

# *Some like it varied: individual differences in preference for feed variety in dairy heifers*

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1 **Some like it varied: individual differences in preference for feed variety in dairy**  
2 **heifers**

3 Rebecca K. Meagher<sup>1,a</sup>, Daniel M. Weary<sup>1</sup>, Marina A.G. von Keyserlingk<sup>1</sup>

4 <sup>1</sup> *Animal Welfare Program, Faculty of Land and Food Systems, University of British*  
5 *Columbia, Vancouver, British Columbia, V6T 1Z4 Canada*

6 <sup>a</sup> *Present address: School of Agriculture, Policy and Development, University of*  
7 *Reading, PO Box 237 Whiteknights, Reading, Berkshire, RG6 6AR UK*

8

9 Corresponding author: Rebecca K. Meagher. E-mail: [rkmeagher@gmail.com](mailto:rkmeagher@gmail.com)

10

11

12 **Abstract**

13

14 Motivation to explore is believed to be widespread among animals, but  
15 exploratory behaviour varies within populations. Offering variety in feed is one simple  
16 way of allowing intensively housed dairy cattle to express exploratory foraging  
17 behaviour. Individuals' exploration of different feed types, as with other new stimuli,  
18 likely reflects a balance between exploratory motivation and fear of novelty. We tested  
19 the degree to which Holstein heifers (n=10) preferred variety in feed vs. a constant, high  
20 quality mixed ration, by first providing varying types of forages and then varying flavours  
21 of mixed feed. We also investigated individual differences in exploratory behaviour by  
22 measuring switching between feed bins. Individual consistency in preferences was  
23 assessed between tests, and longer-term consistency was evaluated by comparing

24 these results with behaviour in novel object and novel feed tests before weaning. On  
25 average, the heifers preferred the constant, familiar feed (spending on average just 20%  
26 of their time at varied feed bins), but this preference varied among individuals (from 0 to  
27 46% of time eating in the forage trial, and 0 to 93% in the flavour trial). Preference for  
28 varied forages correlated positively with intake of novel feed as calves ( $r_s=0.72$ ,  $n=9$ ).  
29 Preference for varied flavours showed a negative correlation with latency to approach a  
30 novel object ( $r_s=-0.65$ ). It thus appears that preference for variety and exploratory  
31 foraging behaviour reflect consistent personality traits. These results suggest that  
32 offering novel feeds on a rotating schedule as a supplement to the regular diet may be  
33 an effective form of enrichment for at least some individuals within a herd.

34

35 **Keywords:** foraging behaviour; individual differences; neophobia; curiosity; animal  
36 welfare; preference

37

## 38 **1. Introduction**

39 Animals are often motivated to explore (Berlyne 1960, Hughes 1997, Špinka &  
40 Wemelsfelder 2011). It has been demonstrated, for example, that opportunities to  
41 explore can be used as reinforcers for learning tasks (Butler 1953: rhesus macaques;  
42 Montgomery 1954: rats), and that rats will sometimes choose to explore new locations  
43 over visiting known reward locations (Franks et al. 2013). Motivation to explore is  
44 presumed to be common across species because it enables gathering of information  
45 about resource availability and proximity of potential threats or mates (see e.g. Inglis et  
46 al. 1997). Although the tendency to explore varies between species and taxa, with  
47 generalist species hypothesized to be more exploratory (see Glickman & Sroges 1966,  
48 Mench 1998), some exploration when feeding is expected in all species (e.g. moving  
49 between locations to try different feed types). Not only is it useful to find higher quality  
50 food patches in the wild, but herbivores must consume more than one type of plant to  
51 meet dietary requirements (Villalba et al. 2010).

52 Modern dairy farms provide few opportunities to perform feed-related exploratory  
53 behaviour; they commonly feed an unvarying diet consisting of a mixture of forage and  
54 grains to all animals of a given age or production stage, provided in a constant location.  
55 Environments with few and unvarying stimuli may be monotonous for the animals and  
56 thus potentially reduce welfare (Wood-Gush & Vestergaard 1991, Meagher & Mason  
57 2012). Some evidence suggests that variation in feed is preferred to such uniform diets  
58 by other ruminants (e.g. Scott & Provenza 1998). Lambs fed a uniform diet with no  
59 opportunity for choice had slower feed intakes than did those allowed to choose  
60 between feeds that varied over time, as well as higher cortisol levels and neutrophil to

61 lymphocyte ratios, suggesting that they might have been experiencing stress (Catanese  
62 et al. 2013). Consistent with the hypothesis that cattle prefer variety, all beef heifers  
63 tested consumed more than one type of feed when they are offered a choice (Ginane et  
64 al. 2002), and calves select different dietary ingredients day to day and at different times  
65 of day (Atwood et al. 2001). Cows have approximately 20,000 taste receptors on their  
66 tongues, compared to less than 7,000 for humans and 1,700 for dogs (reviewed by  
67 Roura et al. 2008), suggesting they may be highly attuned to distinctions in flavour, and  
68 perhaps prone to boredom when fed monotonous diets. The first aim of our experiment  
69 was therefore to determine whether heifers prefer varied feeds to a nutritionally  
70 balanced but unchanging feed.

71         Exploratory behaviour varies within as well as between species. The expression  
72 of this behaviour in response to novelty likely reflects a balance of two competing  
73 motivations (reviewed by Russell 1973): fear of novelty (neophobia) and motivation to  
74 gain information and/or stimulation (i.e. motivation to explore, sometimes called  
75 'curiosity'; see e.g. Hughes 1997 and Litman 2005 for discussions of different theories  
76 of the motivation underlying exploration). Understanding individual differences in such  
77 traits is important because it can influence response to experimental treatments,  
78 susceptibility to stress, and perhaps health (see e.g. Carere and Eens 2005; Cavigelli  
79 2005). However, little experimental work has been done on this topic in ruminants, and  
80 research on feed preferences has typically focused on the group rather than individuals.  
81 Our second aim was therefore to determine whether individual differences in preference  
82 for varied feed were stable across tests, and the extent to which these differences could  
83 be predicted by behaviours associated with fearfulness and curiosity.

84

## 85 **2. Methods**

### 86 *2.1 Animal housing and care*

87           This research was approved by the University of British Columbia Animal Care  
88 Committee (Protocol A15-0117). The subjects were 10 female Holsteins, housed at the  
89 University of British Columbia Dairy Education and Research Centre (Agassiz, BC,  
90 Canada). These animals were exposed to behavioural tests as calves and as weaned  
91 heifers. As calves, animals were housed individually from birth to  $48 \pm 3$  days of age, in  
92 sawdust-bedded pens (1.2 × 2 m). Calves had ad libitum access to water and grain (Hi-  
93 Pro Medicated Calf Starter, Chilliwack BC, Canada). For the first 26 d of life, they were  
94 fed 8 L of milk per day by bottle, split between two feedings. The amount per feeding  
95 was then reduced over two days to a total of 4 L per day. They were then weaned at the  
96 time they were moved to a group pen ( $48 \pm 3$  d).

97           As weaned heifers, the animals were housed as a group in a free-stall pen that  
98 was deep-bedded with sand, containing 13 lying stalls and 13 headlocks at the feed  
99 bunk. All animals had ad libitum access to water. Their regular diet was a total mixed  
100 ration (TMR) of corn silage, local fescue and orchardgrass hay, grain, and grass silage  
101 (35%, 25%, 22%, and 19% of dry matter, respectively; the overall mixture had an  
102 average of 44% dry matter, 17.5% crude protein, 43% neutral detergent fibre, and 0.93  
103 Mcal/kg net energy for gain).

104

### 105 *2.2 Feeding behaviour tests*

106 Preference for variety and expression of exploratory foraging behaviour were  
107 tested when the heifers were aged 41 to 49 weeks old. During the habituation phase,  
108 heifers were introduced to the new feeds to be included in the experiment. Timothy and  
109 alfalfa hays, a local tall fescue/orchardgrass hay mixture and chopped rye straw were  
110 placed in four different bins at the feed bunk simultaneously. Two heifers at a time were  
111 provided access for 20 min each for two days, with feed locations rearranged on the  
112 second day. Over the next four days, the same procedure was followed but with access  
113 to only one forage type per day. The heifers had no access to their regular TMR during  
114 these habituation trials. Heifers were paired during this stage to reduce stress  
115 associated with isolation and encourage feeding while the test conditions and feeds  
116 were novel.

117 In the next phase (i.e. the Forage trial), heifers could choose between a feed bin  
118 containing the regular TMR and a bin containing one of these four forage types, with the  
119 forage varying day-to-day in a pseudorandom order (each forage being presented an  
120 equal number of times once all heifers were eating). Tests were conducted following the  
121 protocol of Huzzey et al. (2013), in which heifers were allowed to approach the feed  
122 bunk one at a time in daily tests, while the other heifers were held in another section of  
123 the pen. The heifers were allowed to enter in the order in which they chose to approach  
124 the gate. Tests were 10 min long, and began at the typical feed delivery time  
125 (approximately 7:30 a.m.) to ensure that the heifers were motivated to eat. Bins were  
126 partially covered by a lid to prevent the animals from seeing the contents before they  
127 approached, but were always in the same locations (see Figure 1). Bins were refilled  
128 between heifers as needed to maintain equal fill. The heifer's first choice of bin (defined



129 by the heifer putting her head in the bin and interacting with the feed) and time spent  
130 interacting with the feed at each bin were recorded within each trial. Additionally,  
131 number of switches between bins was recorded in each trial, reflecting sampling  
132 behaviour (cf. Huzzey et al. 2013; Nielsen et al. 1996), which is a form of exploration  
133 (see e.g. Eliassen et al. 2007), and latency to feed on the first day of the habituation  
134 phase was recorded as a measure of feed neophobia. These tests were continued for  
135 14 days. The first two days of the Forage trial were excluded from analyses of feed  
136 preferences because some heifers were not yet consistently eating; the remaining 12  
137 days of data included three presentations of each of the four forage types.

138         The Forage preference test provides a naturalistic treatment, but can be criticized  
139 because the different forages also varied nutritionally. Thus, in a second test (the  
140 Flavour trial), we used the standard TMR but varied flavour using non-nutritive  
141 powdered flavours (Essentials Inc., Abbotsford, BC, Canada) added to this mixed ration.  
142 Heifers were habituated to the new flavours and a new feeding location over two days in  
143 which they only had access to the flavoured TMR (three flavours on Day 1 and two on  
144 Day 2), as in the Forage trial. On the following day, all five flavours were presented  
145 simultaneously to assess preferences, with heifers tested one at a time. Preferences  
146 were again assessed based on time spent at each bin. Starting the next day, heifers  
147 were given the choice among three bins: one containing the regular (unflavoured) TMR,  
148 one that varied between four flavours (Power Punch [berry flavoured], Peppermint,  
149 Banana and Anise essences), and one with a constant flavour (Caramel Toffee). This  
150 third option had been highly consumed in a short pilot trial in which another group of  
151 heifers was offered all flavours simultaneously. It was provided to test whether heifers

152 simply preferred TMR with flavour added rather than variety in flavour per se. This might  
153 be expected if, for example, the unflavoured TMR had low palatability.

154 This test was conducted in the alley behind the pen to allow the regular TMR and  
155 varied feed to be placed at an equal distance from the entrance to the test area (Figure  
156 2). To control for side biases, we placed the varied feed on the left for half the heifers,  
157 and on the right for the other half of the heifers. The constant flavour was available on  
158 both sides. The same response variables as above were recorded.

159 Health was monitored daily during the testing period following standard farm  
160 protocols; no heifers required medication for any illnesses during the trial.

161

### 162 *2.3 Behavioural tests as calves*

163 Nine of these calves had been given two tests of neophobia and exploratory  
164 motivation as part of an earlier study. A novel object test was conducted at 5 weeks ( $35$   
165  $\pm 3$  d) of age. The object (a ball or plastic basket) was lowered into the pen on a rope.  
166 Latency to touch the object and time in contact were recorded over the next 10 min.  
167 Although both of these measures are likely affected by both motivational systems in  
168 question (e.g. previous work has reported that both are correlated with cortisol and  
169 influenced by anxiolytic administration: Van Reenen et al. 2005, 2009), latency is most  
170 commonly used in assessing fear (see review by Forkman et al. 2007) and contact  
171 duration has been used to measure curiosity or exploration in other species (e.g.  
172 Glickman & Sroges 1966). When heifers were 6.5 weeks ( $45 \pm 3$  d) of age a food  
173 neophobia test was conducted. A bucket containing 3.0 kg of TMR (as described above)  
174 was put on the front of the individual pen in place of the usual grain. Latency to eat was

175 recorded from video, and the 'as fed' amount consumed in 30 min was calculated by  
176 weighing the leftover feed. Predictions for the direction of the relationship expected  
177 between these behaviours and those assessed in the following trial are given in Table 1,  
178 based on the hypothesis that preference for variety reflects exploratory motivation, and  
179 that high latencies to eat when the food is first presented reflects fear of novelty.

180

#### 181 *2.4 Statistical analyses*

182 Preference for variety was assessed within each stage as the proportion of time  
183 eating from a varied bin in relation to the total time spent eating, and whether the first  
184 bin chosen was varied or stable feed. To test whether varied feed was preferred to  
185 normal feed, we calculated the individual means across days within each phase of the  
186 study. For the Forage preference trial, a one-sample t-test was used to determine  
187 whether the consumption in the last set of tests (the last test for each feed type in the  
188 varied bin) differed from zero. This was repeated for the Flavour preference trial, but the  
189 data were non-normally distributed according to Shapiro-Wilk tests, and were log-  
190 transformed to correct this in further analyses. Due to this non-normality, summary data  
191 presented for this trial are medians rather than means. Biases in feeding choices based  
192 on feed locations were assessed by calculating binomial probabilities. We also tested  
193 whether preferences and levels of exploratory behaviour (switching between feed bins)  
194 changed over time within the feeding trials by calculating means for each day across  
195 individuals and regressing against test day, since a decrease in exploration might be  
196 expected due to decreasing information gain. Changes were considered significant at  
197 the  $P=0.05$  level.

198 To assess whether individual differences in preference for variety reflected  
199 lasting differences in fearfulness or exploratory motivation, Spearman rank correlations  
200 were calculated between preference in each phase of the study (Forage and Flavour  
201 trials) and behaviour in the tests conducted while the subjects were calves. Within the  
202 heifer trial, correlations were also calculated between preference for variety in each trial  
203 and latency to eat on the first day of the habituation phase (i.e. neophobia), and with  
204 switches between bins (exploratory behaviour) in each trial. Correlations were  
205 categorized as negligible ( $<0.3$ ), low ( $0.3-0.5$ ), moderate ( $0.5-0.7$ ), high ( $0.7-0.9$ ) or very  
206 high ( $>0.9$ ) according to Hinkle and colleagues (2003). All analyses were conducted in  
207 R (3.2.2, The R Foundation for Statistical Computing).

208

### 209 **3. Results**

#### 210 *3.1 Group-level feeding preferences*

211 The median time spent eating per session in the Forage trial was 456 s of the  
212 600 s possible (interquartile range: 355 – 530 s). Heifers did not spend more time eating  
213 from the varied forage bins than from the familiar TMR; on average, they spent 20% ( $\pm$   
214 17) of their time feeding from the varied forage bin. The linear regression of proportion  
215 of time eating varied forage vs. day showed no change over the 12 days of testing  
216 ( $r < 0.001$ ,  $P = 0.943$ ). Similarly, heifers visited the varied bins first in  $28 \pm 26\%$  of the  
217 trials. The results were similar for the tests using the flavoured TMR: on average,  
218 heifers spent just 6% (median; interquartile range: 4-16%) of their total feeding time at  
219 the varied bins, and again this did not vary over the 12 days of testing ( $r = 0.07$ ,  
220  $P = 0.399$ ). Heifers visited these varied bins first in just 12% (median; interquartile range:

221 2-17%) of trials. In the Flavour trial, heifers spent a median 554 s eating all foods  
222 combined (interquartile range: 517 – 580 s).

223 Heifers showed side preferences in the Flavour trial: on the first day of testing  
224 heifers alone, when all flavours were presented simultaneously, nine of ten heifers went  
225 to the bins on the left first (binomial probability of this or a more extreme result  
226 happening by chance:  $P=0.022$ ) and only ate from those bins. This preference  
227 continued throughout the trial: a median 89% (interquartile range: 44-75%) of feeding  
228 time for the fixed flavour, which was present on both sides, was at the bins to the left of  
229 the gate. This side bias was less obvious during the Forage trial, although by the end of  
230 this trial heifers tended to go to the bins in the half closer to the entry: all nine chose  
231 these bins first on day 12 (vs. 5 of 9 on day 1; 62 of 105 across all heifers and days).

232 The mean number of switches between bins of different feed types did not  
233 change over sessions (Forage trial:  $r=0.13$ ,  $P=0.251$ ; Flavour trial:  $r=0.17$ ,  $P=0.178$ ).

234

### 235 *3.2 Individual differences in feeding preferences as heifers*

236 Individual differences in preference were observed throughout the study. In the  
237 varied Forage trial, individual averages of the proportion of eating time spent at the  
238 varied bins ranged from 0% to 46%. For the Flavour trial, individual differences were  
239 influenced by the side bias: the maximum proportion of time eating from the varied bins  
240 was only 12% when it was placed on the right, versus 93% when on the left (see Figure  
241 3). The preference for variability showed some consistency between the Forage and  
242 Flavour preference trials ( $r_s= 0.47$ ; Figure 4).

243

244 *3.3 Relationships within tests*

245 In the calf tests, the two measures taken during the food neophobia tests, latency  
246 to eat and amount consumed, were positively correlated ( $r_s = 0.63$ ). There was a low  
247 negative correlation between time in contact with the novel object and latency to make  
248 contact ( $n=8$ ,  $r_s = -0.31$ ).

249 In the heifer trial, preference for varied feed was not predicted by latency to eat  
250 on the first day of the habituation phase ( $r_s = 0.25$  for Forage trial and 0.26 for Flavour  
251 trial). There was, however, a low positive correlation between preference for varied feed  
252 and the number of times they switched between bins in the Flavour trial ( $r_s = 0.30$ ), and  
253 in the Forage trial ( $r_s = 0.48$ ).

254

255 *3.4 Relationships between tests*

256

257 In the two tests conducted as calves, neither latency to eat nor intake in the food  
258 neophobia test correlated with the latency to touch a novel object ( $r_s = 0.23$  and 0.26,  
259 respectively).

260 The relationships between the calf novel object test and behaviour in the feeding  
261 trial as heifers are summarized in Table 2. For the purpose of these analyses,  
262 preference for variety is expressed as proportion of time eating from the variable bins;  
263 this measure was very highly correlated with the first choice of bins ( $r_s = 0.94$  and 0.91  
264 in the Forage and Flavour trials, respectively), so using both was unnecessary. There  
265 was a high positive correlation between intake of novel feed as calves and preference  
266 for varied feed over TMR in the Forage trial. A moderate correlation was found between

267 latency to touch a novel object and preference for varied flavour over TMR with no  
268 flavour added. Since the side of the alley to which the varied feed was assigned  
269 affected preferences, the analyses were split by side. We found a high negative  
270 correlation with latency to touch the novel object only when varied flavour was tested on  
271 the right; when the varied feed was on the left, there was no relationship. Total time  
272 spent in contact with a novel object was moderately correlated with preference for  
273 varied feed in the Forage trial.

274           The number of switches between bins, averaged across the Forage and Flavour  
275 trials, had a high positive correlation with intake of novel feed as a calf. There was also  
276 a moderate correlation between latency to eat the novel forage as a heifer and latency  
277 to touch a novel object as a calf; however, this relationship was unexpectedly negative.  
278 All remaining correlations were low or negligible.

279

#### 280 **4. Discussion**

281           On average, heifers did not prefer varied over stable feed, even when there was  
282 no energetic or nutritional cost to choosing the varied feed. This finding is surprising  
283 given that other work has shown that monotonous flavours are generally less preferred  
284 in young animals of another ruminant species, sheep (Scott & Provenza 1998). This  
285 finding also contrasts with results from primates that show a preference for varied over  
286 monotonous diets (Addessi et al. 2010). The current results are more in keeping with  
287 the common wisdom that farms should aim to keep feed as stable as possible (e.g.  
288 Stone 2008). Feeding a consistent diet is thought to improve intake and performance  
289 (e.g. milk yield: Sova et al. 2014, but see Yoder et al. 2013 for a counterexample) and is

290 hypothesized to be better for health (Sova et al. 2014). Cattle and other domestic  
291 ruminants tend to be neophobic with regard to food, i.e. they are reluctant to eat novel  
292 food items and tend to sample small amounts at first (see e.g. Launchbaugh et al. 1997;  
293 Herskin et al. 2003), likely helping them avoid toxic doses (Launchbaugh 1995). If this  
294 neophobia was not fully overcome in the time given, it might explain the greater  
295 consumption of familiar feed in the current experiment. The heifers may also not have  
296 perceived the TMR as uniform or monotonous since it contained many ingredients.  
297 Moreover, individual bites may vary slightly in the exact mixture of elements that the  
298 heifer ingests, and their many taste buds may make them sensitive to fine distinctions.  
299 Still, most heifers consumed at least some varied feed throughout the Forage trial  
300 despite the varied feed having lower average energy and protein content (the two major  
301 nutritional needs expected to guide choice; see e.g. Bailey, 1995; Villalba et al. 2015)  
302 lower than that of the TMR.

303         There are several reasons why feeding behaviour might not always maximize  
304 energy gain (cf. Newman et al. 1992). Optimal foraging theory allows for sampling of  
305 different feeds to obtain information about feed quality, and predicts this sampling to be  
306 more persistent in changing environments, where past experience is a less effective  
307 predictor of current conditions (Stephens & Krebs 1986; Shettleworth 1988). However,  
308 in the Flavour trial, all foods offered were consistently of identical high quality and  
309 therefore little sampling would be expected (Huzzey et al. 2013). If consumption of  
310 varied feed was primarily a form of sampling to gain information about patch quality, we  
311 might have expected this to decrease over time as the heifers learned about the feeds.  
312 If consumption of the varied feed was limited primarily by feed neophobia rather than



313 feed value, by contrast, it would have been expected to increase over time. Instead, we  
314 found that consumption of the varied feed did not change over time, suggesting that the  
315 results reflect a relatively stable preference for some variety in the diet. While the  
316 literature on feed preferences often describes 'partial preferences' for consumption of  
317 more than one feed as opposed to always choosing a single feed (e.g. McNamara &  
318 Houston 1987, Rutter 2010), there is little discussion of how much needs to be  
319 consumed for this to qualify as being partially preferred.

320         Such partial preferences may allow animals to select a more balanced diet  
321 (Newman et al. 1992), and choice based on specific nutrients other than energy and  
322 protein cannot be absolutely ruled out in the Forage trial here. However, partial  
323 preferences can also be seen when there is no evidence of relevant nutritional  
324 differences (Newman et al. 1992, Parsons et al. 1994). Preferring feeds that have not  
325 been recently consumed, as seen in other ruminants (Parsons et al. 1994, Scott &  
326 Provenza 1998; similar phenomena also being reported in other taxa, e.g. Tuttle et al.  
327 1990), may be explained mechanistically by sensory-specific satiety. This is a  
328 phenomenon observed in humans, in which foods become subjectively less pleasant as  
329 they are consumed, before any physiological consequences of the nutrients can be  
330 processed (Rolls 1986). The functional basis for this phenomenon remains unclear, but  
331 likely relates to a more general need for sensory change, which has been suggested as  
332 one reason for what is called "intrinsic exploration" (Hughes 1997): exploration that  
333 appears to be performed for its own sake. This means that opportunities to explore  
334 different feeds would be rewarding for individuals with strong exploratory motivation

335 regardless of the nutritional value of those offerings, and the motivation may be possible  
336 to meet with non-feed-related stimuli as well.

337         Although the average consumption of varied feed in both the Forage and Flavour  
338 trials was low relative to consumption of regular feed, there was large variation in  
339 preference among individuals. While the correlation in preference between the Forage  
340 and Flavour trials was low, greater individual consistency may have been seen if not for  
341 the side bias in the Flavour trial. Moreover, preferences in these trials were correlated  
342 with certain behaviours earlier in life, suggesting some consistent individual traits. The  
343 directions of many of these correlations were predicted by the hypothesis that  
344 preference for variety reflects exploratory motivation, fear of novelty, or both. Calves  
345 that spent more time exploring a novel object at 5 weeks of age were more interested in  
346 varied feed as heifers (41 weeks and older; Forage trial), and those that ate more novel  
347 feed as calves also performed more exploratory behaviour (feed switching) as heifers.  
348 Correlations between the calf tests and behaviour in the Flavour trial were weaker,  
349 again likely due to the side bias.

350         Novel object latency was a strong predictor of preference in the Flavour trial, with  
351 shorter latencies being associated with greater proportional consumption of varied feed,  
352 especially when controlling for the side of the alley to which the feeds were assigned.  
353 These results are similar to the finding that lambs which show fewer signs of distress in  
354 a novel setting consume more of a novel feed (Villalba et al. 2009). In the current  
355 experiment, the correlations between latency to eat novel feed during habituation in the  
356 heifer trials and behaviour in the calf tests were largely weak and were in the opposite  
357 direction to that predicted. The reasons for this need further investigation, but novel feed

358 latency could reflect a different type of exploration than sampling does, with strategies  
359 of exploration differing between individuals (as in birds: Van Overveld & Matthysen  
360 2013). Regardless, the correlations found suggest that preference for varied feed is  
361 related to stable personality traits (defined as individual characteristics describing  
362 stability of behaviour over time; see Gosling [2008] for discussion of the term).

363 Progress in understanding personality traits and their significance in cattle is  
364 hindered by the lack of reliable, validated measures for the species (see e.g. Meagher  
365 et al. 2016; Mackay 2013). To be considered a true measure of personality, an indicator  
366 must be repeatable, yet data on repeatability is often limited (see e.g. Svartberg et al.  
367 2005). There has been criticism of some of the common types of test used in animals,  
368 because they are done in artificial and potentially stress-inducing settings and might not  
369 accurately reflect natural behaviour (Carter et al. 2013; Biro 2013). The types of feeding  
370 test used here, by contrast, were relatively naturalistic. If these types of test prove to be  
371 valid indicators of motivation to explore and neophobia in cattle, they may prove useful  
372 for research as they are quick and easy to conduct, and can be done in the home pen.  
373 These tests also seem to be relatively straightforward to interpret since the animals are  
374 making an active choice between novel or varied feed and routine feeds, whereas  
375 measures such as latency to approach an object are influenced by various competing  
376 motivations (e.g. motivation to lie down) which can be difficult to disentangle.

377 We suggest that offering rarely experienced feeds may provide welfare benefits  
378 for at least some individuals by allowing them to express exploratory behaviour. Varied  
379 feeds might also function as a reinforcer in training cattle to perform desired behaviours  
380 such as entering a robotic milking machine. This use would avoid some of the difficulties

381 with using varied feed as enrichment in the home pen, such as increased competition,  
382 with dominant animals monopolizing access to preferred feeds in group-fed animals  
383 (see Mandel et al. 2016). Offering opportunities for choice may also have psychological  
384 benefits even if little of the less preferred feed is chosen; this may also be true of  
385 choices unrelated to food. Monkeys, for example, “choose to choose”: they prefer to  
386 control the order of tasks themselves rather than having this assigned, all else being  
387 equal (Perdue et al. 2014). The correlations between choice of varied feed and  
388 exploratory behaviour as calves support the conclusion that both relate to a broader  
389 exploratory motivation, rather than something specific to the feed such as flavour  
390 boredom or motivation for a specific highly palatable food amongst the options, and any  
391 opportunities for choice and exploration might improve welfare.

392         It has also been suggested that allowing individuals to choose their own diets is  
393 valuable because physiological needs differ across individuals (Atwood et al. 2001,  
394 Manteca et al. 2008). This assumes that animals have some level of ‘nutritional  
395 wisdom’ and are able to select feeds based on the nutrients they require; there is some  
396 evidence to support this view (Manteca et al. 2008). The importance of personalized  
397 diets taking into account individual differences in needs is increasingly recognized in  
398 human nutrition (e.g. Noecker & Borenstein 2015), and ways of identifying those needs  
399 are currently being studied (e.g. by assessing glycemic responses to meals: Zeevi et al.  
400 2015). Aside from the direct physiological effects of giving animals variety or choice in  
401 their diets, there is some evidence that monotonous prescribed diets can cause stress  
402 (Catanese et al. 2013) and, in early life, even influence later stress responsiveness

403 (Villalba et al 2012). These effects may result from the animals being unable to act upon  
404 their 'wisdom'.

405         There were a few limitations to the current experiment. The side bias may reflect  
406 behavioural lateralization, since cows, like most mammals, do exhibit some laterality,  
407 including in their responses to novelty (Robins & Phillips 2010). However, the bias here  
408 emerged over time, not being evident during the initial preference tests when all flavours  
409 were presented simultaneously, as one might have expected if there was an innate side  
410 preference. The bias may be because the preferred bins to the left of the gate were in  
411 front of the home pen and therefore closer to their social group, while the others were in  
412 front of a neighbouring pen. This preference for being near the home pen may have  
413 become stronger over time as social bonds and familiarity with that pen increased.  
414 Whatever the reason, this bias complicated the interpretation of the results. Randomly  
415 assigning half of the group to each side allowed detection of this problem, but the  
416 strength of the side preference was such that it interfered with our investigation of  
417 individual differences. Side biases must be taken into consideration when designing  
418 similar experiments in future. The effect of timescale should also be considered; this  
419 experiment investigated preferences only in short-term tests over a period of 12 days  
420 per trial. Preferences might change over time as the degree of novelty of the feed  
421 changes (see e.g. Parsons et al. 1994). Testing for only a short period of the day may  
422 also result in individuals being ranked differently than they would be in tests of longer  
423 duration (Dumont et al. 1995), although this may be less of a concern in this context  
424 than when investigating feeding on pastures where factors such as sward height  
425 change over time. Finally, replication of this work is needed to confirm the relationships

426 between feeding preferences and relevant personality traits, and to more clearly  
427 distinguish between fear and curiosity or desire for stimulation as underlying  
428 motivations.

429 Future research should also investigate how the early rearing environment  
430 influences preference for variety. These heifers had been individually reared in indoor  
431 pens, and as such were expected to be less flexible and more afraid of novelty,  
432 including novel feeds, than they would be if they had been housed socially and in more  
433 complex environments (see Meagher et al. 2015; Costa et al. 2015). The animals had  
434 also not been provided much experience with diversity of feed, except in the form of the  
435 brief food neophobia tests described. In lambs, early experience with varied diets  
436 increases willingness to eat novel feeds or flavours (e.g. Catanese et al. 2012). Average  
437 preferences might thus differ in other management systems.

438 In summary, many of the heifers tested choose to consume standard TMR rather  
439 than novel or varied feed, but most individuals exhibited some exploratory feeding  
440 behaviour. The range in time devoted to investigating and consuming feed from varied  
441 bins, even when there was some energetic cost to this behaviour, suggests that at least  
442 some individuals are motivated to obtain variety in their feed. Some individual  
443 consistency in animals' responses to novelty across time can be expected based on the  
444 relationship between their feeding choices and their behaviour during the milk-feeding  
445 period. Offering a choice of feed at least for some portion of the day might improve  
446 welfare, particularly on farms or in pens in which the animals show high levels of  
447 exploration. Responses to changing feeds may also provide a simple, naturalistic  
448 measure of exploratory tendencies for use in future research.

449

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458

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620

621 **Table 1.** Predicted direction of correlations between measures of response to novelty as  
 622 calves and behaviour when offered choice of varied (forage type or flavours) or stable  
 623 feed as weaned heifers.

	<b>Calf</b>	<b>Novel object latency</b>	<b>Novel object contact duration</b>	<b>Novel feed latency</b>	<b>Novel feed intake</b>
<b>Heifer</b>					
Proportion of eating time spent at varied bin, Forage trial		Negative	Positive	Negative	Positive
Proportion of eating time spent at varied bin, Flavour trial		Negative	Positive	Negative	Positive
Latency to eat novel feed (habituation phase)		Positive	Negative	Positive	Negative
# of switches between bins (average)		Negative	Positive	Negative	Positive

624

625

626 **Table 2.** Spearman correlation coefficients for relationships between heifers' behaviour  
 627 in neophobia tests as calves and their behaviour when offered choices between varied  
 628 or stable feed as weaned heifers. n=8 for contact durations, n=9 for all other values.

629

	<b>Calf</b>	<b>Novel object latency</b>	<b>Novel object contact duration</b>	<b>Novel feed latency</b>	<b>Novel feed intake</b>
<b>Heifer</b>					
Proportion of eating time spent at varied bin, Forage trial		-0.26	<i>0.54</i>	-0.39	<b>0.72</b>
Proportion of eating time spent at varied bin, Flavour trial		-0.65	0.29	-0.29	-0.24 <sup>1</sup>
Latency to eat novel feed (habituation phase before Forage trial)		-0.60 <sup>1</sup>	0.24 <sup>1</sup>	-0.48 <sup>1</sup>	0.44 <sup>1</sup>
# of switches between bins (average)		-0.08	0.42	-0.55	<b>0.71</b>

630 Bold text indicates high correlation, italics indicate moderate, according to Hinkle et al.  
 631 (2003).

632 <sup>1</sup> Values are in the opposite direction of the prediction

633

634

635 **Figures**

636

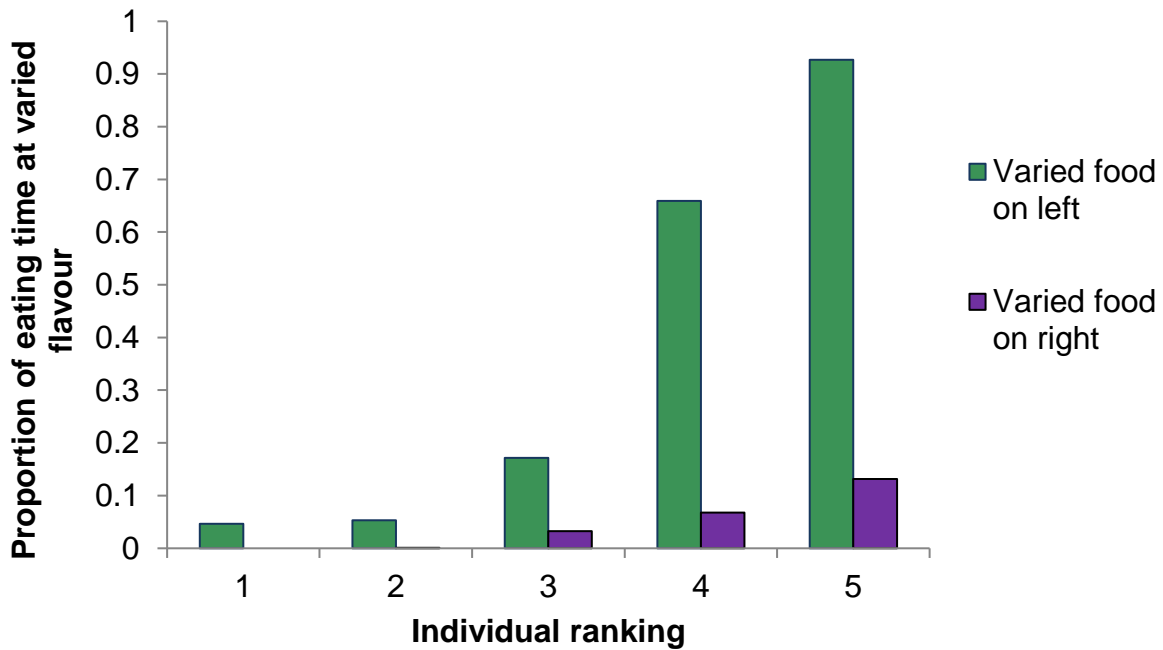
637

638 **Figure 1.** Pen layout for varied forage preference trial. VAR = bins containing a forage  
639 that varied day-to-day; TMR = bins containing regular total mixed ration.

640

641 **Figure 2** Pen layout for varied flavour preference trial. For half of the heifers, the  
642 positions of the plain (unflavoured TMR) and varied (TMR with one of four flavours  
643 added each day) bins were reversed. Fixed flavour bins had the same flavour added  
644 each day.

645

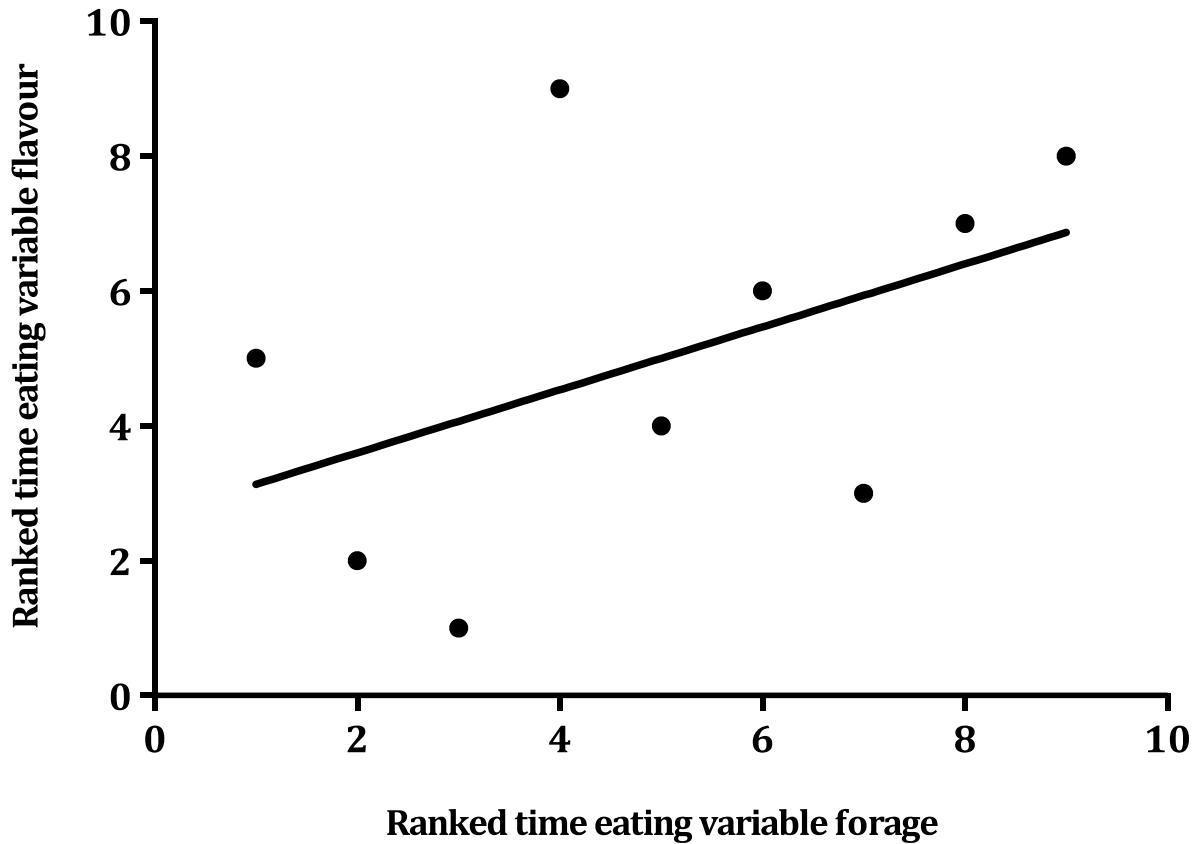


646

647 **Figure 3** Individual differences in the proportion of all time eating heifers spent eating  
648 TMR from bins where the flavour varied, split by the side of the alley in which this bin

649 was placed. High numbers on the x-axis indicate higher proportions of varied feed  
650 consumed relative to other heifers. n=5 per side.

651



652

653 **Figure 4** Consistency in proportion of eating time individual heifers spent at the varied

654 bin when the feed was varied forage vs. TMR of varied flavours. n=9.