizontal start box to when it crossed the line indicating the end of the gradient and horizontal finish box with any part of the body. This was recorded with a stopwatch phone application and immediately inputted into a data spreadsheet. GPs were allowed to have a portion of the food at the top of the ramp (30 s of eating), before being placed into a temporary holding crate whilst the ramp was set to the next height. If the guinea failed to climb a height after 2 min, they were removed for 2 min and then the height was retried. The session was terminated if the GP did not climb the ramp a second time.

Data Analysis

To compare the reliability of the preference tests, non-parametric Friedman analyses were used to compare the rank orders of foods within- and across preference assessments.

To analyze the ramp climbing data, the last completed successful ramp height climbed for each GP was recorded as the 'break point' for each food tested, and the time to complete each climb was recorded. This was tabulated in Excel®. Demand curves for each demand-tested food for each GP were calculated using the exponential model of demand (non-linear least squares regression, Hursh & Silberberg, 2008, Eq 6) in Excel®.

$$\text{Log}(Q) = \log(Q_0) + k(e^{-\alpha Q_0 C} - 1) \qquad \text{Eq 6.}$$

Traditionally, the model is fit to the number of lever or key presses, or duration (in seconds) at each response requirement (cost, price, or ramp height). However, the analysis using this traditional method failed to represent the behavior of the GPs at higher elevations (showing a decline, rather than illustrating a considerable increase in speed), thus the regression was fit to the proportion of average time spent in the ramp at each height (log height in centimeters) out of the total time to accurately depict behavior graphically. The proportion of time spent climbing is presented as a logged value squared, thus, smaller durations are presented as larger logged values to graphically represent an increase in demand for a commodity.

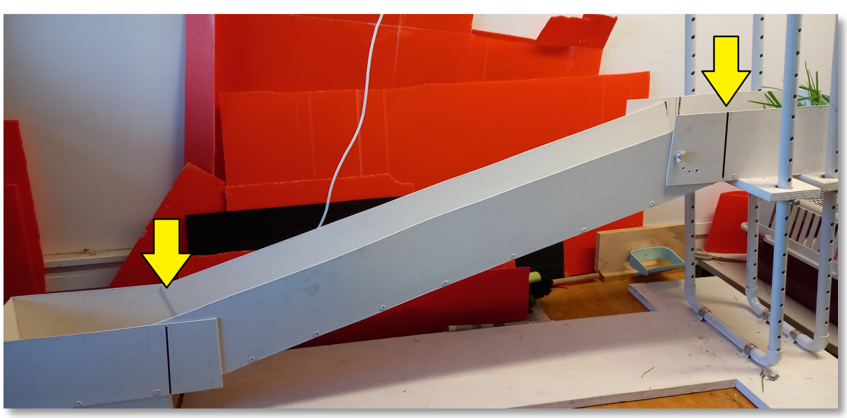
$$\text{Log}(Q/\Sigma Q)^2 = \log(Q_{0p}) + k(e^{-\alpha Q_0^p C_p} - 1) \qquad \text{Eq. 6 modified}$$

The parameter, C_p, is the proportion of time spent at each elevation; Q_0 is the initial demand, as a proportion of total time spent in the ramp, estimated when the commodity is 'free,' Q_0 is also the y-intercept. Alpha (essential value of the commodity) α, is a measure of the rate of change in elasticity as elevation increases. When this value is large, it indicates that the cost of the commodity is affecting responding behavior indicated by the size of the curve, and if positive indicates that the curve moves upward as cost increases—reflecting that the animal is moving faster to obtain the food when cost or effort is greater. The parameter k is the range of proportions based on each climb duration for each height for each GP.

A Fisher exact test was calculated to assess the validity of the most valued food from each of the preference assessments to the results of the demand assessment in the derived parameters for each food and assessment generated by the model using SPSS™ (Version 22).

Figure 1

Custom-Built Ramp Set to a Height of 30 cm



Note. The lines that the yellow arrows point to indicate start and stop locations.

Results

Preference Assessments

The most and least preferred foods were identified for each GP by the PS and MSWO methods (Table 2). For 5/7 GPs (A, B, C, G, H), the same most preferred food was chosen in both the PS and MSWO assessments. Dandelion was chosen most often across GPs, followed by both parsley and apple. The rank order of the most preferred foods for the remaining two GPs (I & J) were within one rank and were one of the three top foods: For 3/7 GPs (B, C, & J), the same least preferred food was chosen in both PS and MSWO assessments – this was either broccoli or carrot. Parsley (A & G) and pellets (I) were also chosen the least in the PS assessment but not the MSWO assessment for three GPs, and one GP (H) chose dandelion as their least preferred food in the MSWO assessment, whereas the same food was ranked 2nd in the PS assessment.

The PS and MSWO preference assessments were conducted three times each and resulted in a consistent rank order of foods for each GP within each session. For the PS assessment: GP A ($\chi^2 = 0.58$, $p = .7471$), B ($\chi^2 = 0.83$, $p = .959$), C ($\chi^2 = 1.75$, $p = .417$), G ($\chi^2 = 0.08$, $p = .959$), H ($\chi^2 = 0.083$, $p = .959$), I ($\chi^2 = 0.25$, $p = .883$), J ($\chi^2 = 0.75$, $p = .687$). For the MSWO assessment: GP A ($\chi^2 = 0.25$, $p = .883$), B ($\chi^2 = 0.58$, $p = .747$), C ($\chi^2 = 0.25$, $p = .883$), G ($\chi^2 = 0.08$, $p = .959$), H ($\chi^2 = 0.33$, $p = .847$), I ($\chi^2 = 1.1$, $p = .588$), J ($\chi^2 = 0.0$, $p = 1.00$). There were similar rank orders of preference between the PS and MSWO assessments: GPs A ($\chi^2 = 0.17$, $p = .683$), B ($\chi^2 = 0.0$, $p = 1.0$), C ($\chi^2 = 0.0$, $p = 1.0$), G ($\chi^2 = 0.17$, $p = .683$), H ($\chi^2 = 0.17$, $p = .683$), I ($\chi^2 = 0.0$, $p = 1.0$) and J ($\chi^2 = 0.00$, $p = 1.0$) indicating both preference assessments provided the same estimation of food value to each GP.

Table 2

Ranking for Foods (1-most preferred, 6-least preferred) for the Paired stimulus (PS) and Multiple Stimulus Without Replacement (MSWO) Assessments.

	A		**B**		**C**		**G**		**H**		**I**		**J**	
	PS	MSWO	PS	MSWO	PS	MSWO	PS	MSWO	PS	MSWO	PS	MSWO	PS	MSWO
Apple	5	5	5	4	5	5	4	3	1	1	2.5	4	2	1
Broccoli	4	6	6	6	2	4	6*	6*	6	2.5	5	3	6	6
Carrots	3	4	3	2.5	6	6	3	5	3.5	5	4	6	4.5	4.5
Dandelion	1.5	1	2	2.5	1	1	1	1	2	6	2.5	1	1	2
Parsley	6	2	1	1	3	3	5	4	3.5	2.5	1	5	4.5	3
Pellets	1.5	3	4	5	4	2	2	2	5	4	6	2	3	4.5

Note. Dark green (high preference) or red (low preference) indicates perfect agreement between a single food identified in the PS and MSWO. The bolded numbers indicate the food that was to be used in the demand assessment.

Demand Testing

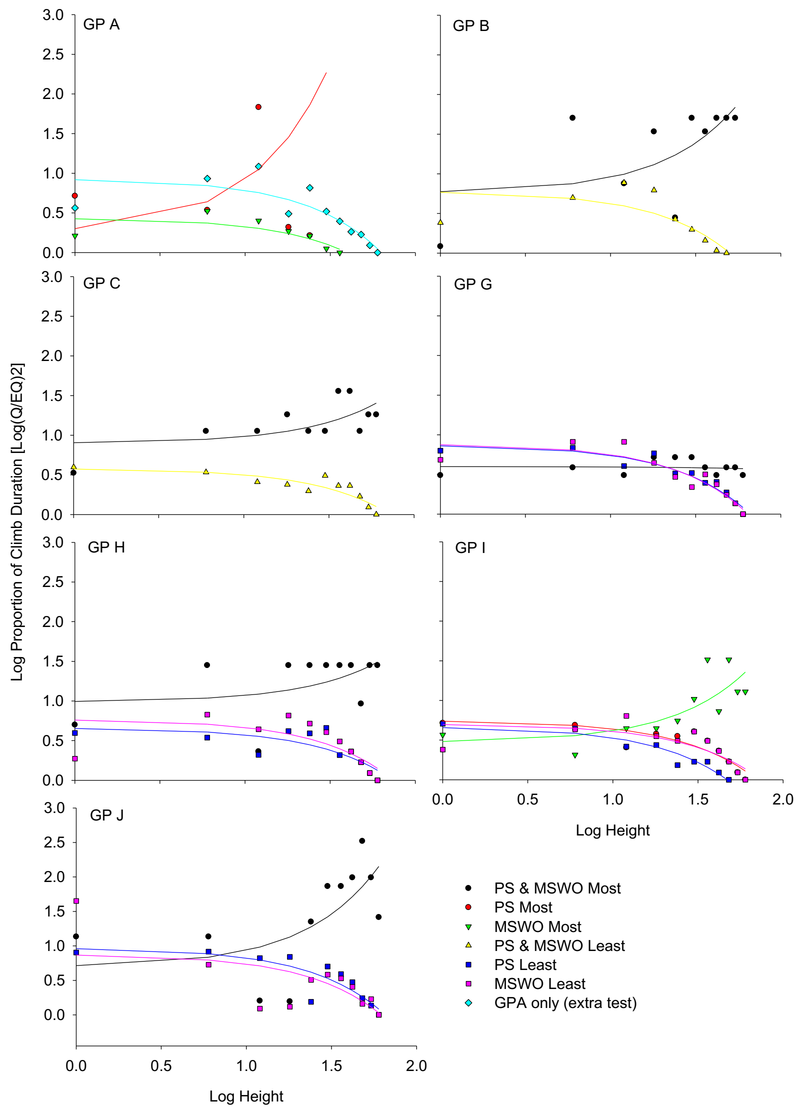
The break point was the maximum height the GPs climbed successfully (Table 3). GPs C, G, H, I and J reached the maximum ramp height of 60 cm for both their most and least preferred foods identified in the PS and MSWO preference assessments. Due to the lack of utility of the breakpoint to separate value for most- versus -least preferred foods, analysis of the climb durations provided a relative measure of demand for different foods. GP A did not respond in the ramp for the least preferred food, so to test the reliability of the task, grass was provided as the reinforcer, for which, GP A climbed the ramp to a height of 60 cm to obtain.

The exponential model of demand, adjusted for proportions of climb duration, fit the data well, with the variance accounted for being greater than 82.9% (*SE* = 8.0% – 1.6%; Table 3). Figure 2 shows the proportion of the average time spent climbing the ramp at each height for each food for each GP and the best-fit line as derived by the non-linear least squares regression. Generally, for most preferred foods identified in the PS and MSWO assessments, the fitted line is an upward curve, and the model predicted a large with a negative essential value (alpha; *M* = -0.025, *SE* = 0.016) and indicates inelastic demand for foods. In contrast, the curves for foods identified as least preferred are directed downward, with a positive essential value (*M* = 0.001, *SE* = 0.0004), and indicates elastic demand for foods. This indicates that the GPs were speeding up to obtain a preferred food and slowing down when the reinforcer was not a valued food, as ramp height increased. Fisher Exact tests revealed a significant association between the essential value if a food was considered most- or least-preferred and resulted in a negative or positive value (*p* = .0031).

The derived parameter indicating initial demand ($LogQ_0$) when the commodity required no effort was required to obtain a food (it was free), was lower on average for the most preferred foods (*M* = 1.41, *SE* = 0.26) compared with the least preferred food (*M* = 2.21, *SE* = 0.09). This is depicted as the y-intercept on the graphs in Figure 2. This indicates that at low cost, GPs are predicted to move faster for most preferred foods, spending less time climbing, than least preferred foods.

Figure 2

Log Proportion of Average [Log $(Q/\Sigma Q)^2$] as a Function of Log Height for Most and Least Preferred Foods Identified by the PS and MSWO Preference Assessments for each Guinea Pig.



Note. The best-fit line is derived using the non-linear least squares regression model modified for use with proportions.

Table 3

Derived Parameters From The Non-Linear Least Squares Regression And Modified Exponential Demand Model.

		α – ('essential value' - rate of change in curve as a function of height)		Q_{0p} (initial climb duration proportion)		k (range of climb duration proportions)		VAC (variance accounted for by the model)		SE (Standard Error of the mean)		Break point height in cm	
		PS	MSWO	PS	MSWO	PS	MSWO	PS	MSWO	PS	MSWO	PS	MSWO
Most	A	-0.1559	0.0088	1.26	1.55	0.33	0.81	0.999	0.996	1.60	0.15	30	60
	B^	-0.0202		0.53		0.46		0.986		0.55		54	
	C^	-0.0260		0.19		0.13		0.829		0.26		60	
	G^	0.0044		1.82		0.06	0.06	0.996		0.10		60	
	H	-0.0026		1.93		1.31		0.840		0.31		60	
	I	0.0059	-0.0428	2.12	0.28	0.86	0.22	0.986	0.969	0.08	0.27	48	60
	J	0.0063	-0.0359	2.42	1.99	0.95	0.34	0.991	0.967	0.41	0.62	60	60
Least	A* (grass)	0.0064	-	2.55	-	0.91	-	0.965	-	0.21	-	60	-
	B^	0.0081		2.19		0.89		0.990		0.24		48	
	C^	0.0054		1.79		0.83		0.998		0.10		60	
	G	0.0063	0.0064	2.40	2.44	0.88	0.89	0.995	0.995	0.08	0.13	60	60
	H	0.0055	0.0055	1.94	2.16	0.85	0.88	0.984	0.962	0.16	0.23	60	60
	I	0.0086	0.0054	1.96	2.03	0.86	0.87	0.998	0.983	0.08	0.17	48	60
	J^	0.0063		2.65		0.89		0.991		0.19		60	

Note. Parameters include *α*, essential value, Q_{0p} (initial demand proportion), *k* (range of the proportions), and VAC (variance accounted for by the model), SE (standard error of the mean), and Break point (last completed ratio in centimetres).*Did not respond in the ramp for the least preferred food, grass was used to test the reliability of the task. ^Same food selected for two preference methods.

Discussion

This study tested the preferences for foods of GPs using two preference assessment methods; paired-stimulus, and multiple-stimulus-without-replacement. Both assessments generally identified the same most preferred food, with slightly less accuracy in identifying the same least preferred food. To test the validity of the preference assessments in accurately identifying a most valued versus lowly preferred food, each GP climbed the ramp to simulate an increase in effort required to obtain each food. The GPs climbed the ramp faster for their most preferred foods compared to their least preferred foods, confirming the utility of preference assessments as a method to value foods in cavies.

The preference assessments identified that most GPs preferred either dandelion, apple or parsley, and did not prefer broccoli and carrot. The precise rank order of foods was different for each GP, however, there are idiosyncratic preferences across GPs, much like is found in possums (Cameron et al., 2013) and dogs (Cameron et al., 2021). Previous studies suggest tailoring reinforcers to the individual to retain motivation in training (Vicars et al., 2014) and for negative aversive experiences such as in handling or medical checks. In addition, catering for individual food preferences to increase well-being (Amdam & Hovland, 2011) and to encourage natural behavior such as foraging for a preferred food (Alegría-Morán et al., 2019; Hewson-Hughes et al., 2011; Martin-Wintle et al., 2015; Mayntz et al., 2009). Although there was a reduced accuracy in identifying a definitive least preferred food for each GPs, the assessments identified a range of foods of value to guineas that could be used to encourage making choices within captive environments which could foster good welfare practices (Amdam & Hovland, 2011), to offer opportunities to emulate choices in the wild, or to ensure all nutritional requirements can be met.

The reasons for the difference in preference may be due to differing nutrient content, palatability, or novelty of presentation during the preference assessment. For example, parsley and dandelion are richer in vitamins K, C, iron, folate, copper, calcium, magnesium, zinc and potassium than carrot, broccoli and apple (Food Struct, n.d.). Arguably, the daily pellets contain a concentrated blend of nutrients for GPs but are likely less palatable, and as they are always available in the home enclosure which, in comparison to foods offered sporadically, would not be preferred. Fresh parsley and dandelion are offered rarely to the GPs as potentially part of their daily fresh greens, therefore, presentation of these foods had a novelty factor. In dogs, foods that are uncommon are preferred over staple foods if effort is required to obtain them and are therefore are more likely to function as effective reinforcers for training (Cameron et al., 2019). Further, if given a choice, captive brushtail possums would choose foods high in sugar (berries) first, then foods high in protein and fat (e.g., locusts *Locusta migratoria*; Cameron et al., 2013). However, if the possum was required to earn the food via lever pressing, the possums would put more effort into earning the more nutrient dense foods over those of that were higher in sugar (Cameron et al., 2015).

The nutrient content, palatability and ease of obtaining the commodity are likely to impact choice. Cameron et al. (2021), proposed that the ability of the preference assessment to accurately identify a valued food for a dog was dependent on the similarity of the context of that assessment to training. In this experiment, effortful behavior (walking a virtual runway) was required prior to making a choice in either a PS or MSWO assessment. Overall, the MSWO was more accurate in identifying a reinforcer as each trial offered the most preferred of all the options (even when done to two or three options) but more trials would provide a valued reinforcer. In comparison, in the PS, a high proportion of trials would not have offered a valued reinforcer for the runway behavior, thus the MSWO always offered the most valued reinforcer first contingent on the target behavior, similar to training, and thus was the more accurate assessment of preference. In GPs, both assessments offered the foods for no effort, they barely had to move to make a choice, thus the presentation resulted in both assessments identifying similar rank orders of preferences, similar to how food is presented in the home enclosure in a pile. In saying this, the experimenters agree that the MSWO was faster and less intense compared to the PS assessment which often required two sessions to complete, a conclusion in line with the findings of Cameron et al. (2021).

The non-linear least regression using the modified demand equation was adequate for describing the change in ramp climbing behavior as the elevation increased. Nearly all GPs increased their rate of movement for most valued foods, shown by an upward function and larger negative essential value as the elevation increased. This indicated a substantive change in pace as elevation increased to continue to obtain the valued foods. In comparison, for foods identified as least preferred in the preference assessments, the function turned downward and resulted in a smaller and positive essential value, indicating the GPs were slowing down with not as much change in pace as elevation increased, as there was for a valued food. In other words, the GPs would work harder to obtain a most preferred food than a least preferred food, and the method for testing guinea preferences is not limited to foods but could be expanded to commodities of substrate, enrichment items or to empirically assess the need for GPs to be housed in pairs.

Ramp use in GPs was identified by Begum-Diamond et al. (2022) as a positive application to husbandry and management of GPs. As GPs will climb steep ramps, they can be used to maximize floor space, or encourage exploration and foraging for highly valued foods as enrichment. The maximum breakpoint achieved over all the GPs was 29.1 cm, which was an angle of 15 degrees. In the current study, all GPs achieved maximum ramp climbs of over double this height, 60 cm, likely due to a consistent line of sight achieved by the addition of a mirror at the top of the ramp. Thus, this study emphasises the application of ramps to improving husbandry. However, it is important to consider the physical ability of the individual animals and assess their ability to climb steep ramps, without creating barriers to resources by restricting food, water, or items associated with behavioral needs, such a hides or hay, with an effortful behavior (Begum-Diamond et al., 2022).

The current experiment was conducted as the second in a series with the same 10 GPs. At the point when the experiment started some of the GPs had started displaying aggression to their cage mates. Due to two GPs needing to go back to the rescue for castration, and others starting to show similar behavior, the experiment had to be shortened where instead of increasing the elevation by 3 cm each day, the elevation was increased after each successive climb by 6 cm, similar to the progressive effect condition in Begum-Diamond et al. (2022). This decreased the number of trials available before reaching the top value, thus providing fewer data points and resulting in the redundancy of the break point as a dependent variable and measure of preference. Another limiting factor was the maximum ramp height of 60 cm which was succeeded in most sessions for most foods. Increasing the ramp height beyond our limit is likely to have safety implications thus, a different ramp design might be required to measure the top elevation possible for GPs. However, these authors believe that this information may not provide any useful information regarding preference and that the climbing duration is a reliable and safe method for measuring relative demand for commodities.

Research has shown that understanding and providing for animal preference within captivity is vital for optimising welfare, as providing for the psychological and physiological needs of individuals is ensured (Alegría-Morán et al., 2019; Amdam & Hovland, 2011; Browning & Veit, 2021; Hewson-Hughes et al., 2011). This research is important for the development of future welfare regulations or formal recommendations for GPs (such as a future Code of Welfare for GPs in New Zealand), as a validated method for measuring preference. We recommend the use of the MSWO method as it is faster for pet owners and animal laboratories, and using this method we identified that highly valued foods are parsley and dandelion. These would be useful as components of enrichment systems, or to negate potentially aversive procedures such as handling or medical checks. The management and husbandry of pet GPs in New Zealand are inconsistent (Cameron et al., 2022a, b), and studies that offer methodologies for measuring animal needs are important for proffering solutions for owners including ways to identify and provide for tailored enrichment (Hunt et al., 2022; Mehrkam & Dorey, 2014), improved health and behavioral expression including choice (Amdam & Hovland, 2011), and potentially create a stronger human and non-human animal relationship (Rault et al., 2020), are all important components of positive animal welfare.

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References

Alegría-Morán, R. A., Guzmán-Pino, S. A., Egaña, J. I., Sotomayor, V., & Figueroa, J. (2019). Food preferences in cats: Effect of dietary composition and intrinsic variables on diet selection. *Animals*, *9*(6), 388. https://www.doi.org/10.3390/ANI9060372

Amdam, G. V., & Hovland, A. L. (2011). Measuring animal preferences and choice behavior. *Nature Education Knowledge*, *3*(10), 74. https://www.nature.com/scitable/knowledge/library/measuring-animal-preferences-and-choice-behavior-23590718/

Animal Welfare Act. (1999). New Zealand Statutes. https://www.legislation.govt.nz/act/public/1999/0142/latest/DLM49664.html

Begum-Diamond, Z., Neuhauser, J. E., & Cameron, K. E. (2022). Measuring ramp use in guinea pigs (*Cavia porcellus*). *Journal of the Experimental Analysis of Behavior*, *118*(2), 292–301. https://www.doi.org/10.1002/JEAB.783

Birkett, L. P., & Newton-Fisher, N. E. (2011). How abnormal is the behaviour of captive, zoo-living chimpanzees? *PLoS ONE*, *6*(6), e20101. https://www.doi.org/10.1371/journal.pone.0020101

Bligh, J. (2021, August 24). *Can guinea pigs eat broccoli? (Safety and nutrition)*. Guinea Pig Hub. https://www.guineapighub.com/can-guinea-pigs-eat-broccoli/

Boughton, B. A. & Abramson, C. I. (2023). The role of comparative psychology in the training of veterinarians. *Animals, 13(14)*, 2315, https://www.doi.org/10.3390/ani13142315

Browning, H., & Veit, W. (2021). Freedom and animal welfare. *Animals*, *11*(4), 1148. https://www.doi.org/10.3390/ANI11041148

Calloway, D. H., Newell, G. W., Calhoun, W. K., & Munson, A. H. (1963). Further studies of the influence of diet on radiosensitivity of guinea pigs. *The Journal of Nutrition*, *79*(3), 340–348. https://www.doi.org/10.1093/JN/79.3.340

Cameron, K. E., Bizo, L. A., & Starkey, N. J. (2013). Food preferences of the Brushtail Possum (*Trichosurus vulpecula*). *International Journal of Comparative Psychology*, *26*, 324-336. https://doi.org/10.46867/ijcp.2013.26.04.01

Cameron, K. E., Bizo, L. A., & Starkey, N. J. (2015). Assessment of demand for food using concurrent PR and FR schedules in the brushtail possum (Trichosurus vulpecula). *International Journal of Comparative Psychology, 28.* https://doi.org/10.46867/ijcp.2015.28.00.06

Cameron, K. E., de Garnham, J., Jensen, K. & Bizo, L. A. (2019). Food preference predicts speed approach on a runway task by dogs. *Pet Behaviour Science*, *18*(8), 1–10. https://www.doi.org/10.21071/pbs.v0i8.11179

Cameron, K. E., Siddall, A., & Bizo, L. A. (2021). Comparison of paired-and multiple-stimulus preference assessments using a runway task by dogs. *International Journal of Comparative Psychology*, *34*, 1–14. https://www.doi.org/10.21071/pbs.v0i8.11179

Cameron K.E., Holder, H. & Connor, R. (2022). Cross-sectional survey of housing for pet guinea pigs (Cavia porcellus) in New Zealand. *New Zealand Veterinary Journal, 70*(4), 228–232. https://www.doi.org/10.1080/00480169.2022.2050320

Cameron K.E., Holder, H., Connor, R. L. & Gear, R.N.A. (2022). Cross-sectional survey of husbandry for pet guinea pigs (Cavia porcellus) in New Zealand. *New Zealand Veterinary Journal, 71(1),* 27–32. https://www.doi.org/10.1080/00480169.2022.2129854

Companion Animals New Zealand. (2020). *Companion Animal Report*. https://www.companionanimals.nz/2020-report

Dawkins, M. S. (2004). Using behaviour to assess animal welfare. *Animal Welfare*, *13*, S3–S7. https://www./doi.org/10.1017/S0962728600014317

DeLeon, I. G., & Iwata, B. A. (1996). Evaluation of a multiple-stimulus presentation format for assessing reinforcer preferences. *Journal of Applied Behavior Analysis*, *29*(4), 533. https://www.doi.org/10.1901/JABA.1996.29-519

Englund, M. D., & Cronin, K. A. (2023). Choice, control, and animal welfare: Definitions and essential inquiries to advance animal welfare science. *Frontiers in Veterinary Science*, *10(1),* 1–5. https://www.doi.org/10.3389/fvets.2023.1250251

Fisher, W., Piazza, C. C., Bowman, L. G., Hagopian, L. P., Owens, J. C., & Slevin, I. (1992). A comparison of two approaches for identifying reinforcers for persons with severe and profound disabilities. *Journal of Applied Behavior Analysis*, *25*(2), 498. https://www.doi.org/10.1901/JABA.1992.25-491

Food Struct. (n.d.). *Carrot vs parsley: In-depth nutrition comparison*. https://foodstruct.com/compare/carrots-vs-parsley

Fulgencio, C. T. (2018). *Preference assessments with shelter dogs* [Unpublished master's thesis]. California State University.

Garner-Richardson, V. (2012). Guinea pig nutrition. *The Veterinary Nurse*, *3*(5), 274–282. https://www.doi.org/10.12968/VETN.2012.3.5.274

Hall, N. J., Péron, F., Cambou, S., Callejon, L., & Wynne, C. D. L. (2017). Food and food-odor preferences in dogs: A pilot study. *Chemical Senses*, *42*(4), 361–370. https://www.doi.org/10.1093/CHEMSE/BJX016

Hewson-Hughes, A. K., Hewson-Hughes, V. L., Miller, A. T., Hall, S. R., Simpson, S. J., & Raubenheimer, D. (2011). Geometric analysis of macronutrient selection in the adult domestic cat, *Felis catus*. *Journal of Experimental Biology*, *214*(6), 1039–1051. https://www.doi.org/10.1242/JEB.049429

Hunt, R. L., Whiteside, H., & Prankel, S. (2022). Effects of environmental enrichment on dog behaviour: Pilot study. *Animals*, *12*(2), 141. https://www.doi.org/10.3390/ANI12020141/S1

Hursh, S. R. (1980). Economic concepts for the analysis of behavior. *Journal of the Experimental Analysis of Behavior*, *34*(2), 219–238. https://www.doi.org/10.1901/jeab.1980.34-219

Hursh, S. R., & Silberberg, A. (2008). Economic demand and essential value. *Psychological Review*, *115*(1), 186–198. https://www.doi.org/10.1037/0033-295X.115.1.186

Lykkesfeldt, J., Perez Trueba, G., Poulsen, H. E., & Christen, S. (2007). Vitamin C deficiency in weanling guinea pigs: Differential expression of oxidative stress and DNA repair in liver and brain. *British Journal of Nutrition*, *98*(6), 1116–1119. https://www.doi.org/10.1017/S0007114507787457

Mancinelli, E. (2016). Guinea pig husbandry - housing, diet and handling. *Vet Times*, 1–11. https://www.vettimes.co.uk/app/uploads/wp-post-to-pdf-enhanced-cache/1/guinea-pig-husbandry-housing-diet-and-handling.pdf

Martin, A. L., Franklin, A. N., Perlman, J. E., & Bloomsmith, M. A. (2018). Systematic assessment of food item preference and reinforcer effectiveness: Enhancements in training laboratory-housed rhesus macaques. *Behavioural Processes*, *157(1)*, 445–452. https://www.doi.org/10.1016/J.BEPROC.2018.07.002

Martin-Wintle, M. S., Shepherdson, D., Zhang, G., Zhang, H., Li, D., Zhou, X., Li, R., & Swaisgood, R. R. (2015). Free mate choice enhances conservation breeding in the endangered giant panda. *Nature Communications*, *6*(1), 1–7. https://www.doi.org/10.1038/ncomms10125

Mayntz, D., Nielsen, V. H., Sørensen, A., Toft, S., Raubenheimer, D., Hejlesen, C., & Simpson, S. J. (2009). Balancing of protein and lipid intake by a mammalian carnivore, the mink, *Mustela vison*. *Animal Behaviour*, *77*(2), 349–355. https://www.doi.org/10.1016/J.ANBEHAV.2008.09.036

Mehrkam, L. R., & Dorey, N. R. (2014). Is preference a predictor of enrichment efficacy in Galapagos tortoises (*Chelonoidis nigra*)? *Zoo Biology*, *33*(4), 275–284. https://www.doi.org/10.1002/ZOO.21151

O'Dell, B. L., Morris, E. R., Pickett, E. E., & Hogan, A. G. (1957). Diet composition and mineral balance in guinea pigs. *The Journal of Nutrition*, *63*(1), 65–77. https://www.doi.org/10.1093/JN/63.1.65

Purdue University College of Veterinary Medicine. (n.d.). *Care of guinea pigs [Brochure]*. https://vet.purdue.edu/hospital/small-animal/primary-care/documents/CareofGuineaPigs.pdf

Rault, J. L., Waiblinger, S., Boivin, X., & Hemsworth, P. (2020). The power of a positive human–animal relationship for animal welfare. *Frontiers in Veterinary Science*, *7*, 870. https://www.doi.org/10.3389/FVETS.2020.590867/BIBTEX

Sachser, N., Künzl, C., & Kaiser, S. (2007). The welfare of laboratory guinea pigs. In E. F. Baumans (Ed.), *The welfare of laboratory animals* (pp. 181–209). Springer. https://www.doi.org/10.1007/978-1-4020-2271-5_9

Tobie, C., Péron, F., & Larose, C. (2015). Assessing food preferences in dogs and cats: A review of the current methods. *Animals*, *5*(1), 126–137. https://www.doi.org/10.3390/ANI5010126

Vicars, S. M., Miguel, C. F., & Sobie, J. L. (2014). Assessing preference and reinforcer effectiveness in dogs. *Behavioural Processes*, *103(1)*, 75–83. https://www.doi.org/10.1016/J.BEPROC.2013.11.006

Waite, M. R., & Kodak, T. M. (2023). Owner-implemented paired-stimulus food preference assessments for companion dogs. *Journal of the Experimental Analysis of Behavior*, *107*(2), 387–396. https://www.doi.org/10.1002/JEAB.846

Warren, D. M. (2015). Small Animal Care and Management (Fourth Edition). Cengage Learning: Boston, MA.

Witkowska, A., Price, J., Hughes, C., Smith, D., White, K., Alibhai, A., & Rutland, C. (2017). The effects of diet on anatomy, physiology, and health in the guinea pig. *Journal of Animal Health and Behavioural Science*, *100*(1), 39–48. https://www.doi.org/https://doi.org/10.1111/jpn.12314

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