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1 **Development of an ethogram for hutch-housed dairy calves and**  
2 **determination of factors influencing their behaviour**

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10

11 **ABSTRACT**

12 The objectives of this study were to investigate the behaviour of hutch-  
13 housed dairy calves, develop an ethogram of general behaviour, and  
14 determine whether housing calves in different hutches, day, gender and  
15 time of day influenced the behaviour of dairy calves using the  
16 developed ethogram. Thirty-one apparently healthy Holstein Friesian  
17 calves (6 ± 1 week old) were recruited for this study. The ethogram was  
18 developed by directly observing the behaviour of ten female dairy  
19 calves housed in two group hutches for five days. Based on these  
20 observations, behaviour was then organized into three categories. The  
21 first category (I) comprised of postures, attentiveness and social  
22 interactive behaviour; the second category (II) comprised of event  
23 behaviour which were recorded each time they occurred while the last  
24 category (III) comprised of movement and activity behaviour whose  
25 duration were recorded. The ethogram was used to record the

26 behaviour of 16 calves (4 males; 12 females) housed in groups of four  
27 using direct and video observations for two consecutive days to  
28 ascertain if there are behavioural differences between dairy calves  
29 housed in different hutches; between days and gender. Furthermore,  
30 the ethogram was used to record the behaviour of an additional five  
31 dairy calves housed in a group hutch to determine the time of day  
32 effect. The behaviour of these five dairy calves were recorded hourly  
33 between the hours of 10:00 and 17:00 for two days using a combination  
34 of direct and video observations. Data were expressed as median  
35 frequency, duration or mean rank and significance was accepted at  $P \leq$   
36 0.05. There were no significant differences in the behaviour of dairy  
37 calves housed in different hutches. Significant variations ( $P < 0.05$ ) were  
38 observed in the response to observer, ear and mouth postures and ear  
39 flicking behaviour between the two days. Tongue position, ear flicking,  
40 tail wagging and walking behaviour were significantly higher ( $P < 0.05$ )  
41 in females than in males while body shaking and sniffing other calves  
42 were found to be significantly higher ( $P < 0.05$ ) in males than in females.  
43 Time of day significantly ( $P < 0.05$ ) influenced the location in the hutch,  
44 head, tail and standing posture; and the duration of standing, walking,  
45 and lying behaviour. While confirmation is needed, findings suggest the  
46 behaviour of dairy calves may be influenced by day, gender, and time of  
47 day and this should be considered when undertaking behavioural  
48 studies.

49 Keywords: Dairy calves; Day; Ethogram; Hutch; Gender; Time

50 **1. Introduction**

51           The rearing of dairy calves remains an integral component of  
52 dairy production. The dairy calf, unlike its beef counterpart, is usually  
53 separated from the dam within the first few hours of birth and reared  
54 individually or in pairs for the first one or two weeks. Depending on the  
55 farm management practice, they can remain in pairs or be housed in  
56 groups until weaning, after which they are reared as herds. It is well  
57 known that housing impacts the welfare of calves and invariably, their  
58 behavior, which can be used as a welfare assessment tool (Stull and  
59 Reynolds, 2008; Pempek et al., 2016). Hutch-housing is a type of  
60 housing system currently in use for dairy calves in many parts of Europe  
61 and America. The predominant hutch type is the commercial plastic  
62 outdoor calf-hutch (made of fiberglass or polythene) which originated in  
63 North America and has been in use for over forty years on this continent  
64 (Hoshiba, 1986; Otterby and Linn, 1981). These plastic hutches are  
65 normally enclosed in an outdoor pen which is considered an enrichment  
66 mechanism and helps calves maintain visual and auditory contact, and  
67 possibly tactile contact (depending on proximity) with calves in other  
68 hutches. The outdoor pen may also serve as a play arena since the inner  
69 hutch provides minimal space for play.

70           Even though the hutches have existed for several years, studies  
71 describing the general behaviour of hutch-housed dairy calves have not  
72 been documented. Behavioural studies which have been performed on

73 dairy calves in hutches commonly focus on a specific area including  
74 feeding and performance (Schingoethe et al., 1986; McKnight, 1978;  
75 Razzaque et al., 2009; oral behaviour (Ertugrul et al., 2000); feed intake  
76 and oral behaviour (Hepola et al., 2006); oral, movement, play and  
77 grooming behaviour (Pempek et al., 2016); locomotor play, sucking and  
78 interactive behaviour (Pempek et al., 2017); feeding, social and lying  
79 behaviour (Wormsbecher et al., 2017); lying down frequency as a  
80 discomfort index in heat-stressed Holstein bull calves (Kovács et al.,  
81 2018). This paucity of research detailing the general behaviour of hutch-  
82 housed dairy calves invariably implies that the assessor/farmer maybe  
83 unaware of the behavioural changes occurring in these calves, especially  
84 following routine procedures performed in dairy calves. For example,  
85 the dairy calf undergoes a number of routine procedures such as ear  
86 tagging, disbudding, vaccination, and medical treatments at an early age  
87 of life, all of which are known to be potential stressors with the capacity  
88 to influence their behaviour. Without proper knowledge of how these  
89 calves behave in their hutches, the assessor/farmer may have difficulty  
90 recognising behavioural changes associated with husbandry practices or  
91 assessing the efficacy of intervention strategies like analgesic regimens.  
92 Hence, the need to address this knowledge gap.

93           Additionally, even though many calf-specific ethograms exist in  
94 the literature, a comprehensive ethogram which considers postures,  
95 social interaction, movement, and activity patterns in dairy calves is  
96 lacking. Examples of dairy calf-ethograms which are frequently used by

97 researchers undertaking behavioural studies in dairy calves include  
98 ethograms of play behaviour (Jensen et al., 1998; Jensen and Kyhn,  
99 2000; Mintline et al., 2013); ethograms of postural (lying and upright),  
100 suckling and social behaviour in Danish Holstein Friesian dairy calves  
101 (Jensen, 2011); ethograms of feeding, social and lying behaviour in dairy  
102 calves (Wormsbecher et al., 2017); ethograms of oral, movement, play  
103 and grooming behaviour in Jersey dairy calves (Pempek et al., 2016);  
104 ethograms of feeding, oral and lying behaviour (Todd et al., 2018);  
105 ethograms of lying, active (standing, attempt to stand, walk, play and  
106 groom) and secondary behaviour including investigatory, social and  
107 drinking in Holstein dairy calves (Gladden et al., 2019). However, none  
108 of the above cited ethograms described all behaviour exhibited by dairy  
109 calves but rather focused on aspects of behaviour depending on the  
110 objectives of each study. Thus, the development of an inclusive  
111 ethogram for dairy calves would be a useful tool for comprehensive  
112 studies of calf behaviour.

113           This study was thus designed to investigate the behaviour of  
114 hutch-housed dairy calves, develop a comprehensive ethogram as a  
115 means of recording calf behaviour, and determine factors influencing  
116 the behaviour of dairy calves in hutches using the developed ethogram.

## 117 **2. Materials and methods**

118           The study was carried out on the University of Bristol Veterinary  
119 School dairy farm (Lower Langford, Bristol, United Kingdom), following

120 ethical approval from the University's Animal Welfare and Ethical  
121 Review Body (UOB/19/00). The dairy farm has a herd of 317 Holstein  
122 Friesian cattle including followers. It serves both teaching and research  
123 purposes for Bristol Veterinary School and runs as a commercial dairy  
124 unit. On the farm, calves are housed in twin or group hutches. Male  
125 calves born on the farm are reared with females for the first few weeks  
126 of life and are sold at about 10-12 weeks of age.

### 127 *2.1 Calves*

128           Thirty-one apparently healthy Holstein Friesian calves aged 6±1  
129 week were recruited for this study. Calves were separated from their  
130 dams within 36 hours of birth and kept in individual pens for 5-7 days.  
131 Thereafter, they were housed in groups of four or five per hutch (Agri-  
132 plastics, The Calf Housing Specialist<sup>®</sup>, Canada). Each group hutch had an  
133 inside and outside dimension of 229cm L x 269cm W x 200 cm H and  
134 296cm L x 254cm W x 191cm H respectively. These group hutches were  
135 enclosed within a four-part galvanized fence (488cm L x 274cm W). The  
136 floor of the hutches was bedded with dry wheat straw while the  
137 outdoor pen was made of rough concrete. The hutches were set on the  
138 ground and not anchored to the concrete floor. The calves were fed  
139 twice daily (early morning and mid-afternoon period) with 50% Calf milk  
140 powder (150g/l; Farm Direct<sup>®</sup>, Devon), wheat straw and Start 'n' Wean  
141 nuts (Wynnstay<sup>®</sup>, Powys) and had access to clean drinking water  
142 (replaced twice daily irrespective of consumption) *ad libitum*. The

143 number of dairy calves as used in each study phase are presented in  
144 Table 1 below.

### 145 *2.2 Calf selection and habituation*

146 The group hutches selected for the study were based on the  
147 absence of illness of all the calves residing in them; hence only hutches  
148 with apparently healthy calves were studied. To habituate the calves, an  
149 observer (with or without a video camera) stood in front of each hutch  
150 watching the calves until the calves showed minimal interest in the  
151 observer. This habituation period lasted for three days.

### 152 *2.3 Development of ethogram*

153 Ten female dairy calves housed in two group hutches were  
154 directly observed for five days. The observer stood just outside the  
155 outdoor pen and documented their postures, activities, and movements  
156 for twenty minutes three times daily (morning, afternoon, and evening)  
157 to establish a list of behaviour exhibited by these calves in their  
158 environment. The ethogram was first organized into activities (chewing,  
159 drinking, defaecating, eating, grooming/licking, playing, scratching,  
160 sniffing and urinating); attentiveness, movements (stand, walk, lie, run,  
161 jump and buck), position in the hutch, postures, social interactive  
162 behaviour and vocalization. However, when this ethogram was used to  
163 record calves by direct observation, it was impossible to score  
164 behaviour simultaneously at the one-minute interval which it was  
165 designed for, and it required looking at each calf more than once.

166 Hence, modification of the ethogram was carried out several times and  
167 the final version chosen based on practicality and efficiency of use. This  
168 version was organized into three categories. The first category (I)  
169 comprised postures (location within hutch, anatomical components of  
170 posture), attentiveness and social interaction; the second category (II)  
171 comprised point or event behaviour which were recorded each time  
172 they occurred during the study period while the last category (III)  
173 comprised movement and activity behaviour whose duration of  
174 occurrence were of interest. This last category was termed 'state  
175 behaviour'. While defining the behaviour contained in the ethogram,  
176 several consultations were made to the literature. Definitions of  
177 behaviour were modified from ethograms of Jensen et al. (1998);  
178 Jensen and Khyn (2000); Mintline et al. (2013); Caray et al. (2015) in  
179 dairy calves and Love (2009) in horses.

#### 180 *2.4 Determination of factors influencing behaviour*

181 The ethogram developed above required pilot use in the hutch  
182 environment to ensure it contained behaviour which are most robust  
183 for measuring in the field. Hence, data collection was carried out using  
184 the ethogram to identify factors which can potentially influence  
185 behaviour. The study ascertained if there are behavioural differences  
186 between dairy calves housed in different hutches due to the limited  
187 number of calves which each group hutch can contain. Additionally, it  
188 also determined whether the behaviour of hutch-housed dairy calves  
189 varies across days, gender, and time of day. Thus, the behaviour of 16

190 dairy calves (4 males and 12 females) housed in four group hutches (n=2  
191 males, 2 females in hutch A; n=4 females in hutch B; n=1 male, 3  
192 females in hutch C; n=1 male, 3 females in hutch D) were recorded  
193 using the developed ethogram for two consecutive days. On each day,  
194 observations began at 10:00 and lasted approximately 80 minutes. Each  
195 calf was focally sampled using direct and concurrent video observations  
196 for five minutes. During each five-minute period, the postural,  
197 attentiveness and social interactive behaviour were recorded at  
198 sampling intervals of 60 seconds by direct observation while the  
199 frequency of the event behaviour, and the duration of movement and  
200 activity behaviour were determined using the video recordings for each  
201 calf. For the direct observation, the observer stood just outside the  
202 fence of the hutch facing the calves. Video recording was obtained using  
203 a Canon camera (Legria HF R606), positioned on a tripod just outside  
204 the fence at the height of 1.2m and angle of 60 degrees (and  
205 manoeuvred by hand when necessary).

206           Variation in the behaviour of dairy calves housed in different  
207 hutches was determined by statistical comparison between the four  
208 groups of calves housed in the four group hutches.

209           To determine whether the behaviour of hutch-housed dairy  
210 calves varies across days, the behaviour of these dairy calves recorded  
211 above was compared between the two days.

212           Due to the presence of male dairy calves in three out of the four  
213 group hutches as described above, the behaviour of the male dairy  
214 calves were compared against the female calves.

215           To determine the influence of time of day on the behaviour of  
216 calves residing in the same hutch, a new group hutch containing five  
217 calves (4 females; 1 male) was selected. This group hutch was selected  
218 because it contained more calves. Calves were recorded at hourly  
219 interval between the hours of 10:00 and 17.00 for two consecutive  
220 days. Using the same protocol outlined above, each calf was focally  
221 sampled for 10 minutes every hour by direct and concurrent video  
222 observations. The behaviour of these calves was then compared across  
223 hourly intervals to ascertain the time of day effect.

#### 224 *2.5 Statistical analysis*

225           Postural and event behaviour were calculated as frequency  
226 while movement and activity behaviour were determined as duration.  
227 To determine the frequency of events, and duration of movement and  
228 activity behaviour, the ethogram was coded into behavioural  
229 observation research interactive software (BORIS<sup>®</sup> version 7.4.15) (Friard  
230 and Gamba, 2016) by assigning a code to each of the behaviors  
231 contained in the ethogram. Behaviour was then logged as each video  
232 clip played on BORIS. Prior to coding and logging of behaviour into  
233 BORIS, the video clips were shown to two behavioural experts and the  
234 various aspects of behavior identified and discussed. A time budget

235 analysis was then performed on all behaviour logged onto BORIS to  
236 generate the frequency of event behaviour and the duration of  
237 movement and activity behaviour. Statistical analysis was performed  
238 with SPSS software (IBM SPSS® version 25.0.0). All the behavioural data  
239 generated were tested for normality and homogeneity using  
240 Kolmogorov-Smirnov and Levene's test, and due to the significant  
241 variations observed; non-parametric tests were chosen for the analysis.  
242 To test for behavioural differences between dairy calves housed in  
243 different hutches, data from the four group hutches were compared  
244 using Kruskal Wallis test. To test for behavioural differences across days,  
245 data from day one was compared with day two (blocked for different  
246 hutch-housing effect) using Wilcoxon Signed Rank test. Additionally, the  
247 influence of gender was determined using Mann Whitney U test  
248 (blocked for different hutch-housing and day effect). The Friedman test  
249 was used to investigate the influence of time of day on the behaviour of  
250 hutch-housed dairy calves. Data were expressed as median frequency,  
251 median duration, or mean rank. Significance was accepted at  $P < 0.05$   
252 unless otherwise stated.

### 253 **3. Results**

#### 254 *3.1. Ethogram development*

255 The full description of the ethogram of hutch-housed dairy  
256 calves is attached as a supplemental material. When subjected to pilot  
257 use, the developed ethogram was found to be comprehensive for

258 hutch-housed dairy calves in this environment and did not need  
259 modifying for the subsequent studies.

### 260 *3.2. Influence of housing calves in different group hutches*

261           There were no significant differences in the behaviour of dairy  
262 calves housed in different hutches.

### 263 *3.3. Influence of day*

264           The frequency of calves 'looking towards' the observer was  
265 significantly higher ( $Z = -2.04$ ;  $P < 0.041$ ) on day 1 (18.25) than on day 2  
266 (11.97) while 'looking away' from observer was significantly higher ( $Z = -$   
267  $0.32$ ;  $P < 0.041$ ) on day 2 (18.03) than on day 1 (11.75). The frequency of  
268 'forward' posture of the ear was significantly higher ( $Z = -2.18$ ;  $P <$   
269  $0.033$ ) on day 1 (18.46) than on day 2 (11.77) while the reverse was the  
270 case with 'side' ear posture ( $Z = -2.90$ ;  $P < 0.004$ ) with frequencies of  
271 10.43 and 19.27 on days 1 and 2 respectively. 'Open mouth' posture  
272 was significantly higher ( $Z = -2.18$ ;  $P < 0.029$ ) on day 2 (17.90) than on  
273 day 1 (11.80) while 'closed mouth' posture was significantly higher ( $Z = -$   
274  $2.18$ ;  $P < 0.029$ ) on day 1 (18.11) than on day 2 (12.10). Ear flicking on  
275 day 1 (15.42) was significantly higher ( $Z = -2.07$ ;  $P < 0.039$ ) than on day 2  
276 (9.23).

### 277 *3.4. Influence of gender*

278           The results of the influence of gender on the behaviour of dairy  
279 calves showed that the frequency of 'tongue inside mouth' posture ( $Z =$

280 -2.27;  $P < 0.023$ ), ear flicking ( $Z = -2.69$ ;  $P < 0.007$ ), tail wagging ( $Z = -$   
281 2.04;  $P < 0.042$ ) and duration of walking ( $Z = -2.02$ ;  $P < 0.044$ ) were  
282 significantly higher in females (16.70, 17.37, 16.16 and 17.68) than in  
283 males (11.22, 8.44, 11.00 and 11.15), while body shaking ( $Z = -2.09$ ;  $P <$   
284 0.036) and sniffing other calves ( $Z = -2.01$ ;  $P < 0.045$ ) were found to be  
285 significantly higher in males (13.50 and 13.33) than in females (16.61  
286 and 18.72).

### 287 *3.5. Influence of time of day*

288           The results of the influence of time of day on behaviour showed  
289 that postural behaviour (such as location in the hutch, head, tail and  
290 standing posture) and movement behaviour (including standing, walking  
291 and lying duration) were affected by time of day as shown in Tables 2  
292 and 3 below respectively. A significant increase in frequency of standing  
293 and relaxed-tail postures together with calves staying in front of the  
294 hutch were observed at the hours of 10:00, 13:00 and 15:00 when the  
295 calves spent most time standing and walking while higher frequency of  
296 low-head and tucked-tail postures coincided with an increased lying  
297 period at 12:00. Day 2 data from the time of day component of the  
298 study were lost due to hardware storage failures.

## 299 **4. Discussion**

300           The objectives of this study were to investigate the behaviour of  
301 hutch-housed dairy calves, develop a comprehensive ethogram as a  
302 means of recording calf behaviour and determine the factors influencing

303 the behavior of dairy calves with the intention of establishing an all-  
304 inclusive ethogram for use in subsequent studies. The arrangement of  
305 the ethogram and score sheet used in this study were chosen based on  
306 practicality and ease of use. The ethogram incorporated every aspect of  
307 dairy calf behaviour seen during the observation period, including  
308 postures (location within the hutch and anatomical components of  
309 posture), social interaction (interaction with calves and observer),  
310 movements (standing, walking and lying behaviour), activities (eating,  
311 drinking, playing, chewing, yawning, head rubbing, body rubbing,  
312 stretching, urinating and defaecating), exploratory (grooming, licking  
313 object) and avoidance behaviour (ear flicking, feet stamping, head  
314 shaking, body shaking, scratching, tail wagging), providing an  
315 opportunity to evaluate the entire calf. Pilot testing of this ethogram  
316 revealed that the developed ethogram was comprehensive for hutch-  
317 housed dairy calves.

318 Calves in the four group hutches all maintained homogeneity in  
319 behaviour. This suggests that there are no differences in the behaviour  
320 of dairy calves housed in different hutches on the same farm. This was  
321 not surprising because of the strong social bond which exists between  
322 groups of cattle due to their gregarious nature (Philips, 2002).

323 Additionally, the visual and auditory contact offered by the outdoor pen  
324 may have contributed to the high level of homogeneity in the behaviour  
325 between the calves despite being housed in different hutches.

326 Homogeneity in behaviour has also been reported in adult cows.

327 Schrader (2002) and Fregonesi et al. (2004) observed consistency in the  
328 behavioural activities of dairy cows throughout weeks while Müller and  
329 Schrader (2005) reported the behaviour of dairy cows to be consistent  
330 between two consecutive lactations.

331           The results also suggest that postural, social interactive and  
332 avoidance behavior may vary across days. However, this is only based  
333 on a two-day observation period and further observations would be  
334 needed to confirm these results. The behaviour and physiology of cattle  
335 is known to be influenced by environmental conditions (Schütz et al.,  
336 2010; Hill et al., 2011; Charlton and Rutter, 2017; Kovács et al., 2018)  
337 which tend to vary across days. However, during the observation period,  
338 environmental conditions were not substantially different between the  
339 two days with temperatures of 8.5°C and 9°C; relative humidity of 94%  
340 and 83% and Wind of 11 mph WSW and 9 mph S in days 1 and 2  
341 respectively. The variation in behaviour between days may indicate that  
342 the calves were not fully habituated to the observer as evidenced in  
343 response to observer behaviour, even after the three days habituation  
344 period prior to data collection.

345           The behaviour of hutch-housed dairy calves was also found to  
346 be influenced by gender. The increase in frequency of ear flicking and  
347 tail wagging in the female calves may suggest that they react more  
348 robustly than the males to the presence of irritants and as a coping  
349 strategy and spent more time walking to avoid irritation. Tail wagging

350 and ear flicking; known as 'avoidance behaviour', occur following  
351 irritation or threat in cattle (Philip, 2002). While the literature is scant  
352 on gender effects on cattle behaviour, gender was reported to influence  
353 play behaviour in calves (Philips, 2002) and grazing behaviour in adult  
354 cattle (Hall, 1986). According to Philips (2002), male calves are the  
355 initiators of play but subsequently become the receivers more than the  
356 female counterparts. While gender did not influence duration of play  
357 behaviour in this study, the above cited literature supports the finding  
358 of gender-based differences in the behaviour of calves. One reason for  
359 the scant literature on the effects of gender is probably due to the  
360 absence of the male animals on dairy farms. In commercial dairy farms,  
361 retention of dairy females is the usual practice and male calves born in  
362 dairy farms are sold off almost immediately depending on the  
363 management practices of the farm. While the findings on gender in this  
364 study together with the above cited literature suggest that a gender  
365 effect be borne in mind while studying behaviour of calves, it is also  
366 important to acknowledge that the small, uneven sample size (4 males  
367 versus 12 females) and the short observation period may have  
368 influenced the results.

369           The time of day influenced the behavior of hutch-housed dairy  
370 calves. While some postural and movement behaviour (categories I and  
371 III) were influenced by time of day, the events were unaffected  
372 (category II). Calves staying in the front part of the hutch together with  
373 increases in postural behaviour such as standing and relaxed tail posture

374 coincided with the active periods of the calves while very low head  
375 posture and tucked tail posture were frequently observed during the  
376 less active periods. The significant variations observed in the duration of  
377 standing, walking, and lying behaviour demonstrate that movement  
378 behaviour are influenced by time of day. Findings also revealed that  
379 calves spent over two-thirds of the entire study period lying while active  
380 movements such as standing, playing, and walking made up the other  
381 one-third. In agreement, Weiguo and Philips (1991, cited in Philips,  
382 2002) reported that calves spent approximately 13 hours per day lying.  
383 Equally, Jensen et al. (1998) observed increased resting time and low  
384 level of play in dairy calves kept in pens. There was no consistent  
385 pattern in the display of active movements since these were observed  
386 both in the morning (10:00) and afternoon periods (13:00 and 15:00). It  
387 is thought that the increase in the duration of standing and walking  
388 behavior at 15:00 was in preparation of the second round of feeding as  
389 these calves were routinely fed between 15:00 and 16:00. In line with  
390 the report of Jensen et al. (1998) and Rushen and de Passillé (2014),  
391 calves spent little time playing in this study. Play behaviour observed  
392 included running, jumping and head to head/frontal push which were all  
393 performed in the outside pen as the inside hutch provided very minimal  
394 space for play. Other aspects of social and locomotor play reported by  
395 Jensen et al. (1998) were not seen during the study period. Under  
396 favourable conditions, young animals are expected to play (Holloway  
397 and Suter, 2004). During the study, the group hutches were observed to

398 reverberate (since they were not anchored to the ground) whenever the  
399 calves jumped or ran. This resonating effect may have elicited fear in  
400 the calves, thereby discouraging play behaviour. Fear was hypothesized  
401 as one of the factors which suppresses the manifestation of play  
402 behaviour in calves (Wood-Gush and Vestergaard, 1991). In their study,  
403 these authors suggested that play behaviour was deterred when fear  
404 counterbalances exploration. However, dairy calves are known to play  
405 less during the weaning phase (Krachun et al., 2010).

406           The limitations of this study include the short observation  
407 period per calf, small sample sizes, and the lost data from day 2 (time of  
408 day component). The small sample sizes were due to the limited  
409 number of calves which each group hutch could accommodate. The lack  
410 of comparative studies in the literature also limits the ability to draw  
411 appropriate conclusion until confirmatory studies are performed. Yet  
412 despite these limitations, the findings provide a valuable insight into the  
413 behaviour of group-housed calves in hutches.

## 414 **5. Conclusion**

415           This study is the first to develop a comprehensive ethogram to  
416 record the full range of calf behaviour. While confirmatory studies are  
417 needed to refine this ethogram, the ethogram will help farmers,  
418 veterinarians and researchers better understand the behaviour of  
419 hutch-housed dairy calves and to recognize changes in all aspect of the  
420 dairy calf behaviour. This study also provides data on the influence of

421 factors such as housing calves in different hutches, day, gender, and  
422 time of day on the behaviour of hutch-housed dairy calves.  
423 Veterinarians and other stakeholders also need to be aware that the  
424 behaviour of dairy calves could be affected by these factors and control  
425 for them in further studies.

426 **Declaration of interest**

427           None.

428 **Acknowledgments**

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433

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532

533 **Table captions**

534 Table 1. Table 1. A table showing the number of dairy calves in each study phase

535 Table 2. Influence of time of day on postural behavior. Median frequencies in a row with different  
536 superscripts differ significantly ( $P < 0.05$ )

537 Table 3. Influence of time of day on the duration of standing, walking, and lying behaviour. Median  
538 duration a row with different superscripts differ significantly ( $P < 0.05$ )

539