A Comparison of Free Access, Multiple Stimulus Without Replacement, and Concurrent Schedule Preference Assessment Methods for Evaluating Food Preference.

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Abstract

Outcomes from three preference assessment methods were examined in a study of food preference with goats. The methods used were: free access, multiple stimulus without replacement, and a concurrent schedule analysis. Results from each method were compared, in terms of the preference ranking they produced. Two male goats, one domesticated wild goat and one Saanen, were used as subjects in this study. Each method yielded similar results, although the concurrent schedule test provided more comprehensive information than either of the other methods. There was moderate agreement between the multiple stimulus without replacement and the concurrent schedule tests, however the free access procedure identified only the two most highly preferred items and provided limited information on preference level of the remaining food items. Five foods were tested in this experiment, all of different texture and composition – crushed maize, sheep and goat pellets, chopped lucerne, lucerne haylage, and timothy and lucerne haylage. During the free access, goats were given unrestricted access to a particular food for 12 seconds. During the multiple stimulus without replacement, goats were presented with all five foods simultaneously and allowed to make one choice. Once the subject had selected a food by pressing the respective cover with their muzzle, that cover was removed to allow access to that food only. When the subject stopped eating, the cover was replaced - subjects could then select another food. This process was repeated until either all five feeds had been sampled or goats had not made contact with any covers for fifteen seconds. The concurrent schedule test involved making two foods available concurrently. Food delivery was determined by a VI 60s schedule and controlled by a computer software program that was linked to the apparatus. The assessment procedure was arranged so that each food was tested alongside every other food. Data was analysed in terms of the proportion of time and responses allocated to each food. Proportion of time and responses varied considerably depending on the food that was available concurrently.

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Chapter 1: Introduction

Wardle, Barker, Yeates, Bonner, and Ghani (2001) reported that goats have been in New Zealand since their arrival 220 years ago, in the late 1700s. They occupied New Zealand native bushland and have since spread to other forested areas of New Zealand. Despite increasing in number and becoming rampant in forested areas, early attempts to transpose this into a dairy goat industry in 1921 were somewhat unsuccessful. Initially goats were farmed in three main production systems: mohair, milk, meat, and skin production. Four main breeds were used: Saanen, Toggenburg, Anglo-Nubian and the British Alpine (Sheppard & O'Donnell, 1979). The 21st century has brought with it renewed attempts at the development of goat milk production systems. Much of the world's goat milk production comes from developed European countries such as France, Spain, Turkey and other, Asian, countries (Dubeuf, Morand-Fehr, & Rubino, 2004). Nonetheless, New Zealand has exhibited substantial growth in its dairy goat industry since the 1980s, with the majority of farms and processing plants being located in the Waikato of New Zealand's north island. The New Zealand dairy goat Co-op was formed in 1984; export markets were then established in 1988. By 2005, company turnover was above $50m. By 2012, company turnover exceeded $100m, $150m in 2014 and $155m in 2015. Currently, in 2017, the New Zealand dairy goat co-op has 85-90 breeders/farmers with an average heard size of 250 (Keith Arnold, personal communication, May 12, 2017). New Zealand exports products made from goat milk to over 20 countries (Mapp, Hutchinson, King, & Rennie, 2011). The association produces an annual milk yield of

38,000,000 litres (Dairy Goat Co-op, 2017b, "Our credentials"). This is the total *from farms within the association*; throughout New Zealand there are many smaller, independently run farms where milk may be given to family/neighbours or sold at a local market. It is likely that total milk yield would exceed 38, 000,000 if one was able to quantify milk quantity from these additional producers (Keith Arnold, personal communication, May 12, 2017).

Contrasted to the quantity of milk produced by dairy farms in New Zealand which approximates 21.3 billion litres (DairyNZ., "NZ Dairy Statistics" 2015), these figures may seem insignificant. The advantage of goat milk, however, is that it is processed faster, within a three-day period, and is suitable for people who are allergic to cow milk. Some infants are allergic to cow milk, so the availability of Goat milk provides an alternative whereby these vulnerable individuals can receive nutrients they require. Whole (goat) milk is processed directly into infant formula; cow milk goes through a higher number of production steps before it is converted to infant formula; the formula therefore is constituted of what is left over from the production process, milk proteins (Dairy Goat Co-op, 2017a, "manufacturing: integrated facilities").

According to Morand-Fehr et al. (2004) the most crucial need for the purposes of goat farming in the 21st century is further research to explore the needs of farmers and promote effective use of financial resources. Particularly for farmers with low income it is important to manage food supplies for the production system in effect that are cost effective. In that respect, understanding foods that contribute to better milk production is important for farmers as well as ensuring adequate nutritive benefit for lactating animals. Mapp et al. (2011)

conducted an analysis of forage supply systems on a group of New Zealand goat farms, members of the Dairy Goat Co-op. Resulting data indicated a need for further research into the cost effectiveness of supplemental feeds; there appeared to be no relationship between the cost (high/low) of supplemental feeds and annual milk yield on farms involved in the study, suggesting that there is room to optimise cost efficiency within New Zealand goat farms. The authors also reported a need for research into understanding potential feed mixes that will ensure adequate nutrition for milking animals (Mapp et al., 2011). Through extensive research it is evident that milking goats require a high protein and high energy diet that is rich in vitamins and minerals (University of Minnesota, 2017). Research which investigates the best utilisation and mixing of feeds to meet these needs is likely to be of benefit.

Effective management of animal feeds requires implementation of a ration that meets nutritive requirements and is sufficiently palatable; this usually includes a mixture of pasture and the use of supplementary feeds and concentrate (Browne-Crowder, 2003). Concentrate feeds can be either carbonaceous (low protein, high in grain material) or proteinaceous (high in protein, sourced from either plants or animals). Typically, most types of concentrate are high in energy and low in fibre, while they also contain essential vitamins and minerals (Schoenian, 2017)

Most farming systems are oriented towards intensification (maximising production) and are therefore focused on increasing amounts of concentrate in livestock diets (Cantalapiedra-Hijar, Yáñez-Ruiz, Martín-García, & Molina-Alcaide, 2009). Forage to concentrate ratio has a strong effect on nutrient digestibility.

Nutrient digestibility is implicated when excess grain or starch is consumed. Ruminal pH drops below minimum when such excesses occur (Wang et al., 2009). The rumen is slowed due to excess acid production and minimal amounts of food are being processed while acid levels increase. Acid production in the rumen is stimulated by the fermentation of carbohydrates. Too much carbohydrate and starch triggers this excess acid production whereby the pH level of the rumen drops too low. The implications of this range from infertility in does to illness and death of livestock when the condition becomes severe. There is a need for adequate management of livestock diets to control the risks associated with ruminal acidosis (Santini, Lu, Potchoiba, Fernandez, & Coleman, 1992).

Increasing voluntary intake of fibrous material and managing meal size of concentrate is one way to manage ruminal acidosis in livestock. Wang et al. (2009) compared the effects of three diets containing differing amounts of starch, on ruminal function in goats. These consisted of low starch, medium starch, and high starch. The authors found that diets containing 46% starch reduced ruminal pH; a diet containing 35% starch was actually better for ruminal pH than a low starch diet, containing 28% starch. This could be challenging to create the optimal balance of starch, concentrate and fibre for the purposes of healthy rumen function.

Fibrous material is associated with longer ruminal retention times as it takes longer to break down than low fibre foods. Goats consume larger quantities of foods that can be digested easily and quickly, usually concentrate feeds that are dense in energy or starch and low in fibre, even though this may not be in the best interests of goats' health in the long term. Rainanzin, Bailoni, and Schiavon (1997) studied the effects of Forage: Concentrate (F:C) ratio on digestion in deer, goats and sheep. It was quite clear from their analyses that higher F:C ratios were associated with greater neutral detergent fibre (NDF) digestibility (a type of fibre contained within forages). This suggests that goats may get important nutritive benefit from fibrous material contained within forages. Most approaches to increase voluntary food intake (VFI) focus on the digestibility of foods as the primary determinant of VFI, however there is evidence that palatability is of similar importance to intake levels.

Greenhalgh and Reid (1967) managed to separate the effects of digestibility and palatability on dry matter intake in ruminants in an assessment of palatability using oat straw and dried ryegrass – two feeds equal in digestibility but differing in texture. By keeping the digestibility of foods constant while ensuring the foods were of different texture, the authors demonstrated that palatability was of equal importance to digestibility. Despite the significance of palatability in determining intake, feeding preferences of goats have received little attention in behavioural research.

Behavioural preference assessments allow us to assess how 'palatable' a food is to an animal. Preference is a behavioural term that describes which foods animals will work for (Heady, 1964). In line with this, foods an animal works most for are considered to be preferred and more palatable than the other available alternatives to which less time and responses were allocated, or those that were chosen less frequently. When we say that a food is preferred relative to the alternatives available, it is with understanding that highly preferred items are more likely to function as effective reinforcers for the individual organism. Identifying effective reinforcers is important during operant conditioning procedures. Training programs may fail if selected stimuli are not functioning as reinforcers for that animal. Preference assessments using non-food items can show us what items animals “like” in some aspect of their environment; for example, flooring type, toys, and other enrichment items (Fernandez, Dorey, & Rosales-Ruiz, 2004). Items an animal spends the most time with or selects more frequently than others may be considered more highly preferred than other alternatives – high preference items are more likely to be consumed in greater quantity and have the longest interaction period.

We can find out what animals “want” by giving them choices in their environment, including choices among an array of items presented simultaneously, the choice as to how long to engage with a stimulus, and the opportunity to respond to two components which have different consequences (Cooper, Heron, & Heward, 2014). We can also assess how hard an animal will ‘work’ to obtain a resource. This enables us to see how important that resource is to the animal (Cronin, 2012). Preference is measured differently with each assessment method, and some of these methods are discussed herein. During a multiple-stimulus or other trial-based measure, approach responses are measured across a certain number of trials. An assumption is made that items approached first are preferred and likely to be most effective as a reinforcer (Cooper et al., 2014). During free access procedures, an animal is given unrestricted access to a food or other resource. Measures are taken of either the amount of time spent engaging with the stimulus, or the quantity of that stimulus which is consumed throughout the access period. Conclusions regarding the level of preference for each stimulus are based on the notion that the longer the period of engagement with the resource, or the greater the quantity consumed, the more highly preferred that resource is. The more highly a resource is preferred, the greater the likelihood it will be an effective reinforcer. Concurrent schedules can also provide us with data on the relative preference of two or more items, whereby two foods are available concurrently, each food reinforcer contingent on a response for that alternative. The alternative to which more time or behaviour is allocated, is understood to be preferred over the alternative to which less behaviour was allocated (Cooper et al., 2014). Assuming equal VI schedules are in place, this demonstrates that the reinforcer to which more time is allocated functions as the more effective reinforcer relative to the alternatives available. We can also identify which items or stimuli animals will work to avoid by conducting preference assessments (Cronin, 2012; Dawkins, 2006; DeLeon, Frank, Gregory, & Allman, 2009; Piazza, Fisher, Hagopian, Bowman, & Toole, 1996; Roscoe, Iwata, & Kahng, 1999). What is typically considered an animal's “motivation” to obtain a particular resource can be measured using the behaviour-analytic concept of ‘motivating operations’. This refers to events that increase or decrease the effectiveness of a stimulus as a reinforcer. For example, an animal will demonstrate a high rate and variety of behaviours that result in the availability of water following a period of water deprivation. Motivating operations can increase or decrease the reinforcing effectiveness of a stimulus and are divided into subcategories Establishing operations and Abolishing operations (Kirkden & Pajor, 2006; Tapper, 2005). An establishing operation is an event that increases either reinforcing or punishing effects of another stimulus (value-altering effect) and evokes or abates behaviours relevant to that event. An abolishing operation represents the inverse, an event which reduces the reinforcing or punishing effects of an event or stimulus and increases or decreases the frequency of behaviours likely to result in that event occurring. For example, food satiation reduces the reinforcing effectiveness of food and decreases the frequency of behaviours likely to lead to the availability of food. These formulations are important to consider when we evaluate food preference in subjects that are not food deprived; that is, when non-regulatory feeding is being assessed. The level of satiation of the animal will, to an extent, act as an abolishing operation to reduce the effectiveness of food as a reinforcer (Tapper, 2005).

Understanding what animals ‘like’ or ‘dislike’ provides valuable information for making decisions about their husbandry and developing feeding regimes that adequately satisfy their nutritional needs while maximising consumption. Assessments of palatability and food preference are tied to the physical and ethological needs of animals and therefore profoundly useful in assessing their welfare status (Kirkden & Pajor, 2006; Sumpter, Foster, & Temple, 2002)

Because we cannot directly assess what animals ‘enjoy’ eating, we rely on behavioural indicators and the outcome of preference assessments. This is based on the notion that animals will work harder for foods they ‘enjoy’. According to Hemsworth, Mellor, Cronin, and Tilbrook (2015), “affective experiences including emotions are subjective states so cannot be measured directly in animals, but there are informative indirect physiological and behavioural indices that can be cautiously used to interpret such experiences” (Hemsworth et al., p. 2). Assessing preference involves giving animals some degree of control over their environment, in the form of choice or operant tests. Choice tests tell us whether the animal has a distinct preference among alternatives (Kirkden & Pajor, 2006). A preference arises when an animal exhibits a stable response pattern in favour of one or more items. Preference is therefore relative to the other options available. Preference is a stable characteristic of the individual or animal and does not differ from moment to moment. For example, an animal may prefer grass over haylage. Choice, in contrast, is not a stable characteristic of an animal’s behaviour. There may be many options available to an animal at any given point in time, and how they respond in that situation is considered a ‘choice’. In that regard, everything down to whether an animal sits or stands, shifts its foot left or right, may be considered choice behaviour (Kirkden & Pajor, 2006).

In behaviour analysis there is a strong connection between choice and estimated measures of preference. When an animal consistently exhibits a stable pattern of responding for any particular alternative, or “chooses’ that alternative, we begin to talk about preference. One of the means by which we evaluate preference is by conducting choice tests which provide information on whether the animal holds a preference among a series of available alternatives (Cooper et al., 2014; Kirkden & Pajor, 2006). Some of the different choice tests used in assessing preference are reviewed below.

Choice tests

There is an array of choice tests that can be used to assess preference; among these are multiple stimulus (with or without replacement), single stimulus (SS), free access (FA), concurrent schedules (CS), paired stimulus (PS) and the T or Y maze. These are all unique in their methodology, the type of results they produce, and how these results are processed to generate measures of preference. Some of these features are addressed below.

Multiple stimulus with replacement

Multiple stimulus procedures are systematic, direct methods used to assess reinforcer preferences with selections being either with or without replacement (DeLeon & Iwata, 1996). Under the multiple stimulus with replacement (MSW) format, a selection of potential reinforcers are made available, presented simultaneously. The subject can choose only one; after this the chosen food is replaced and the order of the items is rotated ready for the next trial. Usually five sessions is considered sufficient to demonstrate reinforcer preferences. Subjects can quite conceivably choose only those food items which it most highly prefers without sampling those of lower preference levels. When scoring, high preference is allocated to the foods which were chosen on the highest number of trials. Foods chosen on the smallest number and percentage of trials are considered ‘low preference’.

Multiple stimulus without replacement

Under the multiple stimulus without replacement (MSWO) format, a selection of available reinforcers is presented simultaneously. The subject can choose only one; this continues until each food has been sampled or it is evident that no further selections will be made, as per some predetermined criteria (DeLeon & Iwata, 1996; Higbee, Carr, & Harrison, 2000; Piazza et al., 1996). No food or other item is replaced once it is chosen, this being the key difference between MSWO and the MSW (multiple stimulus with replacement). With both the MSW and MSWO, results are presented in terms of the number and percentage of trials each food/item was chosen in each position of one through to the total number of items that are being used (e.g., chosen first through to fifth). Foods which are chosen on the highest number of trials are considered more highly preferred than foods which were chosen on a smaller number of trials. Foods selected on the lowest number and percentage of trials are considered ‘low preference’ (DeLeon & Iwata, 1996). MSWO has been proven to produce similar results as PS presentations with the advantage of requiring less time (Higbee et al., 2000).

Paired stimulus

PS procedures have been used successfully in humans and animal species - including dogs, possums, sea lions, orangutans, and other zoo animals (Cronin, 2012; Mehrkam & Dorey, 2015; Vicars, Miguel, & Sobie, 2014). A PS procedure involves presenting two foods simultaneously and recording which is chosen first. The process is repeated until each food has been paired and presented with every other food. High preference is attributed to a stimulus if it was selected on a high percentage of trials on which it was presented, relative to other stimuli. For example, a stimulus selected on 80% of trials in which it was presented will be given a higher preference score than a stimulus which was selected on only 60% of the trials in which it was presented. While the PS assessment produces results similar to the MSWO, the PS has added advantages. The PS compares each food with all other alternatives, individually. Because each potential combination of stimuli is paired and presented, we obtain information about the preference level of a particular food relative to another. We can therefore differentiate between preference level of each of those foods. The multiple stimulus formats involve presenting all items simultaneously and do produce similar preference rankings to the PS, but they do not give us direct comparison of the preference level of one food relative to another. Data obtained from multiple stimulus formats are useful in identifying potential reinforcers, however they may be less effective at providing relative information and making a distinction between stimuli. Windsor, Piché, and Locke (1994) specifically tested a multiple stimulus and a PS format. They found that both procedures identified similar preferences, however the PS produced more stable results and more detailed preference information (Higbee et al., 2000; Windsor et al., 1994).

Single Stimulus

A SS procedure is among the easiest to implement; each stimulus is presented individually and approach behaviour (E.g., time spent sniffing, interacting with the stimulus, or ruminating) is recorded. While simple, this method has been demonstrated to overestimate preference. The animal may interact with the designated stimulus because no other alternatives are available (Hagopian, Rush, Lewin, & Long, 2001). Having said that, there is evidence to suggest that single stimulus procedures can still produce stable results. Like all preference assessment measures, SS procedures are consistently influenced by establishing operations. Individuals respond less to a single stimulus after periods of exposure, suggesting that aside from the availability of a stimulus, satiation may also play a role in outcomes from SS procedures.

Free access

Potentially the simplest preference test to implement is the FA, a single stimulus procedure whereby a subject is given unlimited access to a single food/item at a time for a certain duration (e.g., 30 seconds' access). The amount goats are presented with at the beginning, and the amount left over after the access time, are used to calculate the amount that has been consumed. A series of feeds may be tested individually to give an idea of which is preferred over another, however preference for each feed may be overestimated or underestimated because of the factors described below.

Using the amount consumed as an indicator of preference can bring in confounding factors such as digestibility of the feed. Foods are more or less digestible depending on their cellulose and fibre content (Campbell, n.d) and therefore the cellulose content impacts on how much of a food can be consumed. The amount of concentrate in feeds also impacts on intake; higher concentrate percentage is associated with greater acidity. Desnoyers et al. (2008) fed eight goats two diets in a crossover design; each diet differed in concentrate percentage and therefore acidity. When fed the diet that was higher in concentrate, goats spent longer periods of time drinking water and resting. They also limited their intake, reaffirming that food characteristics are a significant determinant of consumption (Desnoyers et al., 2008).

Characteristics of the feed impact on the quantity an animal consumes (Heaton, Marcus, Emmett, & Bolton, 1988). A small amount of food consumed in a SS preference assessment does not necessarily mean that the respective food is less preferred; it may be highly preferred but less digestible. There are other factors to consider such as the particle size (which impacts on digestibility and metabolism).

Some subjects may approach, consume, or otherwise interact with every stimulus they are presented with even though they may not have if a wider range of items had been available (Fisher. et al., 1992). Fisher et al. (1992) compared a SS and a forced choice presentation; all 'highly preferred' items, according to the forced choice condition, were also identified as highly preferred on the SS condition. In contrast to this, all stimuli that were identified as low or moderately preferred in the forced choice condition were identified as highly preferred in the SS presentation (Fisher. et al., 1992). These findings suggest that SS procedures are useful in identifying potential reinforcers but may overestimate preference. Similarly, a study by Hagopian et al. (2001) found that the SS procedure did not produce preference ratings (e.g., high/low preference) consistent with those identified in the PS condition. SS procedures may be useful in identifying potential reinforcers while having characteristic limitations in determining reinforce efficacy and preference rankings.

Concurrent schedule tests

CS assessments run two or more schedules of reinforcement at the same time (concurrently), responding for each produces reinforcement according to the specifications of that schedule. Each schedule is associated with one alternative, usually food. Animals allocate time or responses to each of the schedules. The alternative to which the most responses or time is allocated is said to be preferred. The required response is termed an "operant" because it requires the animal to manipulate some piece of equipment in the environment such as a lever. Operant conditioning is the process by which that behaviour, the operant, is changed by the consequences it produces – such as reinforcement. Reinforcement is a crucial element of this type of preference assessment (Armistead, 2009).

Skinner (1953) stated, "In operant conditioning we strengthen an operant in the sense of making a response more probable, or, in actual fact, more frequent" (p. 65). In accordance with Edward L. Thorndike's law of effect, the probability of the target behaviour recurring is enhanced post-reinforcement (Thorndike, 1927). The manner in which reinforcers are delivered is determined by the reinforcement schedule being used, usually programmed into a computer so that food is delivered automatically by a feeder (Baum & Davison, 2009). Schedules of reinforcement are termed "concurrent schedules" when more than one is running at one time. In line with this, Concurrent schedules can be used to assess preference for two or more foods concurrently. Schedules of reinforcement operate by interval or by the responses needed for reinforcement (ratio). Both interval and ratio schedules can be either variable or fixed. Where a reinforcer is available after a set period of time, this is termed “fixed interval”. Where reinforcement is available after an average period of time, given a response has been performed, this is a “variable interval” schedule. Similarly, schedules can operate by variable or fixed ratio, in which reinforcers are available after a fixed number of responses (fixed ratio) or an average number of responses – variable ratio. For example, reinforcers may be delivered after every 10 responses (fixed ratio), or after an average of every 10 responses (variable ratio).

Where variable intervals are used, the average of these durations between reinforcers will be the value of the schedule in effect, for example a variable interval 60s (VI 60s) will make reinforcement available, on average, every 60s – contingent on a response. For a reinforcer to be delivered, a response must have been performed in the specified interval. Provided that at least one response has been emitted, reinforcers are delivered after the pre-set schedule value. For example, where a VI 60s is in effect, durations may be 20 seconds, 30 seconds, 80 seconds, 120 seconds - overall the average interval will be 60 seconds. If the schedule value was VI 60s and this was running for both alternatives being assessed, this is considered “concurrent VI schedules”. If the interval is fixed and the same schedule was used for each alternative, this is considered “concurrent fixed Interval schedules”. The most commonly used schedule of reinforcement in preference assessment is the concurrent variable VI schedule (Kirkden & Pajor, 2006).

The advantage of implementing concurrent procedures over other procedures, such as the FA or multiple stimulus formats is that CS performance provides quantifiable measures of the level of preference for each food. Multiple stimulus assessments provide only hierarchical data without providing information on the strength of preference for a food, and FA procedures are known to overestimate the degree of preference because no other alternatives are available (Sumpter et al., 2002). Implemented pairwise, concurrent schedules can identify the degree of preference for a food as a form of response bias. Relative preference is demonstrated when one of the two foods being tested has a greater proportion of time and/or behaviour allocated to it than the alternate food. We can see from resulting data the exact distribution of behaviour and time allocated to each alternative (Findley, 1958). Therefore, we can identify not only a hierarchy of preferences but the relative strength of preference for any particular food. For example, we may observe that an animal allocates 80% of responses to food A and 20% to food B. This tells us which food is preferred, and also gives us an indicator of the degree of preference for food A over food B. Concurrent schedules can be arranged either independently or dependently. With an independent arrangement, each schedule is on its own timer and keeps running and delivering reinforcers regardless of whether reinforcement becomes available under the alternate schedule. When arranged dependently, if reinforcement is made available for one response option (i.e., for one food type) the timer on the other response option stops working until the reinforcer has been collected; this is done to prevent rapid switching or exclusive preference for one option (Sumpter et al., 2002). Results of concurrent schedules are evaluated in terms of Herrnstein's Generalised Matching Law (Baum & Davison, 2009).

The matching law is presented as:

(1) $$\log\frac{B1}{B2} = s\log\frac{r1}{r2} + \log c$$

Where B1 and B2 represent the behaviour allocated to alternatives 1 and 2, and *r*1 and *r*2 represent the reinforcement available on those alternatives. The variable *s* represents the sensitivity of behaviour to changes in reinforcement ratio (how much behaviour is influenced by changes in reinforcement). The variable *c* is indicative of bias from extraneous variables (e.g., effect of time of day, place preference, and individual feed preference; Baum & Davison, 2009). There are three possibilities when data are fitted to this equation; undermatching, strict matching, or overmatching. Undermatching is said to occur when the proportion of responses allocated to an alternative is closer to .5 than would be predicted by the proportion of reinforcement available on that alternative (i.e., they respond less on a comparably richer alternative and are less sensitive to changes in reinforcement). Overmatching is said to occur when *s* has a slope greater than 1.0, where animals respond more on the richer alternative than would be predicted by the proportion of reinforcement available on that alternative. Significant undermatching has been reported in goats and dairy cows (Foster, Matthews, Temple, & Poling, 1997; Foster, Temple, Robertson, Nair, & Poling, 1996). Strict matching was originally used to describe scenarios where the behaviour allocated to each alternative was directly proportionate to the reinforcement available on that alternative. That is, when *s* has a slope equal to 1.0 after data had been plotted into formation of a regression line. In subsequent years, Baum (1979) reported that anywhere between .90 and 1.11 can be considered reasonable approximations of matching. Currently the term ‘matching’ is used to describe any data set that is well accounted for by the generalised matching law (Poling, Edwards, Weeden, & Foster, 2011).

Summary

Behavioural preference assessment measures are crucial for many reasons. These include the effective management of food supplies and therefore financial resources for farmers, maintaining adequate nutrition for lactating animals, reducing physical health problems such as ruminal acidosis, increasing voluntary food intake, and also increasing milk yield in does. What foods an animal prefers is directly related to its nutritional needs - behavioural preference assessments provide us with useful information regarding the factors described above.

We cannot find out directly what an animal “wants, likes, or enjoys” so we rely on behavioural indicators. There are a number of ways to assess preference in animals, called “choice tests” which all provide various forms of information on what foods an animal “prefers” – these choice tests involve giving the animal some degree of control over their environment. Among these choice tests are the MSWO, MSW, PS, FA, and CS tests. Some methods provide more comprehensive information than others, however all have their own set of strengths and weaknesses.

The present study compared outcomes from three preference assessment methods - the FA, MSWO, and CS. Five commonly used feeds were tested, with goats. These preference assessments were selected based on how complex they were to administer and the type of information provided, and so that we could incorporate variety for comparison.

Each of these methods provide progressively more information, however they also require progressively more time to implement as the level of detail of results increases. FA is the easiest to implement, however it does not compare foods directly to one another, and preference is sometimes overestimated because animals are more likely to interact with a stimulus or approach food when it is the only one available. This procedure provides less comprehensive information than either the MSWO or CS assessment. The MSWO method has been shown to produce results similar to the PS, with the advantage of requiring less time and identifying similar potential reinforcers as the PS. The MSWO method does have a limitation in that it does not directly give preference information on one food relative to another, with each potential pair of foods being tested. The CS assessment provides a more comprehensive account of preference, with more detailed information. It is also more complex to administer.

Chapter 2: Method

Subjects

Two goats, named Mayhem and Emmie, participated in the current project. One (Mayhem) was wild and likely to be mixed breed, the other (Emmie) was Saanen (see Figures 1 and 2). Subjects lived at a research facility for domestic and agricultural animals in Ruakura - Hamilton, New Zealand. Both animals were kept here prior to the experiment. Therefore, they were familiar with the environment. Mayhem was captured from the wild by a staff member working at the animal lab and had been tamed at least 2 years prior to the experiment. Neither goat had participated in any experiments prior to the current project. Emmie was raised around people and came from Hamilton's research facility. In the months prior to the experiment, both goats had free access to a large area with a variety of grasses and some small fodder trees. Subjects were exposed to all feeds used in the experimental procedures prior to the experiment - no foods were novel.

Figure 1. Emmie

Figure 2. Mayhem

Feeds

Chopped lucerne, crushed maize, sheep and goat pellets, and two pasture-based haylages were used (lucerne haylage and timothy and lucerne haylage). For simplicity, timothy and lucerne haylage is abbreviated as T+LH throughout this document. The five feeds were selected based on texture. Some were dry (pellets, maize), some were wet (haylages), and one was grass (chopped lucerne). Different food types were chosen to increase the likelihood of obtaining preference data that differed between food types.

All feeds were purchased from the Animal Feed Barn in Te Rapa, Hamilton. The sheep and goat pellets were a custom blend which contained: lucerne meal, soybean meal, wheat pollard, maize, barley, coconut meal, limestone, salt, minerals and vitamins, and molasses. The other feeds contained a single food/ingredient, except for one of the haylages, which contained Timothy and Lucerne.

Experiment

The experiment was carried out in a university research facility which housed agricultural and domestic animals. During training for these experiments, goats were fenced into a smaller working pen of 10.5x14m which contained enough grass for maintenance of healthy bodyweight but without excess, as determined by the lab coordinator. Two of the three experiments took place in a smaller chamber, contained within the working pen, which measured 2.4m x 2.6m.

Due to subsequent depletion of resources, when there was no longer enough grass in the restricted area, the goats were periodically given access to one other paddock close to the working pen (to allow for sufficient maintenance feed). At nine days before the completion of the project, access to the area with additional feed was restricted because subjects stopped responding in situations where they had previously obtained higher numbers of reinforcements during the concurrent schedules component. To test for the possibility that satiation was contributing to the lack of responding and emergence of problematic behaviours when a lever press did not immediately result in food (head butting, charging at the apparatus), the gate was closed overnight to restrict their access to the large grassy area. Head butting, charging at the apparatus, and other aggressive behaviours decreased in frequency and intensity following this short period of restriction.

Free Access

Apparatus

The apparatus was a plastic bucket measuring 26.5cm in diameter and 24.5cm in height. Assessment took place in a chamber measuring 2.4m x 2.6m contained within a larger working pen, a closed grass area of 10.5m x 14m.

Procedure

Training. A brief trial run took place before any data were recorded. The purpose was to acquaint the goats with the specific bucket that was being used and with each feed. Amounts of either 8 cups or 12 cups were measured into the bucket. For pellets, chopped lucerne and the haylages, eight cups of the feed were measured into a bucket. When testing with maize, 12 cups were measured into a bucket. During training, Emmie had consumed maize at a very high rate. Because of this, more of the maize was made available than the other food types. It was crucial that the goats could not eat all of the food in the bucket during the preference assessment. For consistency, 12 cups were used when testing Mayhem also. For all remaining foods, 8 cups were measured into the bucket. The bucket was weighed before and after the access period. Amount consumed was calculated by subtracting the weight of the bucket after the access period from the weight of the bucket before the access period.

Preference assessment. Goats were tested one at a time, with the alternate subject visible to reduce the likelihood of either animal experiencing distress. The test subject was led into a narrow run enclosed by a steel cattle fence. A bucket containing the measured amount of the test feed was placed on the ground within 2m of the subject. The experimenter recorded how long it took for the subject to approach the bucket with a stopwatch, and whether they approached the bucket at all. Subjects were given 12s access to the bucket after which the experimenter removed the bucket and led the subject back into the larger working pen area. The food left in the bucket was then weighed to calculate the amount consumed.

This procedure was repeated on different days, only one time on any day, between 2pm and 4pm with each of the five feeds. Each food was tested twice, making a total of 10 sessions for this component, see Tables 1 and 2.

Multiple Stimulus without Replacement

Apparatus

The experiment took place in a 2.4m x 2.6m chamber (see Figures 3 and 4). Five circles were cut into a mounted plywood structure. The structure sat 50cm off the ground and was 123cm from one end to the other (57cm wide at each end and narrowing with the curve into the centre of the board). A curved shape was used to ensure that the animal was approximately equidistance from each of the 5 feeds and to reduce the likelihood of place preferences developing. One bowl was placed into each hole. Each bowl had a diameter of 8.5cm. Below the board, on the experimenter side of the apparatus, was a series of mesh/wire coverings that were used to prevent the subject from getting access to more than one food at a time. The covers can be seen on the ground beneath the apparatus in Figure 3. During the experiment, the covers were slotted in so that they were between the board and the top of each food bowl.

Figure 3. MSWO apparatus from experimenter view

Figure 4. MSWO apparatus from animal view

Procedure.

Training. Subjects (one at a time) were given access to the testing area (Figures 3 and 4) to sample food from inside the apparatus and to be exposed to the bowls and food concurrently. Training was not complete until subjects had eaten from each of the five locations on the board/bowls. Pellets were used during training to reduce the likelihood that the subject would select some bowls more than the others that contained lower preference feed.

Preference assessment. This component of the assessment process consisted of ten sessions with five trials in each session. Each trial consisted of one presentation of the 5 feeds in a predetermined order (from left to right). The order was changed on each trial to prevent the development of position preference. The orders were as follows: ABCDE, BCADE, CEABD, EABCD, DECAB.

Each of the five bowls was covered in a steel mesh cover to prevent the goats from accessing multiple foods. To make a selection, subjects pressed the mesh cover with their muzzle; they learned quickly to perform a 'sliding' motion which moved the mesh cover slightly, or even pushed it off. Each time the subject made a choice by pressing the cover with their muzzle or sliding the cover partly off, the cover was removed by the experimenter and the goat was free to consume that food. The experimenter waited until the goat made muzzle or hoof contact with one mesh cover for five seconds to indicate preference for that food, then removed the cover. In some situations, the goats made contact with several of the mesh covers before making a selection by attempting to remove one of them. The experimenter waited until the goat had maintained contact with a mesh cover, for one of the five feeds, for five seconds before removing the respective cover. Sniffing the food beneath the cover was not considered a selection. In some cases, the goats "chose" a particular food but did not consume any of it once the cover was removed. If a subject had "chosen" a food but not consumed any, the cover was replaced after 15 seconds and that bowl was left in the apparatus until that trial was over - at which point the bowls were rearranged. The experimenter noted whether "all, some, most, or none" of the food was consumed each time the goat made a selection.

Foods were recorded as "chosen first", "chosen second", etc. The process continued until all five feeds had been chosen or the animal had not made contact with any further mesh covers for fifteen seconds. At the end of a trial the bowls were refilled (two tablespoons of each food type) if required and rearranged for the next trial.

Concurrent Schedules

Apparatus

The apparatus was located inside a chamber measuring 2.1m x 2m which was closed in by a metal fence. The apparatus consisted of a 120cm wooden board mounted onto a brick platform so that it sat 40cm off the ground. A bowl (28cm in diameter) was fitted into the middle of the board for the delivery of food. There was an omnidirectional limit switch to the left and the right of this bowl (see Figure 5). The manipulable part of the switches were 15-cm, wound-wire springs. A distinct beep, and click, was made when a switch was manipulated sufficiently far in any direction; at this time a response was recorded by the computer. If a switch was activated at the same time a food delivery was available (as determined by the VI schedule in effect), the relevant feed container was released automatically by the computer. Rectangular holes measuring 20cm x 19cm were cut into the backboard, so the animals could see and smell the food behind the hole and covered by mesh to prevent the goats from getting access to the feed. The switches were one in front of each rectangular hole. The food behind each switch was the food that could be earned by operating that switch.

A large backboard, 120cm wide x 86cm tall, blocked the animals from seeing or accessing the experimenter (this can be seen below in Figure 5).

Figure 5. View of apparatus from the side to which goats had access.

Feeds were delivered semi-manually via a feeding device that dropped a pre-loaded food into the bowl via a plastic chute. The feeder consisted of two acrylic glass boxes which sat inside a 32 x 20 x 23cm acrylic glass frame, see Figures 6 and 7. Each box measured 16cm deep and narrowed to a 2-cm width at the bottom, forming a trough (where the pre-loaded food sat). The apparatus was operated via a software program, MedPC (Med Associates., 2017). This program was installed on a computer and interfaced with the apparatus by our lab technician. There was a micro-switch attached to a lead on the experimenter side of the apparatus; pressing this button started the experiment. At this point the program began recording the time and cumulative number of all switch activations on each side, the time spent on each switch/lever, the number of food deliveries on each side, and the total session length which ran to a maximum of 1800s, or until 40 food loads had been delivered. Food deliveries were determined by VI schedules which were programmed into the computer. On the experimenter side of the apparatus was a small chamber containing a chair for the experimenter. Goats did not have access to this area. The apparatus from the experimenter view can be seen in Figures 6 and 7 below.

Figure 6. Feed containers viewed from above

Figure 7. Rear/experimenter view

Two foods were available concurrently, one on the left and one on the right. Each time the feeder dropped a load of food into the bowl, it was replaced by the experimenter. The feeder dropping was associated with a distinct click and a simultaneous beep.

Procedure.

Training. Goats were trained to eat from the bowl placed inside the apparatus before they were trained to activate the limit switches. During the initial stages of training, switch activation was manually reinforced by the experimenter. This required the goats to learn the behaviour of activating the switch. To do this, we initially reinforced successive approximations of the target behaviour – e.g., walking toward the apparatus, sniffing the apparatus, sniffing the switches. Reinforcement of these behaviours gradually reduced and reinforcement was only delivered for closer approximations of the target behaviour. Following shaping, reinforcement was only delivered for activation of either switch. Activation of a switch resulted in the immediate availability of food from that side. The experimenter then terminated reinforcement on that side once the subject had obtained 20 units of food across three sessions - food was then only given for using the alternate switch. In the next step, food was only available for alternating between the two switches (left, right, left etc.) so that subjects were less likely to be biased toward either side. Once the goat was responding on both switches, a VI schedule was introduced. Initially a VI 5s was used with both switches, meaning that a unit of food was available every five seconds, on average. The VI value was increased once the goat had obtained 20 food opportunities in 3 consecutive sessions. During training, pellets were used on both the left and right switch. The purpose was to get the goats manipulating the apparatus without bias for left or right, which would happen if different foods were used during training. The VI value in effect increased once the subject had obtained 20 food deliveries on each side, across 3 sessions. Values increased by 15 seconds, beginning at VI 15s and ending at VI 60s. Once the goats were responding consistently under a VI 60s schedule, they progressed to the preference assessment.

Preference assessment. Both switches were operating on a VI 60s schedule of food delivery throughout the preference assessment. Sessions started at either 10am or 2pm each day. At the beginning of each session, the experimenter gathered the relevant foods in a bowl and placed them on the experimenter side of the apparatus, behind the appropriate rectangular cut-out so the goats could see and smell the foods. Food pairings were arranged so that each food was paired, in turn, with all of the other foods used in the preference assessment. Each food pairing was repeated, making a total of 2 sessions for each food comparison. The reason these sessions were repeated, was so that each of those two foods being tested could be available on both the left and the right. With five foods, this made a total of 20 sessions for this preference assessment.

Throughout the preference assessment, Mayhem was tested first (before Emmie). I guided him into the chamber by holding out a bowl of crushed maize. Once inside the chamber, I closed the gate and moved quickly to the chamber on the other side of the apparatus and pressed the button to start the experimental session. For the remainder of the session, I replaced food after a load was released into the bowl. One tablespoon of food was measured out for each food load. Sessions ended after 40 food deliveries, or after 30 minutes had elapsed since the beginning of the session, whichever occurred first. A double beep signalled the end of a session. After the session ended, the timer stopped and the levers no longer produced a beep as they had done during the session. After the session, goats were released into the paddock area where they resided throughout the experiment between sessions.

Chapter 3: Results

Free Access

Figure 8, and Tables 1 and 2, shows the amount consumed of maize, pellets, chopped lucerne, lucerne haylage, and T+LH for both subjects. Emmie's data is depicted in black, Mayhem's data is depicted in grey. The same data are recorded in Tables 1 (Emmie) and 2 (Mayhem). Emmie consumed a higher amount, in weight, of pellets than he did each of the four remaining feeds (see Figure 8). Second to pellets, Emmie consumed more maize than either chopped lucerne, lucerne haylage, or T+LH. Emmie consumed less chopped lucerne than any of the other foods, including the haylages. Emmie consumed amounts of lucerne haylage and T+LH that were very similar. Table 1 shows the average amount consumed and amount consumed for each food on trials 1 and 2, for Emmie. Emmie, on average, consumed more of both haylages than he did chopped lucerne, in grams (Table 1). Mayhem, on both trials, consumed no haylage (Table 2 and Figure 8). Over all he consumed more pellets than he did maize or any other feed. He consumed only a minimal amount of chopped lucerne, and only on Trial 1. No chopped lucerne was eaten on Trial 2. The amount of maize eaten on Trial 1 was the same as the amount of pellets that had been eaten on Trial 2, so there were some similarities in the amount consumed for maize and pellets. On average, the amount of pellets consumed, in grams, was much larger than the amount, in grams, of maize that was consumed, or any other food.

Table 1

Amount consumed in a Free Access assessment of preference, for Emmie

Food	Trial number	Amount consumed (g)	Average amount consumed (g)
Maize	1	76	76
	2	76	
Pellets	1	192	134
	2	76	
Chopped Lucerne	1	20	15
	2	10	
Lucerne Haylage	1	26	25
	2	24	
T+L Haylage	1	22	24
	2	26	

Table 2

Amount consumed in a Free Access assessment of preference, for Mayhem

Food	Trial number	Amount consumed (g)	Average amount consumed (g)
Maize	1	44	23
	2	2	
Pellets	1	72	58
	2	44	
Chopped Lucerne	1	6	3
	2	0	
Lucerne Haylage	1	0	0
	2	0	
T+L Haylage	1	0	0
	2	0	

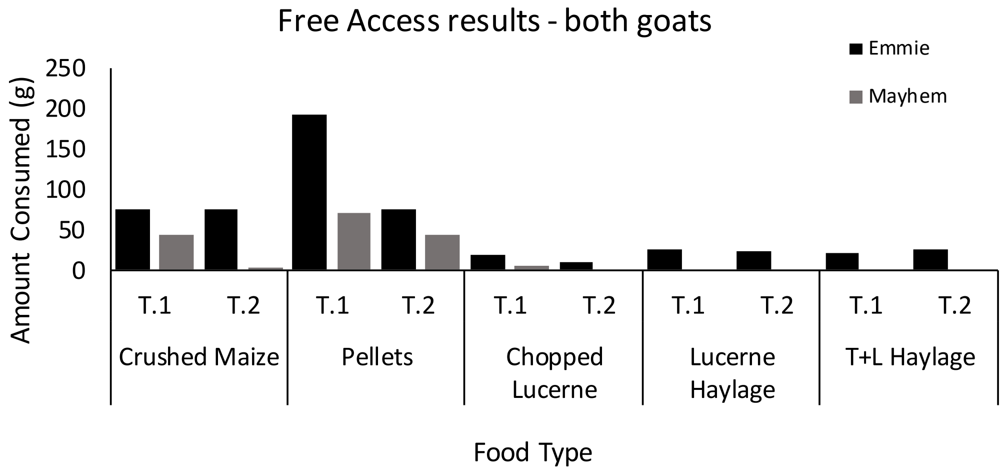

Figure 8. Amount consumed, for both goats, in a Free Access assessment of preference.

Multiple Stimulus Without Replacement

Tables 3 and 4 show the number of times each food was chosen first through fifth across 50 trials for both goats during the multiple stimulus without replacement preference assessment. Foods are represented by letters A, B, C, D, and E in accordance with the legends in Figures 3 and 4: crushed maize (A), pellets (B), chopped lucerne (C), lucerne haylage (D), and T+LH (E). Figures 9 and 10 show the percentage of presentations each food was chosen first through fifth. Both goats chose maize first on a higher number of trials than any other feed. For Mayhem, maize was chosen first on 35 out of 50 presentations, for Emmie this was 27 out of 50. Emmie chose maize first on 54% of presentations, second on 44% of occasions, and third on 2% of presentations (see Figure 9). Mayhem chose crushed maize on 70%, 24%, and 2% of occasions, first through third (see Figure 10).

Emmie did not choose chopped lucerne first on any occasion, however he chose it second on 8% of trials and third on 84% of trials. Mayhem chose chopped lucerne second on 2% of trials and third on 10% of trials. He never selected chopped lucerne first and he never selected chopped lucerne fourth or fifth. Emmie selected pellets second on 48% of trials and first on 44% of trials. He chose pellets third on 8% of trials. Mayhem chose pellets first on 26% of trials and second on 58% of trials. He never selected pellets third, fourth or fifth. Emmie chose lucerne haylage fourth on 14% of trials and fifth on 2% of trials. Lucerne haylage was never selected first, second or third by Emmie. Mayhem never selected lucerne haylage or T+LH (see Figure 10). Overall, both goats chose maize and pellets on a higher number and percentage of trials than any of the other three feeds.

Table 3.

Number of times each food was chosen first through fifth, by Emmie, out of 50 trials

Food	Choice number				
	1	2	3	4	5
Maize (A)	27	22	1	0	0
Pellets (B)	22	24	4	0	0
Chopped Lucerne (C)	1	4	42	0	0
Lucerne Haylage (D)	0	0	0	7	1
T+L Haylage (E)		0	0	6	1

Table 4.

Number of times each food was chosen first through fifth, for Mayhem, out of 50 trials

Food	Choice number				
	1	2	3	4	5
Maize (A)	35	12	1	0	0
Pellets (B)	13	29	0	0	0
Chopped Lucerne (C)	0	1	5	0	0
Lucerne Haylage (D)	0	0	0	0	0
T+L Haylage (E)	0	0	0	0	0

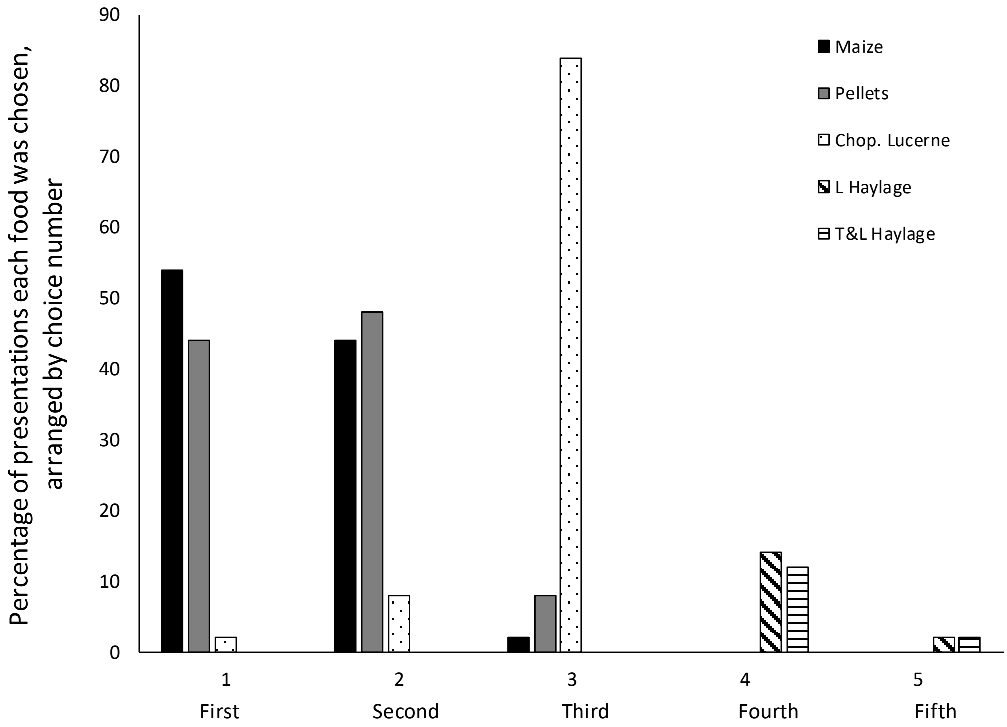

Figure 9. Percentage of trials five feeds were chosen by Emmie in a Multiple Stimulus Without Relacement assessment of preference. Bars show the percentage (of all presentations) that feeds were chosen by choice number.

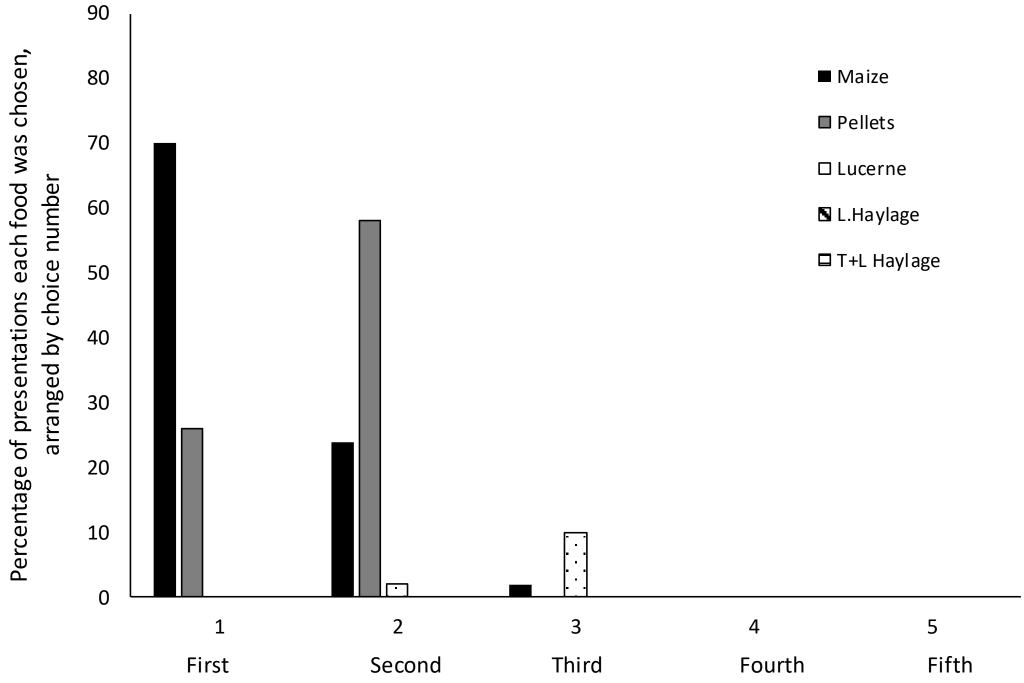

Figure 10. Percentage of trials five feeds were chosen by Mayhem in a Multiple Stimulus Without Relacement assessment of preference. Bars show the percentage (of all presentations) that feeds were chosen by choice number.

Concurrent Schedule Assessment

Emmie. Figures 11-15 show the proportion of responses and time allocated to maize, pellets, chopped lucerne, lucerne haylage, and T+LH during a concurrent schedules assessment of preference, for Emmie. Each figure displays the proportion of responses and time for a food when that food was compared to each of the remaining four feeds. For example, Figure 11 is headed 'Maize' and shows the proportion of responses and time when maize was paired with each other food type. The bottom panel of each figure shows the proportion of time allocated to the respective food, when presented to the left and right of each the other four foods in turn. Maize received substantially more responses and time when paired with 3 of the remaining feeds, except for Pellets (refer to Figure 11). Across all feeds, Emmie allocated more time and responses to maize when it was presented on the left, as opposed to the right of any other food, including pellets. Time allocated to maize was similar to the proportion of responses for maize, for all food comparisons. Responding for maize was highest when paired with lucerne haylage.

As is evident from Figure 12, pellets received a higher proportion of responses and time when paired with lucerne haylage and when paired with T+LH, than when paired with either chopped lucerne or maize. Responding for pellets was very similar to the proportion of time spent on pellets across all food comparisons. When paired with maize, responding for pellets was notably greater when pellets were presented on the left. When paired with chopped lucerne, responding for pellets was greater when presented on the right. In contrast, pellets had very similar response proportions on both left and right presentations when paired with the each of the two haylages.

The proportion of responses allocated to chopped lucerne was very similar when it was paired with lucerne haylage and when it was paired with T+LH (Figure 13). The proportion of responses for chopped lucerne was lowest when paired with maize and pellets, and highest when paired with each of the haylages. A higher proportion of responses was seen when chopped lucerne was available on the right, for 3 of the 4 feeds. The remaining food, maize, was associated with a higher proportion of responses for chopped lucerne when chopped lucerne was on the left. Time spent responding for chopped lucerne when paired with pellets and maize, individually, closely resembled the proportion of responses to chopped lucerne with those comparisons. There was a much larger difference between responses and time for chopped lucerne when it was compared to each of the haylages.

Lucerne haylage received much fewer responses and less time when it was compared to maize or pellets, than when it was compared to the other 3 feeds (see Figure 14). Responding and time for lucerne haylage was highest when paired with chopped lucerne. Lucerne haylage had the fewest responses when it was available to the right of T+LH. When lucerne haylage was on the left, responding was much higher than the time allocated to lucerne haylage. When lucerne haylage was available on the right of T+LH, time allocation was higher than responding for lucerne haylage, albeit by a smaller difference than the difference between time and responses when lucerne haylage was on the left.

As is demonstrated in Figure 16, T+LH had a higher proportion of responses and time when paired with lucerne haylage, than when T+LH was compared to any of the 3 remaining feeds. The fewest responses occurred when T+LH was paired with pellets. Time allocation was similar to responding for T+LH across all food comparisons.

Table 5. *Proportion of responses/time allocated to the left food option with each food combination, Emmie*

Right Food

Left Food

	Maize	Pellets	Lucerne	LH*	T+LH**
Maize	0.54/0.5	0.54/0.53	0.71/0.64	0.81/0.76	0.79/0.73
Pellets	0.61/0.56	0.43/0.42	0.47/0.44	0.78/0.75	0.82/0.79
Lucerne	0.38/0.41	0.38/0.39	0.52/0.5	0.42/0.22	0.49/0.48
LH	0.14/0.12	0.24/0.27	0.41/0.58	***	0.37/0.12
T+LH	0.19/0.2	0.1/0.2	0.3/0.52	0.88/0.81	***

*Lucerne Haylage (LH)

**Timothy and Lucerne Haylage (T+LH)

***No data available

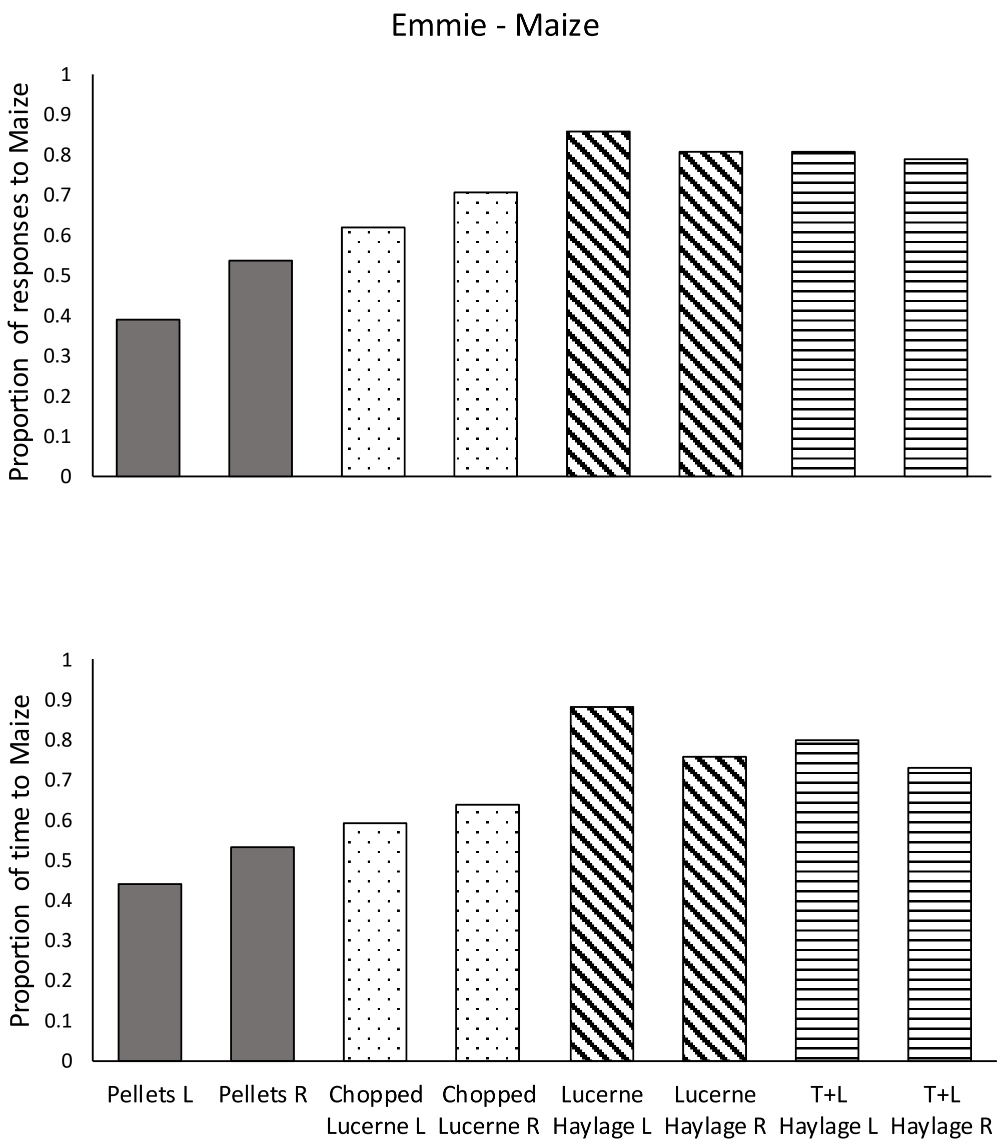

Figure 11. Proportion of responses (top panel) and time (bottom panel) allocated to Maize when it was presented to the left and the right of each other food.

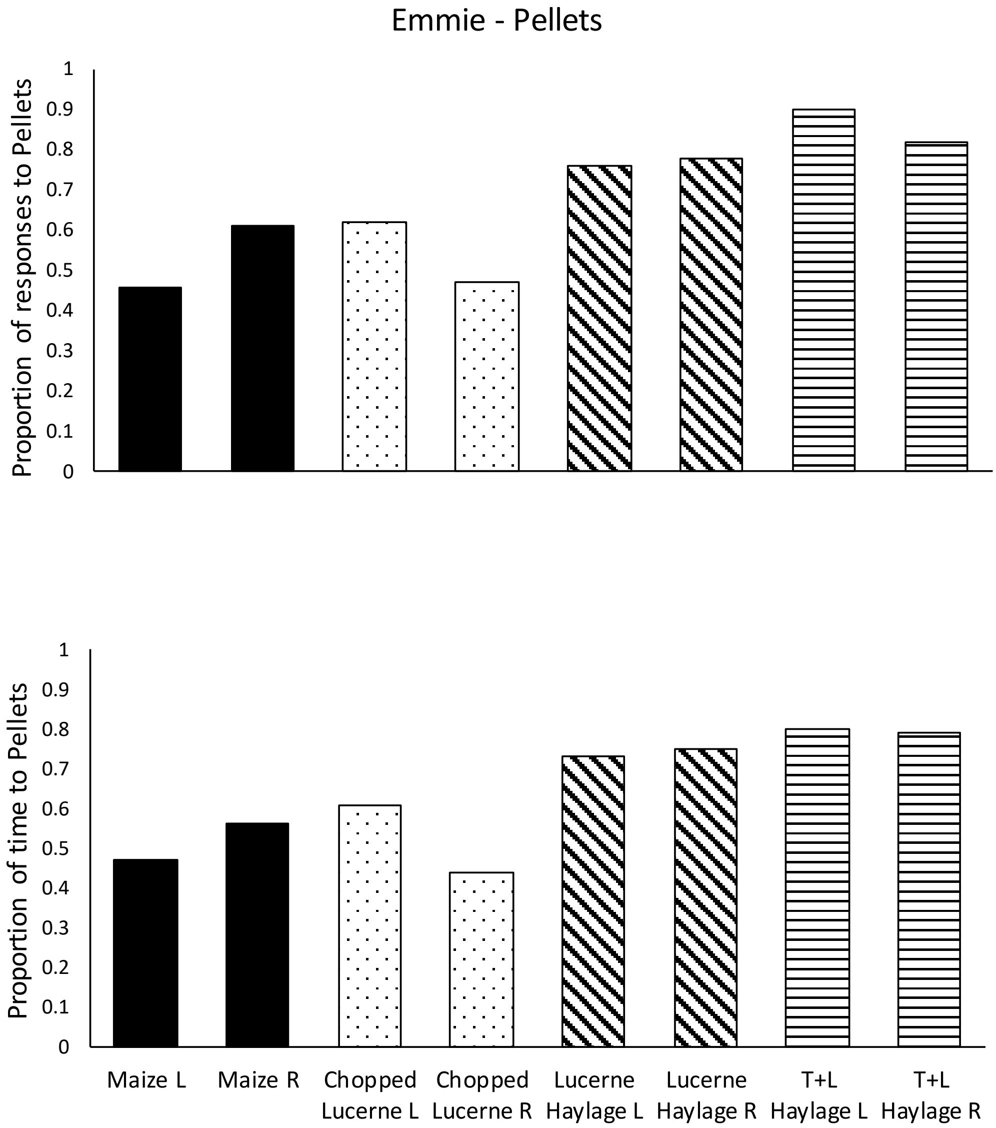

Figure 12. Proportion of responses (top panel) and time (bottom panel) allocated to Pellets when they were presented to the left and the right of each other food

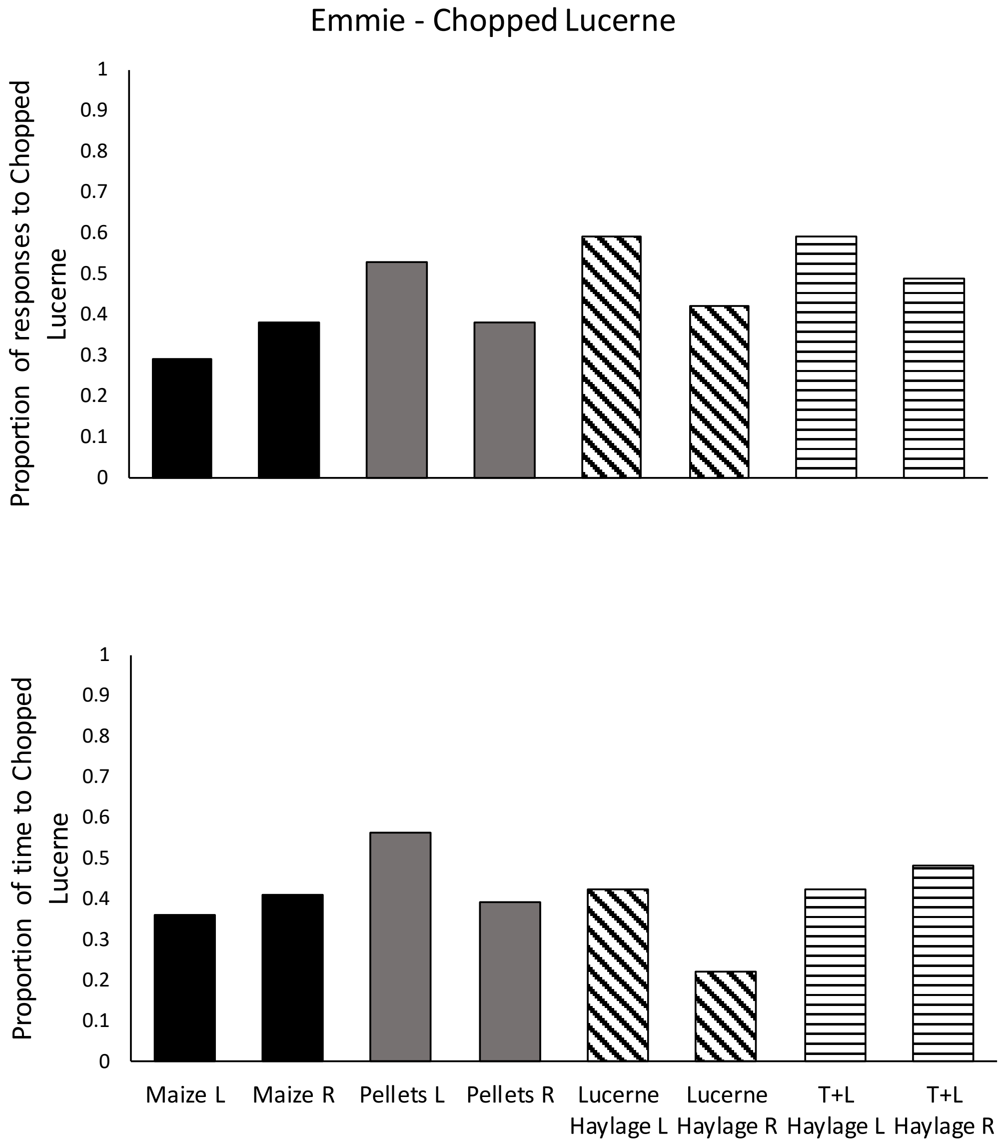

Figure 13. Proportion of responses (top panel) and time (bottom panel) allocated to Chopped Lucerne when it was presented to the left and right of each other food

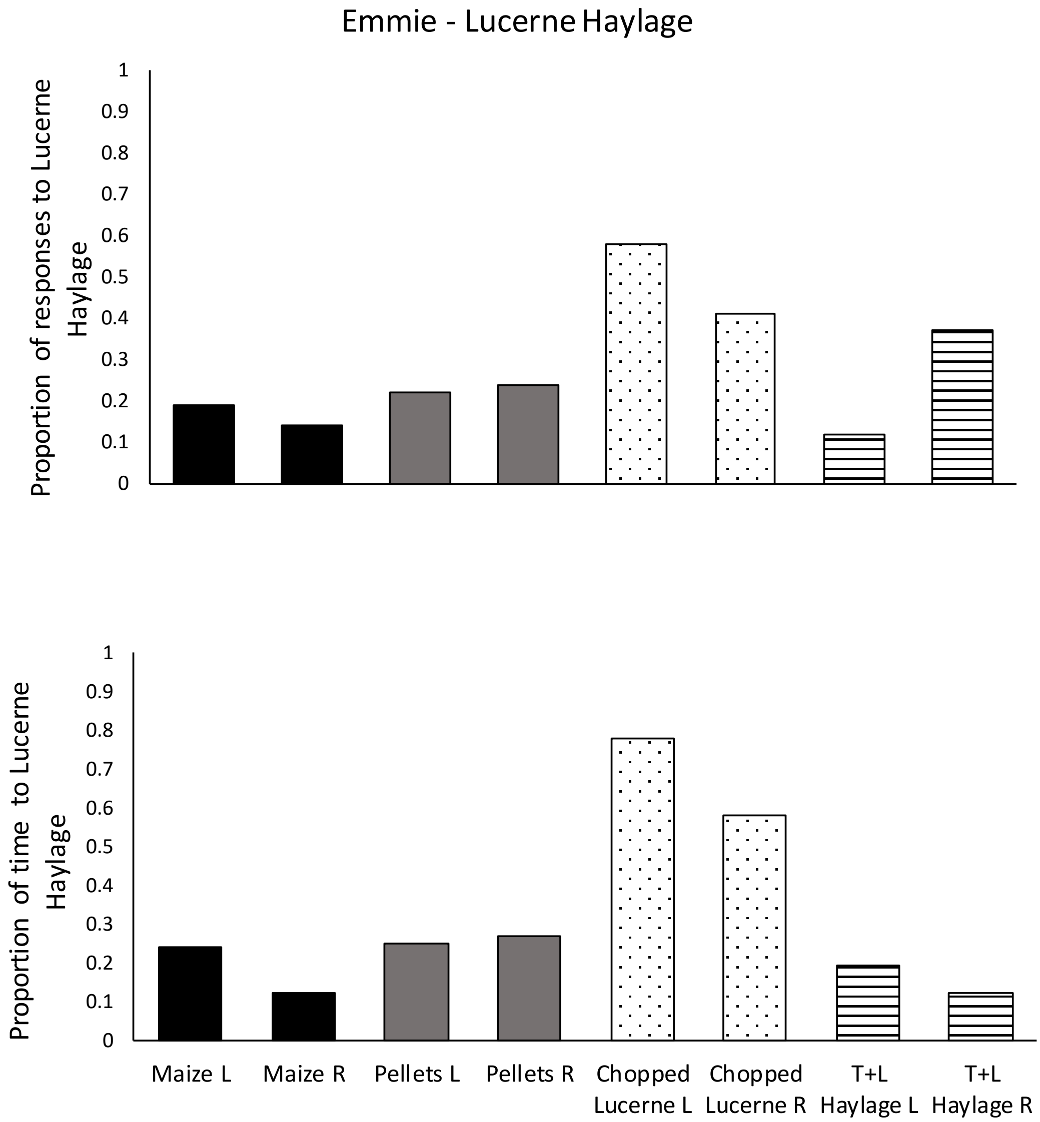

Figure 14. Proportion of responses and time allocated to Lucerne Haylage when presented to the left and right of each other food.

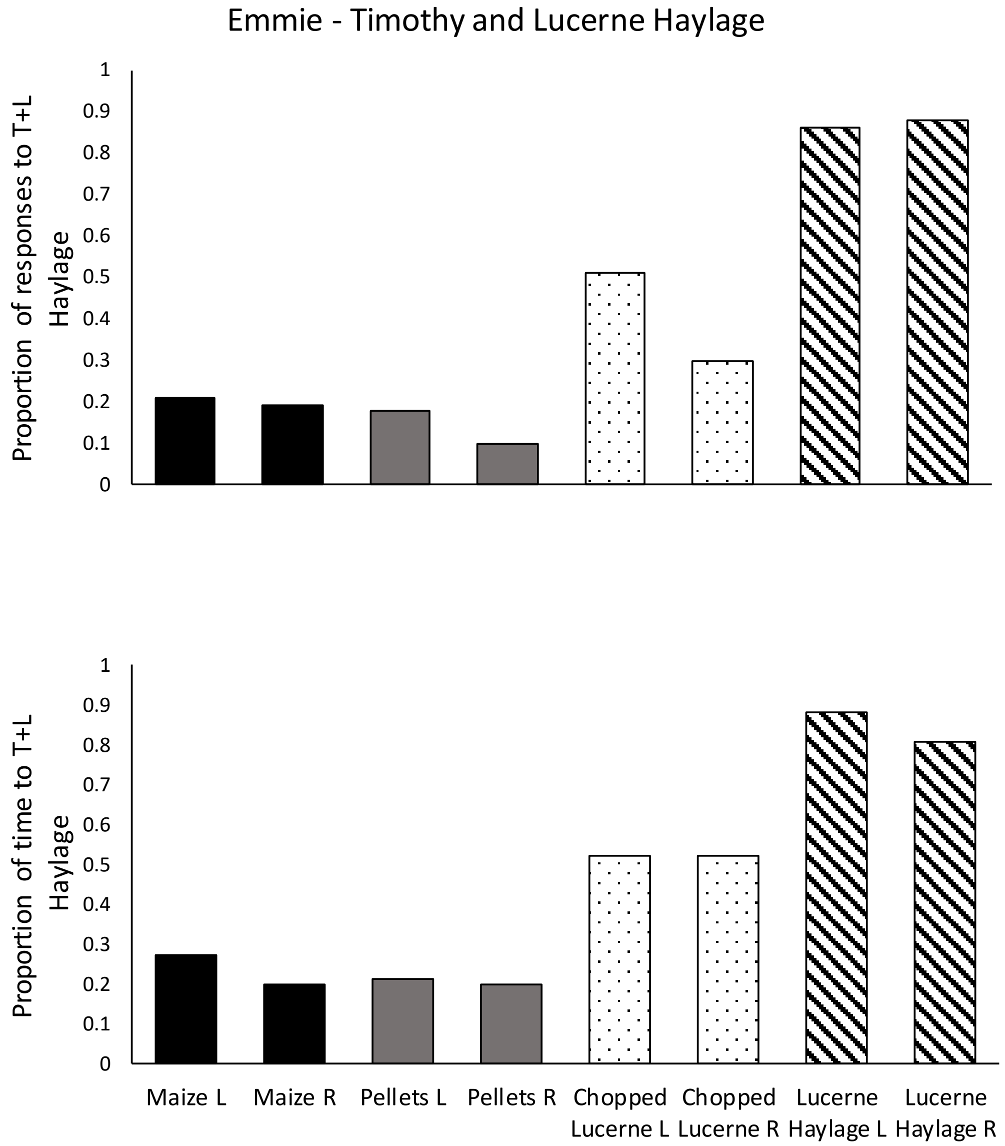

Figure 15. Proportion of responses (top panel) and time (bottom panel) allocated to Timothy and Lucerne Haylage when presented to the left and the right of each other

Mayhem. Figures 16-20 show the proportion of responses and time allocated to maize, pellets, chopped lucerne, lucerne haylage, and T+LH during a concurrent schedules assessment of preference, by Mayhem. In each figure, the proportion of responses and time for a food when that food was compared to each of the remaining four feeds is displayed. The experiment took place over 20 sessions. Data was extracted into a 5x5 table, each cell representing a combination of foods (See Table 6). The proportion of responses and time, for the food on the left, were recorded in each cell. Maize received the most responses when paired with T+LH and the least when paired with pellets (Figure 16). When maize was paired with pellets, chopped lucerne, and lucerne haylage, the time spent on maize was very similar to the responses for maize (both when maize was presented on the left and when it was on the right). When paired with T+LH, maize received more responses and less time when maize was presented on the right. When maize was presented on the left, there were fewer responses for maize and more time spent on maize.

Responding for pellets was least when paired with maize (Figure 17). Responding was highest when pellets were paired with each of the haylages. Time spent on pellets was also lowest when paired with maize. The proportion of responses for pellets was similar to the proportion of time spent on pellets when paired with 3 of the other foods, i.e. maize, chopped lucerne, lucerne haylage. Responses and time (for pellets) were similar when pellets were available on the left and when pellets were available on the right. Responses that pellets received when paired with chopped lucerne and lucerne haylage was similar to the proportion of time pellets received when paired with chopped lucerne and lucerne haylage, both when pellets were presented on the left of either food, and when pellets were presented to the right of either food. There was a much larger difference between the proportion of responses for pellets and the proportion of time spent on pellets when pellets were presented to the right of T+LH, not when pellets were presented on the left of T+LH. When pellets were presented to the left of T+LH there was a similarity between time and responses for pellets. In contrast, when pellets were presented to the right of T+LH there were substantially more responses than time allocated to pellets.

Chopped lucerne received the least responses when paired with maize and when paired with pellets, and the most responses when paired with lucerne haylage (Figure 18). More time, than responses, was spent on chopped lucerne when chopped lucerne was available on the left of lucerne haylage. When chopped lucerne was available to the right of lucerne haylage, the proportion of responses was similar to the proportion of time spent on chopped lucerne. The highest proportion of responses for chopped lucerne was when paired with lucerne haylage, followed by T+LH, pellets, and maize. Responding for chopped lucerne was similar to the time spent on chopped lucerne when chopped lucerne was paired with maize and when chopped lucerne was paired with pellets. Responding for chopped lucerne was also similar to the time spent on chopped lucerne when chopped lucerne was presented on the left of T+LH. There was a large difference between time and responses for chopped lucerne when chopped lucerne was available to the right of T+LH and when chopped lucerne was available to the left of lucerne haylage. When chopped lucerne was paired with each of the haylages, more responses for chopped lucerne was seen when it was available on the right (for both lucerne haylage and T+LH).

Responding for lucerne haylage when paired with maize was very similar to the responses seen when lucerne haylage was paired with pellets (Figure 19). Responses for lucerne haylage when paired with maize, and when paired with pellets, represented the least responses for lucerne haylage of the four food comparisons. Separately, lucerne haylage received the most responses when paired with chopped lucerne and when paired with T+LH (both comparisons representing the highest proportion of responses for lucerne haylage). The highest proportion of time spent on lucerne haylage was seen when lucerne haylage was available on the right of T+LH. The lowest proportion of time spent on lucerne haylage was seen when lucerne haylage was available to the right of chopped lucerne. Time was very similar to responses for lucerne haylage when lucerne haylage was paired with maize and when lucerne haylage was paired with pellets (both on left and right presentations). When lucerne haylage was available to the right of chopped lucerne, lucerne haylage received significantly more responses than time. When lucerne haylage was available to the left of chopped lucerne, responses and time lucerne haylage received were similar.

T+LH received the most responses when paired with lucerne haylage and the least responses when it was paired with maize (Figure 20). Likewise, the most time spent on T+LH was when it was paired with lucerne haylage. The least time was spent on T+LH when it was paired with pellets. When T+LH was available to the right of maize, time and responses were quite similar. In contrast, when T+LH was available to the left of maize, much more time was spent on T+LH than the responses it received. For all four feed comparisons, T+LH received more responses when presented to the right of any given food. For three of the feed comparisons, more time was allocated to T+LH when it was available on the right of any given food, than when T+LH had been presented on the left of the relevant food. In contrast to this, more time was allocated to T+LH when it was available to the left of maize, the remaining of the four feeds.

Table 6**.** *Proportion of responses/time allocated to the left food option with each food combination, Mayhem*

Right Food

Left Food

	Maize	Pellets	Lucerne	LH*	T+LH**
Maize	0.37/0.27	0.55/0.54	0.67/0.71	0.65/0.64	0.65/0.73
Pellets	0.48/0.44	0.46/0.45	0.63/0.59	0.65/0.69	0.58/0.68
Lucerne	0.4/0.3	0.46/0.59	0.59/0.58	0.6/0.85	0.45/0.5
LH	0.27/0.23	0.3/0.4	0.69/0.63	***	0.43/0.2
T+LH	0.2/0.43	0.23/0.14	0.48/0.12	0.37/0.32	***

*Lucerne Haylage (LH)

**Timothy and Lucerne Haylage (T+LH)

***No data available

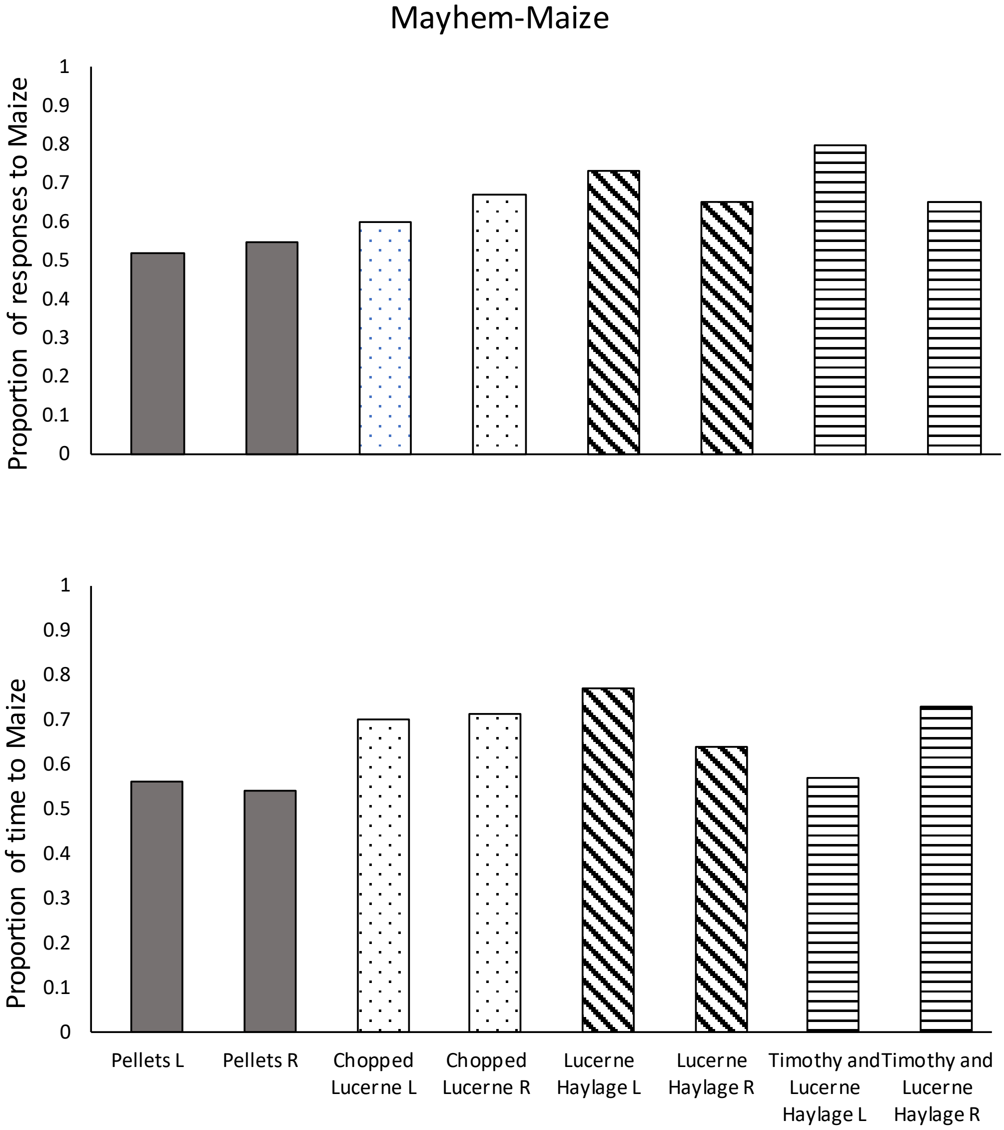

Figure 16. Proportion of responses (top panel) and time (bottom panel) allocated to Maize when it was presented to the left and the right of every other food when it

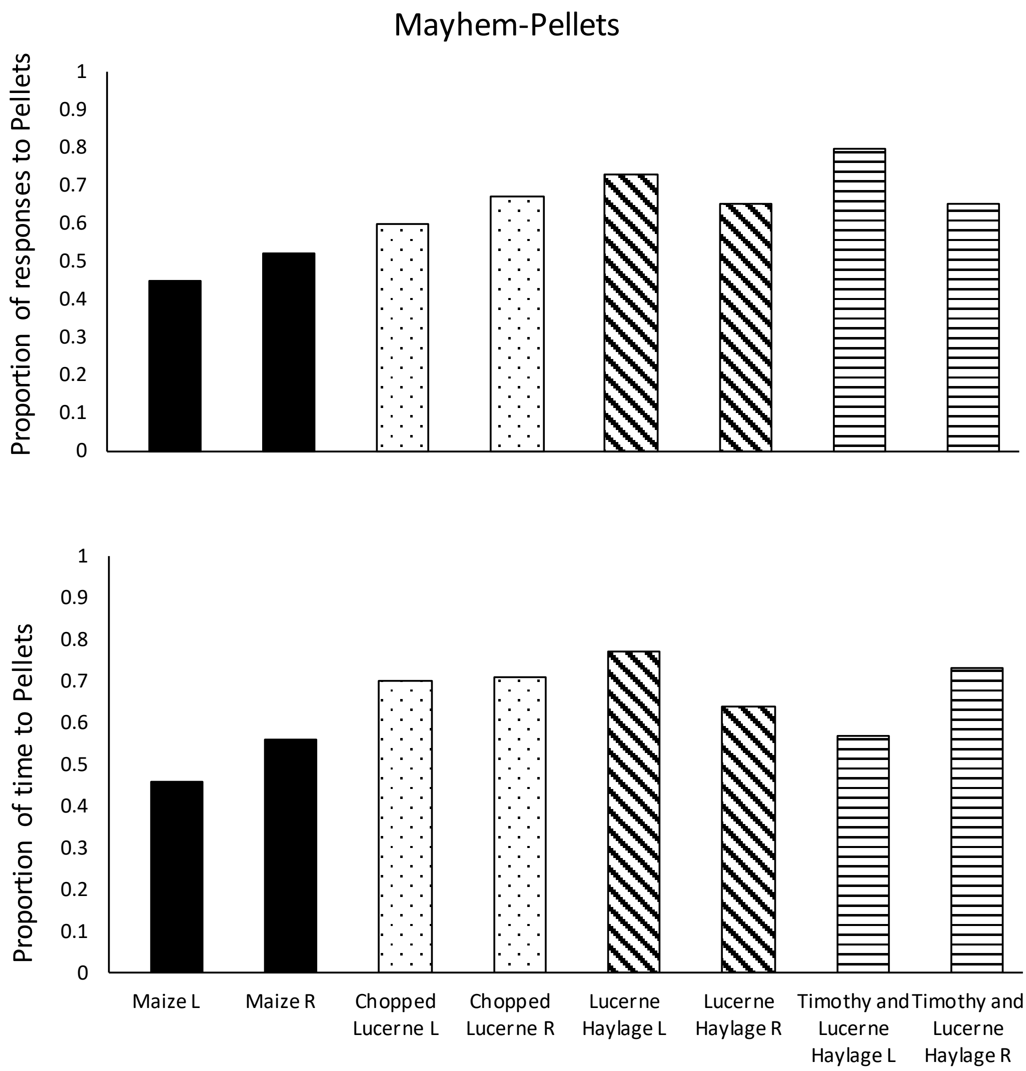

Figure 17. Proportion of responses (top panel) and time (bottom panel) allocated to Pellets when they were presented to the left and right of each other food

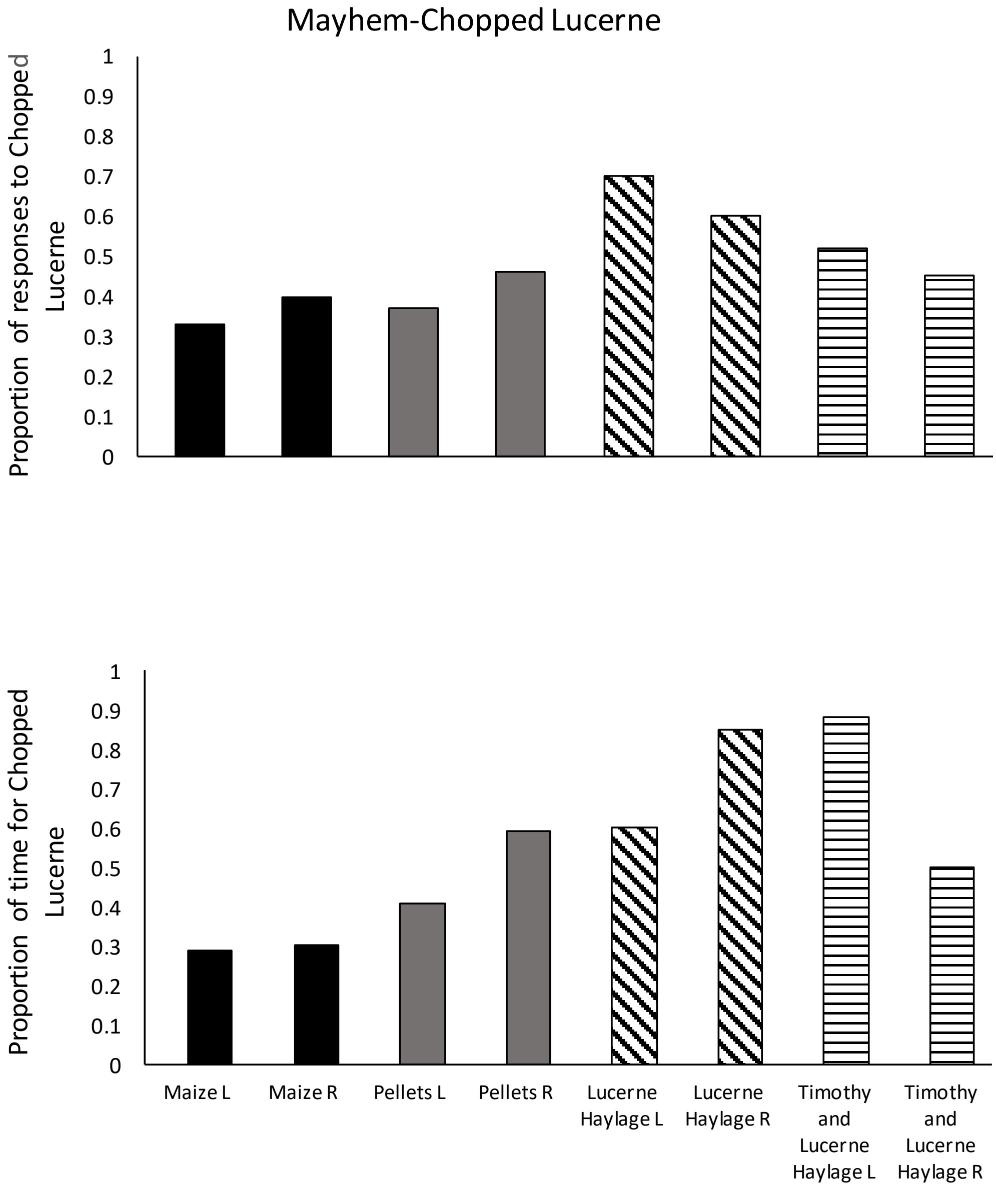

Figure 18. Proportion of responses (top panel) and time (bottom panel) allocated to Chopped Lucerne when presented to the left and right of each other food.

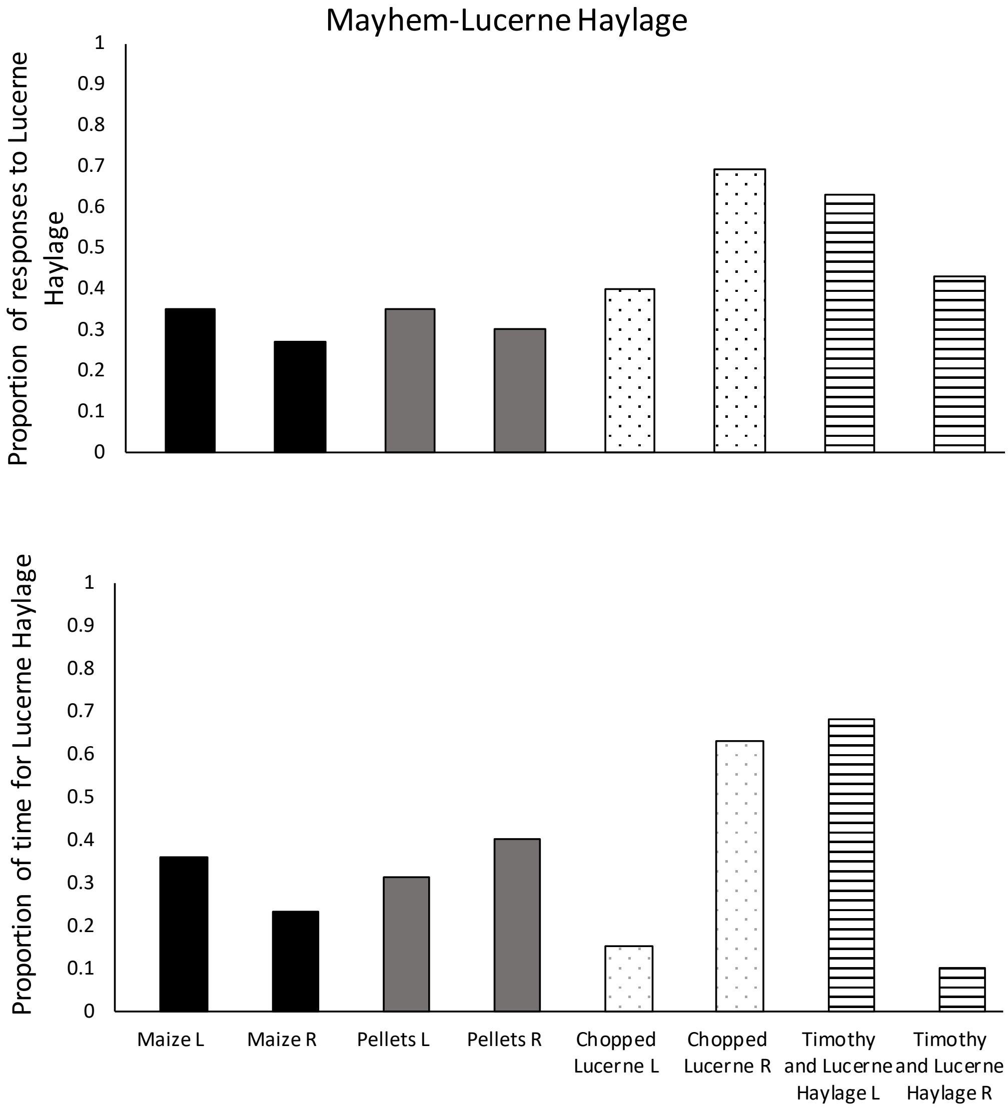

Figure 19. Proportion of responses (top panel) and time (bottom panel) allocated to Lucerne Haylage when it was paired with each other food.

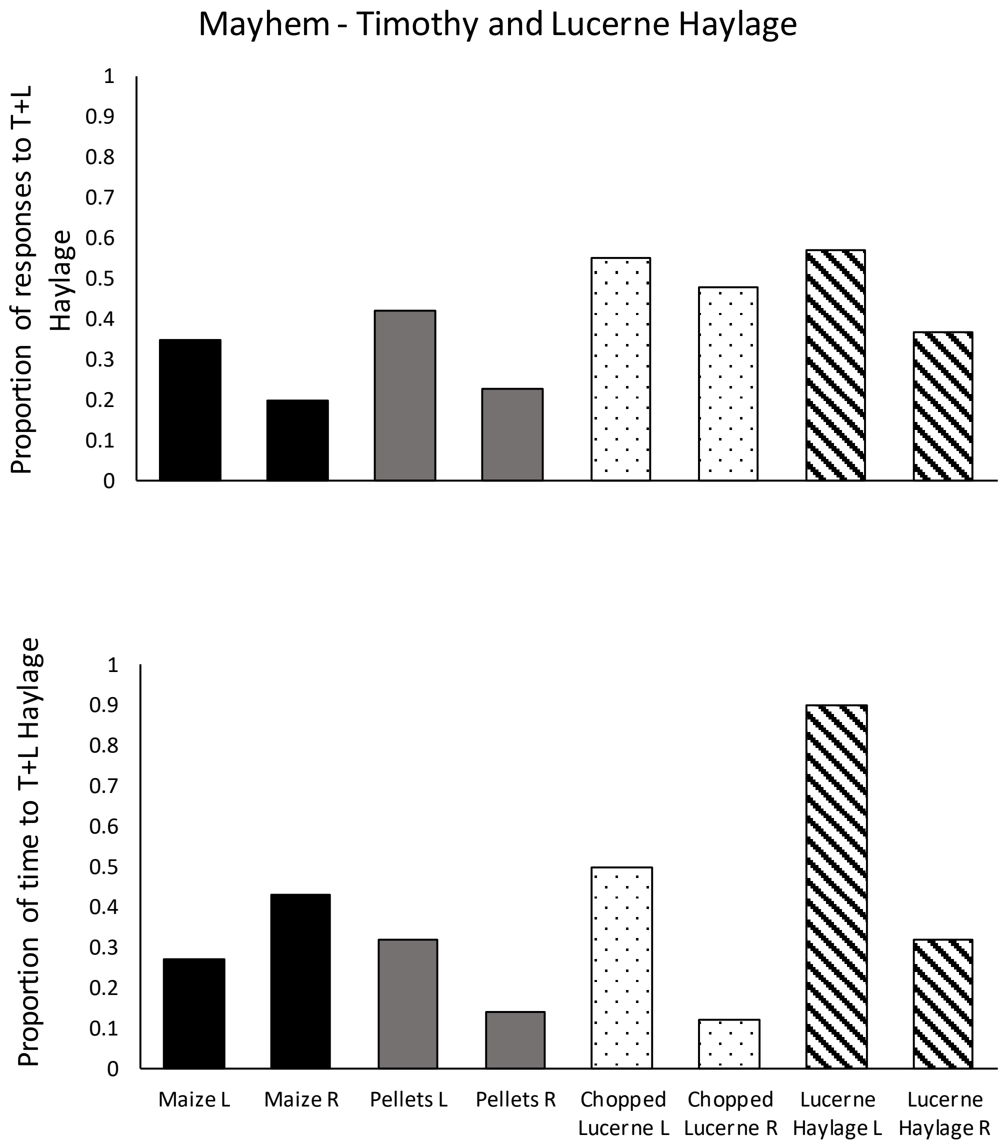

Figure 20. Proportion of responses (top panel) and time (bottom panel) allocated to Timothy and Lucerne Haylage when paired with each other food.

Preference rankings produced by each preference assessment are summarised below, in Tables 7 and 8. For the FA data, rankings were determined by calculating the average amount consumed across Trials 1 and 2. With the MSWO, rankings were produced by counting the number of times each food was chosen first, second, third, fourth, and fifth. These numbers were weighted – the number of times a food was chosen first was multiplied by 5, the number of times chosen second multiplied by 4; third by 3; fourth by 2; and fifth by 1 (i.e., no adjustment). The CS data were used produced two rankings – one based on the proportion of responses allocated to each food, and the other based on the proportion of time allocated to each food, when that food was presented with each other food. The value used to rank each food type was calculated by taking the average proportion of responses or time allocated to the relevant food type when it was presented to the left and to the right of each other food type. The rankings produced by each of these approaches for each assessment type are displayed in Tables 7 and 8 below.

All methods identified pellets or crushed maize as being most highly preferred. The FA ranked pellets first whereas both the other procedures ranked maize first for both goats. The two haylages were ranked lowest by all assessment methods with the exception of the ranking produced by time data for Emmie which ranked chopped lucerne lowest, alongside lucerne haylage.

This represents the only inconsistency between time and response data from the CS procedure, for both goats – mostly, time and responses produced the same ranking. For Mayhem's data (responses and time) there is a clear ranking of maize, pellets, chopped lucerne, lucerne haylage, T+LH. Emmie's time and response data also agreed for the most part, but there was one instance in which they did not agree – for chopped lucerne and T+LH. It is, however, important to note that there was only a small difference between the mean proportion of time for chopped lucerne and the mean proportion of time for T+LH.

Mayhem's data (based on average time and average responses for each food), produced a clear hierarchy of the five foods that was consistent across CS time and CS responses. Average figures for response allocation roughly matched those for time allocation with Mayhem (Table 8).

There was moderate consistency between rankings produced from the MSWO and the concurrent schedule (CS) assessment for both goats. Preference rankings from the CS assessment did not match those from the FA procedure with Emmie (see Table 7). With Mayhem, there were some similarities between the FA preference rankings and those produced by the CS, however it was not possible to determine order of preference for the two haylages that were ranked lowest, because no amount of either haylage was consumed (Table 8). Chopped lucerne was ranked third by both methods, and the two haylages were ranked least preferred by both methods, with Mayhem. It was not possible to determine a particular rank order of the haylages with the FA or MSWO methods for Mayhem because he consumed none of either haylage.

All three preference assessments produced a particular rank order of the haylages with Emmie, however these were not in perfect agreement (Table 7).

Table 7. *Food rankings produced by each preference assessment, for Emmie*

Ranking	Free Access[a]	MSWO[b]	CS Responses[c]	CS Time[d]
1	Pellets (134g)	Crushed Maize (226)	Crushed Maize (.69)	Crushed Maize (0.67)
2	Crushed Maize (76g)	Pellets (218)	Pellets (.68)	Pellets (0.64)
3	Lucerne Haylage (25g)	Chopped Lucerne (147)	Chopped Lucerne (.47)	Timothy and Lucerne Haylage (0.45)
4	Timothy and Lucerne Haylage (24g)	Lucerne Haylage (15)	Timothy and Lucerne Haylage (.38)	Chopped Lucerne (0.42)
5	Chopped Lucerne (15g)	Timothy and Lucerne Haylage (13)	Lucerne Haylage (.28)	Lucerne Haylage (0.32)

[a]mean amount consumed across Trials 1 and 2

[b]MSWO selection score weighted according to order selected across all trials (1st = 5 x multiplied, 2nd = 4 x multiplied, 3rd = 3 x multiplied, 4th = 2 x multipled, 5th = 1 x multiplied

[c]mean proportion of responses allocated across all pairings

[d]mean proportion of time allocated across all pairings

Table 8. *Food rankings produced by each preference assessment, for Mayhem*

Ranking	Free Access[a]	MSWO[b]	CS Responses[c]	CS Time[d]
1	Pellets (58g)	Crushed Maize (226)	Crushed Maize (0.64)	Crushed Maize (0.65)
2	Crushed Maize (23g)	Pellets (116)	Pellets (0.6)	Pellets (0.59)
3	Chopped Lucerne (3g)	Chopped Lucerne (19)	Chopped Lucerne (0.43)	Chopped Lucerne (0.52)
4	Haylage* (0g)	Haylage*	Lucerne Haylage (0.42)	Lucerne Haylage (0.37)
5	Haylage* (0g)	Haylage*	Timothy and Lucerne Haylage (0.4)	Timothy and Lucerne Haylage (0.36)

*Haylage- both haylages were ranked of lowest preference and it was impossible to determine whether one was ranked above another

[a] mean amount consumed across Trials 1 and 2

[b] MSWO selection score weighted according to order selected across all trials (1^{st} = 5 x multiplied, 2^{nd} = 4 x multiplied, 3^{rd} = 3 x multiplied, 4^{th} = 2 x multipled, 5^{th} = 1 x multiplied

[c] mean proportion of responses allocated across all pairings

[d] mean proportion of time allocated across all pairings

Discussion

Summary of results

MSWO and CS tests identified maize as being most highly preferred, with pellets ranked second most preferred for both goats. In contrast, the FA method identified pellets as being most highly preferred, with maize ranked second, for both goats. All three preference assessments identified the two haylages as being least preferred, with the exception of FA and the proportion of time measure from CS for Emmie.

With Emmie, pellets and maize were ranked first across all methods, and chopped Lucerne was ranked third across both the MSWO and CS, however lucerne haylage was ranked third (not chopped lucerne) with the FA, and CS time showed that T+LH was ranked third, even though response data had ranked chopped lucerne third (Emmie).

There was moderate consistency between the CS and the MSWO, with slight discrepancies between the positioning of low preference foods (haylages). Preference rankings from the concurrent schedule assessment did not match those from the FA for Emmie, although rankings produced by the two methods were very similar for Mayhem. The dependent variable for the free access procedure, amount consumed, was similar across Trials 1 and 2 for one Emmie. For Mayhem, amount consumed for all foods differed greatly across presentations (Trials 1 and 2). The FA may have ranked pellets and crushed maize differently than the other methods because weight was used as the primary dependent variable, as opposed to selection or response-based measures that were used in the other two procedures. As described earlier, an amount of either 8 or 12 cups for any given food was measured into a bucket, to be measured before and after the specified access period. Eight cups of pellets would have been heavier than eight cups of crushed maize. Even if the goats ate the same amount of two foods, in volume (e.g., 1 cup), the “amount consumed” in weight would still be greater for the heavier or more dense feed, based on weight. This may have also been a contributing factor for the ranking of the haylages as more highly preferred than chopped lucerne, with Emmie, when the other preference assessments ranked chopped lucerne as more highly preferred than the haylages. The haylages were damp feeds, whereas the chopped lucerne was dry, and weighed a lot less than the haylages. Because the chopped lucerne was so light in weight, the changes observed on the scales, post-consumption, were minimal.

Additionally, the preference level for pellets may have been overestimated. Pellets were ranked above crushed maize during the FA procedure, when the other methods placed crushed maize above pellets in preference level. It is possible that, aside from weight factors, a greater quantity of pellets may have been consumed than would have been if the subjects were given a choice over pellets, maize or other alternatives. An absence of other alternatives can mean that subjects may interact with or consume some of a stimulus they would not choose in a forced choice situation. This is a common finding in free access and other single stimulus procedures. As mentioned earlier, in Hagopian et al. (2001), animals may consume or otherwise interact with a stimulus more than they would if other food or other items had been available (Hagopian et al., 2001). During the FA, Emmie did consume some amount of certain foods that he never selected during the MSWO procedure or did not allocate many responses to during the concurrent schedule assessment. The present study seems to mirror the findings of Fisher. et al. (1992) who purported that basic preference assessments such as the FA may identify potential reinforcers as more highly preferred than other measures of preference would suggest.

Differences between the FA and the MSWO seen in the present study reflect the findings of Hagopian et al. (2001), who found that a SS procedure yields less reliable results than a PS procedure. SS procedures are similar to the FA, a type of SS procedure used in the present study. The PS that was used by (Hagopian et al., 2001) is similar to an MSWO that was also used here – it has been shown that the PS produces results similar to the MSWO (DeLeon & Iwata, 1996). There was, consistent with this, a similar finding regarding the FA and MSWO procedures in this experiment. The MSWO provided more detailed and reliable results than the FA.

The experiment by (Hagopian et al., 2001) evaluated reinforcer identification by comparing those reinforcers identified by a Single Stimulus Engagement procedure (SSE) and those identified by a PS procedure. As described in the introduction, preference rankings from each method in this study matched for 2 of 4 participants. Although preference rankings matched for 2 of 4 individuals, rankings from the SSE were less stable than those obtained from the PS across presentations. The PS procedure gave a more accurate prediction of reinforcer efficacy than the SSE. The authors concluded that Single Stimulus procedures are useful for determining potential reinforcers in situations where more elaborate procedures are impractical, with the limitation of providing less stable measures of preference than other common methods of preference assessment.

Rather than a paired stimulus procedure, as was used in Hagopian et al. (2001) the present study used a single stimulus (FA) procedure and a restricted operant (MSWO) procedure. Although a PS procedure was not utilised in the present study, DeLeon and Iwata (1996) showed that the PS procedure yields similar results to the MSWO, the procedure we used in the present study. The same items were identified as most highly preferred by both the PS and MSWO procedures across all participants, suggesting the two procedures were of similar usefulness for identifying potential reinforcers. The outcomes from the MSWO procedure and the FA procedure in the present study were comparable to the relationship between the PS and the single stimulus procedures observed in the aforementioned study by Hagopian et al. (2001). The study by Hagopian et al. (2001) used a different type of single stimulus assessment, a single stimulus engagement procedure (SSE), as compared to a FA procedure that was used in the present study. The authors used a PS procedure as opposed to a MSWO that was used here. The MSWO procedure provided more detailed information than the FA procedure, our single stimulus procedure - results produced by the FA were less consistent with the MSWO and CS analysis. This inconsistency may infer that the FA was less reliable in determining potential reinforcers – a reinforcer assessment would determine this. For the most part, the MSWO and concurrent schedule data agreed with one another, and one would infer that these are more likely to identify potential reinforcers than the FA procedure.

The concurrent schedule procedure provided more detailed information than either of the other methods, but took a lot of time for training and to administer.

Foods identified as being most highly preferred from the MSWO were the same foods that had been identified as most highly preferred by both of the other methods. The FA ranked the top two foods (maize and pellets) inversely to the other methods, however they were still ranked first and second, of highest preference. Chopped Lucerne was ranked third by the MSWO. It was also ranked third by the FA and CS. Of key interest is that the MSWO produced no distinction between either of the two haylages, which were of lower preference. The reason for this is that the MSWO assessment does not require an animal to select or consume any given food. When a food is not selected, it is not possible to gauge what location in a preference hierarchy it occupies because we have no data on 'order of selection' or the value of a food relative to another. Despite the limitations around ranking of lower preference foods, the MSWO was advantageous in that it was quick to administer and agreed with the other methods regarding ranking of the foods of higher preference. In contrast, although the CS took a lot longer to administer, it produced information on the degree of each food relative to each other type of food. This level of information was not available from the MSWO assessment. It also showed that the proportion of responses for left and right presentations of each food differed between left and right presentations – the potential for response bias is important to consider when attempting to discern preference by CS procedures. If the subject responds more on one lever than the other, it can appear the food is more highly preferred than it actually is because a higher proportion of responses may be allocated to that food than would have been if that food had been presented on the alternate side. To reduce the likelihood of this occurring, the present study presented foods on both the left and the right and data from both the left and right presentations were used to calculate the hierarchies so that bias could be removed from the rankings. It took a substantial amount of time to train both goats to use the limit switches on the CS apparatus, however the procedure yielded much more detailed data than the FA or MSWO methods because it provided information on the degree of preference for one food type relative to another, as opposed to simply identifying which foods are preferred relative to others. That is, in addition to demonstrating that food A is preferred over foods B, C, D, and E – the CS provided data on how much food A is preferred over foods B, C, D and E.

Limitations

This study had a number of limitations, particularly around controlling establishing operations throughout the study. The goats escaped the experimental area many times throughout the project and that may have influenced resulting data. An example of this can be seen in the FA data. Despite being a high preference food, Mayhem consumed very little maize on Trial 2 of the FA procedure (as compared to Trial 1), potentially because both goats had escaped prior to this session. It is likely that the goats having escaped reduced an average figure for the amount consumed because they had FA during the time they escaped - satiation may therefore have reduced amount consumed. Subjects having escaped prior to a session, and the satiation accompanying this, may be a contributing factor to maize being ranked differently to the other two methods used, if less maize was consumed due to satiation. The FA procedure was carried out on a different day to the other procedures. There may have been decreased preference on other occasions for the same reason. Following episodes of leaving the penned area, there were issues with satiation and the goats working less for food. This was a source of variability that should be carefully monitored and controlled when it is possible to do so.

This study did not include a reinforcer assessment, which some studies have done (DeLeon & Iwata, 1996; Fisher. et al., 1992; Higbee et al., 2000; Piazza et al., 1996; Vicars et al., 2014). Higbee et al. (2000) found that stimuli identified as high preference functioned as reinforcers in 6 of 9 participants from their study. However, no low preference stimuli underwent reinforcer assessment to determine whether low preference stimuli functioned as reinforcers. While it is often inferred that stimuli which are ranked as highly preferred are likely to function as reinforcers, it is not safe to make the assumption they will function as reinforcers because they are highly preferred. The advantage of concurrent schedule procedures is that the animals' continued responding reflects that the stimulus is acting as a reinforcer.

Piazza et al. (1996) used a choice assessment to identify stimuli as being of high, middle, or low preference level and in a second component they proceeded to evaluate which of those items identified as being preferred actually functioned as reinforcers. Items identified as being of high preference functioned as reinforcers for all participants, items identified as being of middle preference level functioned as reinforcers for 2 of 4 participants when they were measured against stimuli identified as lower preference. Lower preference stimuli did not function as reinforcers at all. Vicars et al. (2014) conducted a study of preference similar to that of Piazza et al. (1996) but with dogs, and followed this up with a reinforcer assessment. A PS assessment of food preference was conducted with dogs and followed up with a concurrent schedule condition and a progressive ratio condition to evaluate the effectiveness of those foods as reinforcers. Before preference assessment, owners had filled in a questionnaire about items they believed their dog liked or disliked, to identify potential stimuli for testing in the PS. The study found that, in this case, the items identified of high preference in the PS procedure also functioned as reinforcers in all subjects - as determined by the concurrent schedule assessment (Vicars et al., 2014).Other authors such as Hagopian et al. (2001) have also reported that the PS effectively identified reinforcers.

It is possible, given the reported similarities between the MSWO and the PS (DeLeon & Iwata, 1996) that the MSWO used in the present study may have effectively identified reinforcers. Future research similar to the present research might include a reinforcer assessment. It is unknown whether a repeat of the present study, using the same foods, would identify the same relationship as that identified by Piazza et al. (1996) whereby high preference stimuli function as reinforcers more than middle preference items, and low preference items do not function as reinforcers.

The present study used only two subjects, of different breed and history of exposure to humans. It is difficult to determine whether the differences between the two sets of data are because the preference assessments are not accurately identifying an existent preference hierarchy that is consistent across goats, or if the preference assessments are in fact very accurate at identifying preference level and the differences in data simply reflect that each subject had a unique hierarchy of preference. If a larger sample was used, it is possible that one would see a more distinct pattern regarding preference hierarchies and that one may be able to develop a more informed judgment regarding the efficacy of these measures.

The concurrent schedule assessment had value in determining preference level of the feeds used in this study and provided information on the degree of preference for each food relative to each other food (rankings of the all food types are displayed in Tables 7 and 8, and proportions cited in Tables 5 and 6 of the results section). There was one inconsistency in the CS data, Emmie's mean time allocation for T+LH and chopped lucerne did not match the ranking produced by response data. However, the CS time values calculated for the different rankings of T+LH and chopped lucerne for Emmie were very similar. For all other food types, time and response data were in agreement, across both goats. (see Table 7). Concurrent schedule data shows that Emmie allocated more of his responses to T+LH than he did lucerne haylage. Mayhem allocated more time and responses to lucerne haylage than he did T+LH, but the difference was small (see Table 8). This difference posed question as to whether one of the haylages was in fact preferred over another, or if preference for each of the haylages relative to the other foods was approximately equal.

These results may have been influenced by some of the factors mentioned above, such as the issues around controlling food intake outside of experimental sessions. The goats also had less exposure to the haylages than any of the other feeds, which may have contributed to the very low ranking of the haylages.

Future studies

Future studies might use the same methodology that is used here to explore the consistency between outcomes from those assessment methods we explored, and outcomes from other preference assessment methods that have been used in other studies. For example, it may be useful to compare the PS, MSWO, and CS in one project. Previous studies have explored the relationship between the MSW and PS outcomes, the MSWO and PS outcomes, and the two MSW procedures. The current study was the first to test the single stimulus (free access), MSWO, and a CS for consistency. Understanding the relationship between all of these methods would potentially be of benefit for anyone looking to choose a preference assessment method that best suits their needs, whether with humans or other animals.

Further studies might also repeat this procedure with non-food items, for example preference for enrichment items or flooring types. These conditions are important for meeting the needs of animal species and improving animal welfare. Applying the methods used in the current study to non-food items may provide the information necessary to improve aspects of animal welfare other than food. This may also give an idea of the usefulness of the methods used here for assessing preference for non-food items. An additional means of adding to the value of this study may be to repeat the same procedure with more subjects; having only two participants was a key limitation of this study. Given that male goats were used in this study, it may also be useful to repeat these procedure with does to test whether they also prefer the same foods as bucks. This may give the study more credence in terms of applications for the dairy goat industry and identify which foods are going to be of best benefit for production.

To test whether the preference assessments used here are effective at identifying potential reinforcers, it would be useful to follow up with a reinforcer assessment. As was mentioned earlier, preference assessments are a means to identify potential reinforcers. While preference level is generally predictive of reinforcer efficacy, preference assessments themselves do not tell us whether stimuli are effective as reinforcers. To determine whether the preference assessments, and resulting preference rankings used in this study have told us what foods will function as reinforcers for these subjects, future studies could follow up with a reinforcer assessment.

The methods used in this study may provide a useful means to assess what foods (or other) resources are likely important to goats', or other animals' welfare status. Preference usually reflects welfare and food preference is related to the physical and ethological needs of an animal or its species and are therefore valuable in the assessment of welfare (Kirkden & Pajor, 2006; Sumpter et al., 2002). Giving an animal choices over its environment allows us to identify its preferences. We can also measure whether that resource functions as a reinforcer for the animal, and how hard it will work to obtain that resource (reinforcer assessment). Concurrent schedule procedures are a valuable method for identifying which foods function as reinforcers and comparing different food types, while providing quantifiable data about the degree of preference. If a food functions as a reinforcer, it is likely that it is important to the animal's wellbeing in some way. This could provide the key to discovering more about the nutritional needs of ruminants and to establishing feed mixes that are more palatable for does in commercial dairy goat farms and that also support adequate milk yield. It is well known that there is an excess of carbohydrate and a shortage of fibrous material, in livestock diets - this can cause significant health problems; particularly ruminal acidosis which can be life threatening. Effective management of feeds requires a combination of foods that meet nutritive requirements and are sufficiently palatable. If we can identify the more fibrous foods that are most palatable to goats and increase intake of those foods, we may be on the way to reducing potential health problems in the future.

Results observed from this study suggest that basic preference assessment methods such as the FA and MSWO have value in determining preference and may provide useful information that can inform agricultural/farming practice. However, in commercial farming systems where productivity is crucial, it may be beneficial to have a clearer understanding of preference than can be gained from FA or MSWO. Particularly when some feed types appear to be of similar value but there is a need to differentiate between them, it may be useful to implement a CS procedure for better accuracy and more detailed results.

References

Armistead, M. J. (2009). *A comparison of demand for two different feeds with horse*s (Masters' thesis, University of Waikato, New Zealand). Retrieved from https://hdl.handle.net/10289/4271

Baum, & Davison, M. (2009). Modeling the dynamics of choice. *Behavioural Processes, 81*(2), 189-194. doi:10.1016/j.beproc.2009.01.005

Baum, W. M. (1979). Matching, undermatching, and overmatching in studies of choice. *Journal of the Experimental Analysis of Behavior, 32*(2), 269-281. doi:10.1901/jeab.1979.32-269

Browne-Crowder, I. (2003). Feeds and nutrition of dairy goats: An overview of the nutritional needs and requirements of dairy goats. Retrieved from http://www.milkproduction.com/Library/Scientific-articles/Other-milking-animals/Feeds-and-nutrition/

Campbell, A., & McLeay, L. (n.d). Animal structure & function: The digestive system. Retrieved from http://sci.waikato.ac.nz/farm/content/animalstructure.html

Cantalapiedra-Hijar, G., Yáñez-Ruiz, D., Martín-García, A., & Molina-Alcaide, E. (2009). Effects of forage: Concentrate ratio and forage type on apparent digestibility, ruminal fermentation, and microbial growth in goats. *Journal of Animal Science, 87*(2), 622-631.

Cooper, J., Heron, T., & Heward, W. (2014). *Applied behavior analysis* (Pearson new international edition). Harlow, Essex Pearson.

Cronin, I. R. (2012). *Possum food preferences under progressive-ratio and concurrent-schedules of reinforcement* (Thesis, University of Waikato, New Zealand). Retrieved from https://hdl.handle.net/10289/6638

Dairy Goat Co-op. (2017a). Manufacturing: Integrated facilities. Retrieved from http://www.dgc.co.nz/manufacturing.cfm

Dairy Goat Co-op. (2017b). Our credentials. Retrieved from http://www.dgc.co.nz/facts.cfm

DairyNZ. (2015). New Zealand Dairy Statistics Retrieved from https://www.dairynz.co.nz/publications/dairy-industry/new-zealand-dairy-statistics-2015-16/

Dawkins, M. S. (2006). Through animal eyes: What behaviour tells us. *Applied Animal Behaviour Science, 100*(1), 4-10. doi:10.1016/j.applanim.2006.04.010

DeLeon, I. G., Frank, M. A., Gregory, M. K., & Allman, M. J. (2009). On the correspondence between preference assessment outcomes and progressive-ratio schedule assessments of stimulus value. *Journal of Applied Behavior Analysis, 42*(3), 729-733. doi:10.1901/jaba.2009.42-729

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), 519-533. doi:10.1901/jaba.1996.29-519

Desnoyers, M., Duvaux-Ponter, C., Rigalma, K., Roussel, S., Martin, O., & Giger-Reverdin, S. (2008). Effect of concentrate percentage on ruminal pH and time-budget in dairy goats. *Animal: An international Journal of Animal Bioscience, 2*(12), 1802-1808. doi:10.1017/S1751731108003157

Dubeuf, J. P., Morand-Fehr, P., & Rubino, R. (2004). Situation, changes and future of goat industry around the world. *Small Ruminant Research, 51*(2), 165-173. doi:10.1016/j.smallrumres.2003.08.007

Fernandez, E. J., Dorey, N., & Rosales-Ruiz, J. (2004). A two-choice preference assessment with five cotton-top tamarins (Saguinus oedipus). *Journal of Applied Animal Welfare Science, 7*(3), 163-169. doi:10.1207/s15327604jaws0703_2

Findley, J. D. (1958). Preference and switching under concurrent scheduling. *Journal of the Experimental Analysis of Behavior, 1*(2), 123-144. doi:10.1901/jeab.1958.1-123

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), 491-498. doi:10.1901/jaba.1992.25-491

Foster, M., Matthews, L., Temple, W., & Poling, A. (1997). Concurrent schedule performance in domestic goats: Persistent undermatching. *Behavioural Processes, 40*(3), 231-237. doi:10.1016/S0376-6357(97)00018-1

Foster, M., Temple, W., Robertson, B., Nair, V., & Poling, A. (1996). Concurrent-schedule performance in dairy cows: persistent undermatching. *Journal* *of the Experimental Analysis of Behavior, 65*(1), 57-80. doi:10.1901/jeab.1996.65-57

Greenhalgh, J. F. D., & Reid, G. W. (1967). Separating the effects of digestibility and palatability on food intake in ruminant animals. *Nature, 214*(5089), 744-744. doi: 10.1038/214744a0

Hagopian, L. P., Rush, K. S., Lewin, A. B., & Long, E. S. (2001). Evaluating the predictive validity of a single stimulus engagement preference assessment. *Journal of Applied Behavior Analysis, 34*(4), 475-485. doi: 10.1901/jaba.2001.34-475

Heady, H. F. (1964). Palatability of herbage and animal preference. *Journal of Range Management, 17*(2), 76-82. doi:10.2307/3895315

Heaton, K. W., Marcus, S., Emmett, P., & Bolton, C. (1988). Particle size of wheat, maize, and oat test meals: Effects on plasma glucose and insulin responses and on the rate of starch digestion in vitro. *The American Journal of Clinical Nutrition, 47*(4), 675-682. doi: 10.1093/ajcn/47.4.675

Hemsworth, P. H., Mellor, D. J., Cronin, G. M., & Tilbrook, A. J. (2015). Scientific assessment of animal welfare. *New Zealand Veterinary Journal, 63*(1), 24-30. doi:10.1080/00480169.2014.966167

Higbee, T. S., Carr, J. E., & Harrison, C. D. (2000). Further evaluation of the multiple-stimulus preference assessment. *Research in Developmental Disabilities, 21*(1), 61-73. doi:http://dx.doi.org/10.1016/S0891-4222(99)00030-X

Kirkden, R. D., & Pajor, E. A. (2006). Using preference, motivation and aversion tests to ask scientific questions about animals' feelings. *Applied Animal Behaviour Science, 100*(1–2), 29-47. doi:http://dx.doi.org/10.1016/j.applanim.2006.04.009

Mapp, N., Hutchinson, K., King, W., & Rennie, G. (2011). Where to from here? Optimisation of forage supply systems for the dairy goat industry. Retrieved from maxa.mpi.govt.nz

Med Associates. (2017). MedPC. Retrieved from http://www.med-associates.com

Mehrkam, L. R., & Dorey, N. R. (2015). Preference assessments in the zoo: Keeper and staff predictions of enrichment preferences across species. *Zoo Biology, 34*(5), 418-430. doi:10.1002/zoo.21227

Morand-Fehr, P., Boutonnet, J. P., Devendra, C., Dubeuf, J. P., Haenlein, G. F. W., Holst, P., . . . Capote, J. (2004). Strategy for goat farming in the 21st century. *Small Ruminant Research, 51*(2), 175-183. doi:10.1016/j.smallrumres.2003.08.013

Piazza, C. C., Fisher, W. W., Hagopian, L. P., Bowman, L. G., & Toole, L. (1996). Using a choice assessment to predict reinforcer effectiveness. *Journal of Applied Behavior Analysis, 29*(1), 1-9. doi:10.1901/jaba.1996.29-1

Poling, A., Edwards, T. L., Weeden, M., & Foster, T. M. (2011). The matching law. *The Psychological Record, 61*(2), 313-322. doi:10.1901/ jaba.2009.42-575

Rainanzin, M., Bailoni, L., & Schiavon, S. (1997). Effect of forage to concentrate ratio on comparative digestion in sheep, goats and fallow deer. *Animal Science, 64*, 163-170. doi:10.1017/S1357729800015678

Roscoe, E. M., Iwata, B. A., & Kahng, S. (1999). Relative versus absolute reinforcement effects: Implications for preference assessments. *Journal of Applied Behavior Analysis, 32*(4), 479-493. doi:10.1901/jaba.1999.32-479

Santini, F. J., Lu, C. D., Potchoiba, M. J., Fernandez, J. M., & Coleman, S. W. (1992). Dietary fiber and milk yield, mastication, digestion, and rate of passage in goats fed alfalfa hay. *Journal of Dairy Science, 75*(1), 209-219. doi:10.3168/jds.S0022-0302(92)77755-8

Schoenian, S. (2017). Nutritional requirements of goats. Retrieved from https://www.tractorsupply.com/know-how_pets-livestock_livestock-other_goat_nutritional-requirements-for-goats.

Sheppard, R., & O'Donnell, D. (1979). *A review of the New Zealand goat industry.* Lincoln College, New Zealand. Retrieved from https://hdl.handle.net/10182/999.

Skinner, B. F. (1953). *Science and human behavior* (Free press paperback ed.). New York, US: The free press.

Sumpter, C. E., Foster, M. T., & Temple, W. (2002). Assessing animals' preferences: Concurrent schedules of reinforcement. *International Journal of Comparative Psychology, 15*(2), 107-122.

Tapper, K. (2005). Motivating operations in appetite research. *Appetite, 45*(2), 95-107. doi:10.1016/j.appet.2005.05.002

Thorndike, E. L. (1927). The law of effect. *The American Journal of Psychology, 39*(1/4), 212-222. doi:10.2307/1415413

University of Minnesota. (2017). Dairy extension: Supplemental feeding. Retrieved from https://www.extension.umn.edu/agriculture/dairy/feed-and-nutrition/feeding-dairy-goats/

Vicars, S. M., Miguel, C. F., & Sobie, J. L. (2014). Assessing preference and reinforcer effectiveness in dogs. *Behavioural Processes, 103*, 75-83. doi:10.1016/j.beproc.2013.11.006

Wang, Y. H., Xu, M., Wang, F. N., Yu, Z. P., Yao, J. H., Zan, L. S., & Yang, F. X. (2009). Effect of dietary starch on rumen and small intestine morphology and digesta pH in goats. *Livestock Science, 122*(1), 48-52. doi:10.1016/j.livsci.2008.07.024

Wardle, D. A., Barker, G. M., Yeates, G. W., Bonner, K. I., & Ghani, A. (2001). Introduced browsing mammals in new zealand natural forests: Aboveground and belowground consequences. *Ecological Monographs, 71*(4), 587-614. doi:10.1890/0012-9615(2001)071[0587:IBMINZ]2.0.CO;2

Windsor, J., Piché, L. M., & Locke, P. A. (1994). Preference testing: A comparison of two presentation methods. *Research in Developmental Disabilities, 15*(6), 439-455. doi:10.1016/0891-4222(94)90028-0