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Short report

Effects of price and pellet type on food waste in mice

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ABSTRACT

When laboratory mice are provided with free access to food, they often fragment their food such that it collects on the cage floor – wasted. An operant analysis of food waste, however, has not yet been conducted. The purpose of the present study was to evaluate the effect of response requirement and pellet type on food waste using a behavioral economic paradigm. Sixteen mice responded under a series of escalating fixed ratio schedules. Nose pokes were reinforced with either a grain-based pellet or a fiber-based pellet (diluted with non-digestible cellulose) across conditions. We found that mice spilled a greater percent of the total earned pellets at low response requirements. Additionally, mice spilled more fiber-based pellets relative to grain-based pellets. This difference was most pronounced when the fixed ratio requirement was low and was attenuated as the fixed ratio was increased, and this decrease in food waste across prices was well accounted for by an exponential model. Mice may have been extracting the calorically dense components of the fiber-based pellets only when the schedule of reinforcement was rich. When the schedule of reinforcement was lean, responding for a new pellet likely was a more functional behavior than fragmenting a pellet and discarding portions.

1. Introduction

In non-operant feeding experiments, food typically is provided ad libitum, and the difference between the weight of the food presented initially and the weight of the food remaining at the end of the observation period provides a measure of food intake. Several studies have shown, however, that mice can fragment and spill a significant amount – up to 40% – of food (e.g., Koteja et al., 2003). For a handful of studies in which quantification of wasted food was the reported purpose, explanations of spillage behavior appear to be disparate. For example, Koteja et al. suggested that food gnawing might be a captivity-induced stereotypy, whereas Pritchett-Corning et al. (2013) concluded that food fragmenting and handling are species-specific behaviors associated with foraging.

Though the etiology of spillage behavior remains to be elucidated, some variables affecting the extent to which it occurs have been identified. Nutrient deficiencies (Barnes et al., 1968; Tagliaferro and Levitsky, 1982) as well as old age (Starr and Saito, 2012) tend to increase the amount of fragmented and spilled food. When mice were provided with sunflower seeds in addition to standard chow, introducing this alternative gnawing enrichment proved effective at decreasing spillage (Pritchett-Corning et al., 2013). Koteja et al. (2003) showed that lowering the temperature of colony room (i.e., increasing energy requirements) resulted in less food spillage. Cameron and Speakman (2010) reduced food availability by only 20% (of ad libitum intake) and spillage was eliminated entirely in those mice. Additionally, they reported that spillage was negatively correlated with diet hardness. Although mice grinded and spilled more of the softer, high fat diets, increased spillage also was associated with an increase in cellulose content of the diet. Determinants of spillage behavior have not yet been addressed from an operant perspective, however.

Anecdotal observations in our laboratory seemed to reveal that mice often produced little to no food waste when responding under a fixed-ratio (FR) schedule with a relatively high response requirement. The purpose of the present study was to systematically evaluate the effects of price as well as pellet type on food waste using a behavioral economic paradigm. Food waste in the United States at the production, retail, and consumer levels is becoming increasingly problematic, and some of the primary factors that contribute to human food waste include overproduction, low quality food, low demand, and high income (Buzby and Hyman, 2012). Our experiment aimed to address some of these variables using an animal model.

2. Method

2.1. Subjects

Sixteen male C57BL/6 mice, approximately 4 months old, were obtained from Harlan Labs, Indianapolis, IN. Prior to the start of

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the experiment proper, mice were individually housed in polycarbonate cages with free-access to standard rodent chow (Harlan) and water. The colony room was temperature- and humidity-controlled, and a 12:12-h light:dark cycle was in effect. Daily sessions were conducted in operant chambers and lasted 23 h, during which food pellets served as the reinforcer and water was available ad libitum through a sipper. Mice were moved from the operant chambers to the homecages, where they had free access to water but not food, for approximately 1 h each day. As per IACUC regulations, mice were removed from the study if they lost 15% of their free-feeding weight.

2.2. Apparatus

The experiment was conducted in 16 standard operant-conditioning chambers (Med Associates, St. Albans, VT) enclosed in ventilated, sound-attenuating cubicles. A 15-w light in the cubicle provided general illumination according to a 12:12-h light:dark cycle. Interior dimensions of the chambers measured 14 cm × 14 cm × 12 cm. The sidewalls of the chambers were Plexiglas, and the front and rear panels were aluminum. Steel rods, spaced 0.5 cm apart, comprised the chamber floor. A drop pan was located 4.5 cm below the floor. A nose-poke manipulandum, measuring 1 cm in diameter, was located on the front panel, approximately 3 cm from the right wall and 2 cm above the chamber floor. A 0.75-cm diameter cue light was illuminated white for the duration of the session and was located 5 cm above the nose-poke manipulandum and 4.5 cm from the ceiling. A food trough, through which earned pellets could be accessed, measured 2.5 cm × 2 cm. The food trough was horizontally centered on the front panel, positioned 1.5 cm to the left of the nose-poke manipulandum and 1 cm above the floor. A computer operating Med-Associates software (St. Albans, VT) controlled experimental events and recorded data.

2.3. Procedure

All mice initially were given free access to 45-mg pellets that were formulated to contain 50%, by weight, of non-digestible cellulose fiber (Test Diet catalog #1815596-380) in their homecages for three days. Then mice were randomly assigned to one of two groups. One group received a 45-mg nutritionally complete standard grain-based pellet (5TUM; Test Diet, approximately 25% protein, 11% fat, 64% carbohydrate; ~3.2 kcal/g) as the within-session reinforcer, whereas the other group received the fiber-based pellet (~1.6 kcal/g) described above. All mice were exposed to three sessions of adaptation and response acquisition under an FR 2 schedule of reinforcement (response shaping was not necessary). Completing the response requirement resulted in the delivery of either 1 grain- or fiber-based pellet, depending on the experimental condition. The FR requirement then was increased every fifth session according the following progression: FR 5, FR 10, FR 25, FR 50, FR 100, FR 200. One mouse did not experience FR 200, and others did not complete four determinations at FR 200 because of a proactive concern regarding body weight. For this reason, results from the FR 200 assessment are excluded from all analyses.

Next, mice were returned to the homecages, with free access to standard rodent chow and water, for 1 week. The experiment was repeated with the pellet type reversed across groups. Each FR from the series was in effect for 2 sessions each during this phase.

2.4. Data analysis

Wasted food was quantified at the end of each session. Whole pellets remaining in the drop pan were counted, and any fragmented pellets were weighed (in mg). The mg measure later was converted to pellets. Means for each mouse were based on the individual determinations at each FR. Then these 16 values were used to determine the group means.

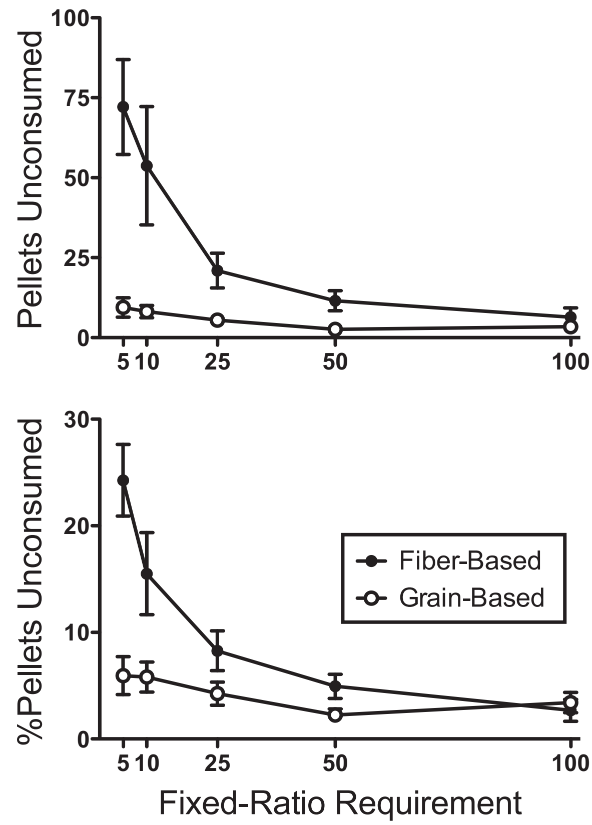

Fig. 1. Group means for food waste expressed as number of pellets (upper panel) and as a percent of total pellets earned (lower panel) as a function of the FR requirement for fiber-based pellets (closed circles) and grain-based pellets (open circles). Error bars denote SEM.

3. Results

The upper panel of Fig. 1 shows the mean number of pellets (±SEM) earned but not consumed as a function of the FR requirement for both fiber- and grain-based pellets. A 2 × 5 (Pellet Type × FR) repeated-measures ANOVA was conducted. Because the assumption of sphericity was violated for this and all subsequent ANOVAS, all F values in this report were adjusted using the Greenhouse-Geisser correction. There was a main effect of Pellet Type, with mice wasting more fiber-based pellets than grain-based pellets, $F(1,15) = 11.18$, $p = .004$, partial $\eta^2 = .43$. The number of unconsumed pellets decreased significantly as a function of the FR [$F(1.75,26.26) = 13.78$, $p < .001$, partial $\eta^2 = .48$], particularly so for the fiber-based pellets as evidenced by a significant Pellet Type × FR interaction, $F(1.35,20.21) = 11.06$, $p = .002$, partial $\eta^2 = .42$.

To further explore this interaction, we conducted separate repeated-measures ANOVAS for each pellet type. The main effect of FR was significant for both fiber-based [$F(1.51,22.70) = 12.85$, $p < .001$, partial $\eta^2 = .46$] and grain-based [$F(1.63,24.50) = 3.86$, $p = .04$, partial $\eta^2 = .20$] pellets. Finally, we conducted five planned comparisons (t-tests for dependent samples) examining food waste between pellet types at each FR. To control for family-wise Type I error, we set the criterion $\alpha = .01$ for all analyses. Mice wasted significantly more fiber-based than grain-based pellets at FR 5, 25, and 50.