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1 **Interplay between productive traits, the social rank, and the cow's stability**  
2 **in the order of entrance to the milking parlour**

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17

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26 **Conflicts of Interest**

27 The authors declare there are no conflicts of interest.

28 **Ethical Standards**

29 Animal care and procedures were carried out according to the guidelines of the Animal Care and  
30 Use Committee of the Pontificia Universidad Católica de Chile (ID No. 150908002).

31

32 **Interplay between productive traits, the social rank, and the cow's stability**  
33 **in the order of entrance to the milking parlour**

34 **Abstract**

35 The aim of this study was to investigate whether social rank and stability in the order of entrance  
36 to the milking parlour are associated with production traits. The study was conducted on a dairy  
37 farm where cows (n = 215) were managed in three groups according to lactation stage (Group 1:  
38 78 cows 0-100 DIM; Group 2: 65 cows 101-200 DIM; and Group 3: 72 cows >200 DIM). Social rank  
39 (SR) was calculated from observations made from agonistic behaviour performed at the water  
40 troughs and feed bunks of each pen (n = 3). The animals were classified in 3 levels of dominance  
41 based on at least 5 clear interactions, resulting in: 61 dominant, 75 intermediate and 69  
42 subordinate cows based on SR. Stability in the order of entry was estimated as the standard  
43 deviation of the entry position. SR was weakly correlated to milk yield, urea and protein content in  
44 milk. The results showed that stable cows had higher milk production and entered the milking  
45 parlour after the non-stable animals. Stability in the order of entry to the milking parlour was not  
46 affected by social rank. Overall, the use of milking facilities appears to be associated with  
47 production traits rather than social rank.

48

49 **Keywords:** Social hierarchy, animal welfare, dairy, milking order.

50

51

52 **Introduction**

53 Dairy cows form a social hierarchy through dominance establishment and this is associated with  
54 higher-ranking individuals having supremacy in the use of resources (Phillips and Rind, 2002). In a  
55 dairy herd, the social rank is related to factors such as age and animal size that can be measured as  
56 body condition score and live weight (Sottysiak and Nogalski, 2010). These factors are associated  
57 with physical strength and the competition for space that becomes a driver for aggressiveness of  
58 cows in confined spaces (Galindo and Broom, 2000). Aggressive social interactions create stress  
59 conditions between dominant and subordinate cows, which may affect milk production, especially  
60 for the subordinate cows (Chebel et al., 2016)

61

62 Dairy cows enter the milking area in a specific order and their behaviour is often expressed in a  
63 relatively consistent pattern (Paranhos da Costa & Broom 2001; Polikarpus et al., 2015).  
64 Consequently, preference for one side of the milking parlour seems to be a stable characteristic of  
65 a dairy cow (Hopster & van der Werf 1998; Grasso et al., 2007). Social rank (Melin et al. 2006),  
66 health-related characteristics (Flower et al. 2006; Polikarpus et al. 2015) and productive-related  
67 characteristics (Górecki & Wójtowski 2004) can influence the efficient use of milking facilities. For  
68 example, social rank, social structure of the herd and individual characteristics, such as anxiety,  
69 fear and stress, can influence side preference (Prelle et al. 2004). In addition, cows with  
70 locomotion and udder health problems can have problems to reach milking facilities (Gleeson et  
71 al., 2007).

72

73 The knowledge about milking order in dairy systems may provide data that can be used for early  
74 detection of health problems and prevention of production and economic losses (Polikarpus et al.,  
75 2015). Many studies have pointed out different factors affecting the use of milking facilities but to  
76 our knowledge, the interplay between productive traits, the social rank, and the stability of cows  
77 in the order of entrance to the milking parlour remain unexplored. Thus, the aim of this study was  
78 to determine whether social rank and stability in the order of entrance to the waiting area and  
79 milking parlour were affected by productive traits. To address the study's objective animals were  
80 initially classified by their social rank. We investigated the relationship between social rank and:  
81 (a) health related traits (locomotion score, body condition score and udder hygiene score); (b)

82 stability in the order of entrance to the waiting area and milking parlour; and (c) and milk  
83 production.

## 84 **Materials and Methods**

### 85 *Animals, housing and management*

86 Animal care and procedures were carried out according to the guidelines of the Animal Care and  
87 Use Committee of the Pontificia Universidad Católica de Chile (project ID No. 150908002). The  
88 study was conducted in a commercial dairy farm located in Pirque, Chile (33°38'28"S, 70°34'27"W).  
89 Lactating cows (n = 205; Holstein × Montbeliarde) were managed in three groups according to  
90 lactation stage (Group 1: 63 cows 0-100 DIM; Group 2: 77 cows 100-201 DIM; and Group 3: 65  
91 cows >200 DIM). Animals were housed in dry lots (n=3; 80 × 80 m) with shade and had continuous  
92 access to water. Each pen had a rectangular-shape concrete water trough (3.5 × 1.5 m) and feed  
93 bunks were located in one side of the pens (approximately 60 linear meters per pen). Cows were  
94 fed three times per day (08:00, 10:00 and 17:00 h). Animals were milked in a 2 × 6 parallel milking  
95 parlour equipped with DELPRO™ farm manager system (DeLaval, Sweden), three times per day  
96 (03:30, 12:00 and 18:00 h). The walking distance from the pens to the milking parlour varied from  
97 50 to 100m, depending on the group's location. Milk yield was recorded daily and analysed as total  
98 means. Body weights were individually measured after the first milking using a livestock chute  
99 with a weighing bar system. Body weights were recorded every 6 days and means were analysed.  
100 Milk components were recorded every 21 days (milk components were analysed by using an  
101 infrared analyser: Milko-Scan CombiFoss 6000; Foss Electric, Hillerød, Denmark) and means were  
102 analyzed.

103

### 104 *Behavioural observations and social rank determination*

105 During 42 days, agonistic interactions (agonistic encounters included bunting, pushing,  
106 threatening, avoiding and fighting) were registered to calculate the social rank index of each  
107 animal and its subsequent correlation analysis with productive traits (milk production, somatic cell  
108 count, locomotion score, body condition score and udder hygiene score). In addition, the  
109 sequence of entrance to the waiting area and the milking parlour was used to define two indices  
110 of individual stability.

111

112 Behavioural observations were undertaken using a video recording system (SONY, YC-231G).  
113 Numbered coloured collars were used to facilitate animal identification. Agonistic interactions  
114 were registered through direct observation at the water trough after two milking times (12:00 and  
115 18:00 h) during two consecutive days. Water trough access was denied from the moment the  
116 group left the pen to be milked until 30 minutes after the last cow entered to the pen  
117 (approximately one hour and 40 minutes without having access to water troughs in total). Each  
118 group was observed during five consecutive days for 30 hours. At the feed bunks, during two  
119 consecutive days, agonistic interactions were registered through direct observation two times per  
120 day (08:00 and 17:00 h). Each group was observed for 1 hour and 30 minutes by the same  
121 observer.

122

123 A social rank (SR) was calculated for each cow within each group from all observations (from water  
124 troughs and feed bunks). This SR was calculated based on methodology described by Galindo et al.  
125 (2000) and Hohenbrink and Meinecke-Tillmann (2012):  $\text{Social rank} = \frac{\text{interactions won}}{\text{won} + \text{lost}}$   
126 interactions). Animals showing a score of 0.0 to 0.4 were classified as subordinates. Individuals  
127 with a score from >0.4 to 0.6 were classified as intermediate. Cows with a score from >0.6 to 1.0  
128 were classified as dominant.

129

### 130 *Health and productive related characteristics*

131 The locomotion score (LS), body condition score (BCS) and udder hygiene score (UHS) were  
132 considerate as health and productive related characteristics. After behavioural observations,  
133 these characteristics were recorded at the end of the midday milking (12:00 h) during six  
134 consecutive days. The LS considered five individual aspects (spine curvature, tracking, speed, head  
135 carriage and abduction/adduction) of locomotion in a five-point scale as reported by O'Callaghan  
136 et al. (2003) and observations were done for once daily for 6 consecutive days. The BCS was based  
137 on a five-point scale where 1 = emaciated to 5 = overly fat (Wildman et al. 1982). A four-point  
138 score was used to measure the UHS based on Ruegg (2006) where 1= completely free of dirt or has  
139 very little dirt; 2= slightly dirty; 3 = mostly covered in dirt; and 4= completely covered, caked on  
140 dirt. The same person who was trained for those measurements carried out scorings for  
141 locomotion, body condition and udder hygiene.

142

143 *Milk production and stability in the order of entrance to the waiting area and milking parlour*

144 An automated management information system (DELPRO™, DeLaval, Sweden) recorded the  
145 entrance time to the milking parlour, milking duration, milking unit and individual milk yields and  
146 associates them with the ear tag embedded identification from each cow. Before each milking, all  
147 cows from each group were taken together to a waiting area. During this period, cows were free  
148 to choose their position in relation to the entrance in the milking parlour without any intervention  
149 of the stockman. The waiting area (120 m<sup>2</sup>) was in front of the milking parlour (Figure 1). Both  
150 sides of the milking parlour were identical and accessed through automatic gates. The gates were  
151 open as soon as a milking unit was empty.

152

153 The entrance order to the waiting area and the milking parlour were video-recorded (SONY, YC-  
154 231G). Nine records of entrance positions to the waiting area were obtained from each animal. For  
155 the entrance to the milking area 15 records of positions per animal were obtained. With these  
156 data, the individual stability of each animal was calculated as the standard deviation of its position  
157 records. With this information, 30% of the most stable cows and 30% of the less stable cows were  
158 selected to form two stability groups for production trait analyses. These groups (stable and non-  
159 stable) were compared for production characteristics such as milk production, urea, protein, fat  
160 and somatic cells in milk.

161

162 The sequence of entrance to the milking parlour was determined using the data obtained by the  
163 DelPro™ program (DeLaval) routinely used in the dairy farm, where the starting time of milking  
164 and milking unit used by each cow was recorded. Based on the different numbers of animals from  
165 Groups 1, 2 and 3, the positions in the order of entrance to the waiting area and milking parlour  
166 were standardize from 1 to 9.

167

168 *Statistical analysis*

169 Correlations were analysed using Pearson (parametric data: social rank, milk composition and milk  
170 yield) or Spearman (non-parametric data: locomotion score, body condition score, udder hygiene



171 and dominance level) tests. Additionally, Chi-square tests were performed to assess whether there  
172 was a dependency between Locomotion score (LS), body condition score (BCS) and udder hygiene  
173 score with social rank.

174

175 Productive characteristics, social rank, and order of entrance to the waiting area and to the milking  
176 parlour from stable and non-stable cows were analyzed by using ANOVA. The groups of cows  
177 (stable and non-stable) and their lactation stage were considered as fixed effects in the following  
178 model:

179

$$180 Y_{ijk} = \mu + \alpha_i + \beta_k + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

181

182 Where  $Y_{ijk}$  is the dependent variable;  $\mu$  is the overall mean;  $\alpha_i$  is the effect of lactation stage;  $\beta_k$  is  
183 the effect of stability group; and  $\varepsilon_{ijk}$  is the experimental error.

184

185 The homogeneity of variances was analysed with the Levene test. This was followed by the  
186 Student-Newman-Keuls multiple comparison of means procedure at  $P < 0.05$  to determine  
187 differences between the different groups. Results were expressed as mean  $\pm$  standard deviation.  
188 Probability of  $P < 0.05$  was defined as significant. The SPSS statistical software for Windows was  
189 used (version 15.0.0; SPSS Inc., Chicago IL, USA). When statistical analyses were performed, the  
190 outliers identified were identified as the consequence of extraordinary events, such as health  
191 problems (i.e., clinical mastitis and abortion), and the need for some veterinary treatment.  
192 Therefore, as they did not represent an important segment of the study population, they were  
193 eliminated from the analyses.

194

195 Additionally, to assess whether there was an effect of position on the standard deviation of the  
196 position data, the cows were grouped into 9 groups according to the average position obtained  
197 during the observations, and the SD of their locations was calculated. ANOVA or Kruskal-Wallis  
198 test were performed with these data, after heteroscedasticity test of variances. When there was  
199 no heteroscedasticity of variance, the multiple comparison was performed using the Tukey's

200 Honest Significant Difference test, and otherwise, through the non-parametric test by Notched  
201 Box Plots.

202

## 203 **Results**

204 Out of the initial 215 cows in the herd, five cows were culled out due to health problems during  
205 the study period; one additional cow had an abortion and was discarded from the study due to the  
206 need for veterinary treatment. Of the remaining 209 cows, 4 were eliminated from the results  
207 database, because they presented outlier values in some of the variables analyzed. Table 1 shows  
208 the final production and health related characteristics for each group. Briefly, group 1 consisted of  
209 77 animals, of which 27% were dominant, 38% were intermediate and 35% were subordinate.  
210 Group 2 (n = 63) had a distribution of 32% dominant animals, 29% of intermediate animals and  
211 38% of subordinate animals. Group 3 (n = 65), where the animals in their last third of lactation had  
212 a distribution of 30% of dominant animals, 39% of intermediate animals and 31% of subordinate  
213 animals. The social rank evaluation from all animals (n = 205) resulted in 61 dominant animals, 75  
214 intermediate animals and 69 subordinate animals. The agonistic interactions during water  
215 consumption represented less than 20% of the total interactions (Table 2).

216

217 There was a significant correlation between the SR and parity, which means that multiparous cows  
218 tend to be dominant individuals in the herd (Table 3). A weak correlation between parity and  
219 locomotion score ( $r = 0.464$ ,  $P < 0.001$ ) was found, which in a way indicates that animals with more  
220 parities have higher locomotion scores. Body condition score had a tendency to be weakly  
221 correlated with the dominant animals, where dominant animals had better scores than the  
222 subordinate animals ( $r = 0.126$ ,  $P = 0.095$ ). Table 4 shows the distribution of locomotion score,  
223 body condition score and udder hygiene score of cows within social ranks. Regardless of social  
224 rank in the herd, 88% of the cows had a locomotion score of 2, 86% of the cows had a body  
225 condition score between 2.75 and 3.25 and 78% of the cows had a udder hygiene score between 1  
226 and 2. The Chi-square test showed that there was no dependency between locomotion score [Xi  
227 (205) 6, 3.94,  $P = 0.689$ ], body condition score [Xi (205) 10, 14.3,  $P = 0.155$ ] and udder hygiene  
228 score [Xi (205) 6, 4.3,  $P = 0.634$ ] on social rank (Table 4).

229

230 The stability in the order of entrance to the waiting area had a significant effect on milk  
231 production, thus, stable cows had higher milk production than non-stable cows (Table 5). In  
232 relation to milk fat, stable cows presented a higher content at the waiting area and in the milking  
233 parlour, however, significant differences were only observed in the milking parlour. The stability in  
234 the order of entrance also affected the concentration of urea at the waiting area with higher  
235 contents detected in stable cows.

236

237 As shown in Figure 2, the standard deviation of the position of the cows was related to their  
238 average position, thus, at the waiting room, the ANOVA test was significant, and differences were  
239 observed between the standard deviations of each category. Thus, the Kruskal-Wallis test was  
240 used, which gave a value of  $P = <0.001$ . This test showed differences between categories 1, 2 and  
241 9, which presented the smallest standard deviations, with the central groups from 4 to 7. At the  
242 milking parlour, the ANOVA test was not significant ( $P = 0.068$ ) and, as in the waiting room, the  
243 standard deviation of the data presented heteroscedasticity, so the Kruskal-Wallis test was used,  
244 which was significant ( $P = 0.004$ ), obtaining differences between the means of groups 1, 2 and 8  
245 with group 4.

246

## 247 **Discussion**

### 248 *Productive traits and social rank*

249 In this study, the social rank was determined on agonistic interactions from each group that was  
250 observed during the first minutes when there was no access to water. These findings coincide with  
251 a study conducted by Kondo et al. (1984) who observed a rapid decrease in the frequency of  
252 agonistic encounters as time passes. Similarly, at the feed bunk, Menke et al. (2000) reported that  
253 agonistic behaviour decreases in a relative short period.

254

255 Normally, the hierarchy is expressed mainly at the feed bunks (Val-Laillet et al. 2008). In this study,  
256 cows had water *ad libitum* after the 1:40 min restriction imposed after milking and feed was  
257 offered three times a day. In this regard, feed availability was restricted creating more competition  
258 among animals, resulting in a greater number of agonistic interactions at the time of feeding  
259 (Proudfoot et al. 2009). The results of a study conducted by DeVries and Von Keyserlingk (2006),

260 concluded that dairy cows experience a lower number of agonistic interactions when they are  
261 given more than the standard of 0.61 m of feeder/animal (Grant & Albright 2001). In the current  
262 study, animals had 0.8 m/animal. Previous studies showed that fresh cows, first calving heifers and  
263 cows recently integrated into a group are submissive cows; and larger and older cows in a group  
264 are often the most dominant (Guhl & Atkeson 1959; Grant & Albright 2001; Phillips & Rind 2002).

265

266 The correlations between locomotion scores and parity found in this study were weak, however  
267 they pointed at the fact that older animals are more prone to having foot problems (Galindo &  
268 Broom 2000). Hetticha et al. (2007) reported that the number of births and, therefore, the age,  
269 was a risk factor for the presentation of this pathology, where cows with three or more lactations  
270 presented 3.8 times more chances of suffering from this condition. This agrees with Sogstad et al.  
271 (2005), who found that cows with three or more lactations had higher risks of lameness than those  
272 with less than three lactations. In this study, animals that are more dominant had increased body  
273 conditions scores. This finding suggest that dominant animals have unrestricted access to different  
274 resources (i.e., feed, water, and bedding), while subordinate animals have restricted access to the  
275 feeding places, which could affect their feed intake (Dickson et al. 1970; Llonch et al., 2018) and,  
276 therefore, their body condition score. Overall, in this study, given the weak correlations and non-  
277 significant Chi-square values found between locomotion score, body condition score, udder  
278 hygiene score and social rank. These results therefore, should be interpreted with caution as this  
279 was based on observations from 205 animals, which was not sufficient to have a greater  
280 dispersion of scores.

281

282 There was a weak correlation between milk yield (mean milk yield for each cow) and dominance;  
283 dominant animals had higher performance than the subordinate animals ( $r = 0.191$ ,  $P < 0.001$ ). In  
284 dry-lot pens, where feeding is not available *ad libitum*, animals unable to adapt to a competitive  
285 environment may be at a disadvantage in terms of the quantity and quality of the feed they have  
286 access to (Zobel et al. 2011), which could affect their consumption and, therefore, decrease their  
287 production. It is very important that the cows have good access to the diet and water throughout  
288 the day, to ensure the health, welfare, production and efficiency of the cow (Shabi et al. 2005). In  
289 farms where feed is limited, and competition is high, dominant cows eat more feed (Grant &  
290 Albright 2001) and drink more water (Teixeira et al. 2009) than subordinate cows.

291

292 There were weak correlations between social rank and body weight ( $r = 0.276, P < 0.001$ ), parity ( $r$   
293  $= 0.339, P < 0.001$ ) and milk yield ( $r = 0.191, P < 0.001$ ). In this study, when social rank was  
294 determined at the water troughs and feed bunks, it was observed that dominant animals with  
295 larger body size, had unimpeded access to feed and water, while the subordinates were displaced  
296 and forced to move to other places without being able to consume feed. These results coincided  
297 with the study on a single herd carried out by Dickson et al. (1970), who suggested that live body  
298 weights and age were the factors most closely related to the position of the cow in the social  
299 hierarchy. In addition, Schein and Fohrman (1955) reported a high significant relationship between  
300 the range of dominance and age, and live body weight as well. On the other hand, the correlation  
301 between the social rank and body condition score and udder hygiene were low; the correlation  
302 coefficients were between  $0.096$  and  $0.126$  (Table 3). No significant correlation was observed  
303 between SR and locomotion scores nor somatic cell count (Table 3).

304

305 *Stability in the order of entrance to the waiting area and milking parlour*

306 *At the waiting area*, we observed a relationship ( $P = 0.008$ ) between SR and milk yield, since stable  
307 cows (lower standard deviation) were those with higher milk yield, compared to non-stable cows  
308 (higher standard deviation) (Table 5). Furthermore, although stable cows entered into the waiting  
309 area 0.12 places after non-stable cows (Table 5) this is not expected to be biologically significant.  
310 According to (Grasso et al. 2007) the cows have a coherent order of entry to the waiting area,  
311 which is considered as a social characteristic of the animals belonging to a dairy system.

312

313 The milk urea contents in both groups are within the normal expected range (150 to 420 mg/L)  
314 (Westwood et al. 1998). Stable cows had higher contents of milk urea. The concentration of milk  
315 urea is related to the supply of nitrogen in the diet, specifically the balance between degradable  
316 proteins and energy in the rumen. A high nitrogen intake or an energy deficiency produce an  
317 excess of ammonium in the rumen, which is absorbed and transformed into urea in the liver. This  
318 increases its concentration in both blood and milk, and its excretion in the urine. These  
319 concentrations are important since they can have repercussions for the health, fertility or  
320 efficiency in the milk production of the animal (Noro & Wittwer 2003).

321

322 We observed a relationship ( $P < 0.001$ ) between the stability in the order of entrance to the milking  
323 parlour and milk fat contents (Table 5). There were no studies found on the association that might  
324 exist between the stability in the order of entrance to milking facilities and milk composition. It is  
325 known that breed, parity and stage of lactation affect milk yield and milk composition (Kelsey et al.  
326 2003). In this study, we were not able to select animals based on parity or number of calvings,  
327 which could be helpful to explain the observed relationship.

328

329 In relation to the stability in the order of entrance to the milking parlour, the stable animals  
330 entered 1.7 positions after non stable animals, which agree with Hopster and van der Werf (1998)  
331 who found that cows with a consistent side choice took more time to enter the room. Rathore  
332 (1982) found that high-yield cows voluntarily entered the milking parlour earlier than low-yielding  
333 cows, and that was explained by the fact that cows were relieving the pressure of the udder  
334 caused by the milk, and that was the source of motivation to enter the milking parlour early.  
335 However, in the current study, we did not observed a relationship between the stability in the  
336 order of entrance to the milking parlour and milk yield. Conversely, Grasso et al. (2007) observed a  
337 positive correlation between milking order and milk production in primiparous cows, although the  
338 correlation coefficient was not high ( $r = 0.22$ ). As shown in Table 5, there were no interactions  
339 between lactation stage (G) and stability (S) for milk yield, which could indicate that stability is a  
340 characteristic associated with the animal independently from its days in milk.

341

342 Overall, results showed that a cow that prefers to come in first place would likely have less  
343 variation in her milking position than a cow in the middle of the herd because it may be easier to  
344 consistently be first than consistently be last. Also, because there is less scope for variation at each  
345 end of the milking order. Although, our study used 205 animals, the heteroscedastic nature of  
346 milking position variance in the milking order was also reported in larger herds of around 500  
347 lactating cows (Beggs et al., 2018).

348

349 *Limitations of the study*

350 Additional factors need to be taken into account when interpreting the data from this study. The  
351 weak correlations obtained are from the total available animals, without differentiating them by  
352 production level. Thus, there was a high percentage of the variance that is a consequence of other  
353 factors, some of which were considered in the analysis (lactation group and body weight) and  
354 others that the study did not account, such as the number of calvings and months of gestation. In  
355 this sense, the significance of the correlations could indicate that, by decreasing the sources of  
356 variation in the analyzed variables, the value of their correlation with social dominance could  
357 increase. Thus, although correlation values weak, they could be considered as the basis for a larger  
358 controlled experimental design in which the effect of the aforementioned variables are included or  
359 isolated.

360

### 361 **Conclusion**

362 In the current study, social rank was weakly correlated to production parameters such as milk  
363 yield, protein content, urea content, parity and body weight. Social rank did not affect cow's  
364 stability in the order of entrance to the waiting area and milking parlour. Stable cows had higher  
365 milk production and entered the milking parlour after non-stable animals. Overall, under the  
366 conditions of this study, the stability of the milking order appeared to be more closely associated  
367 with production traits rather than social rank.

368

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462 **Table 1.** Productive parameters, health related characteristics and social ranks (mean  $\pm$  standard  
 463 error)

Parameter	Group 1 (n = 77)	Group 2 (n = 63)	Group 3 (n = 65)
	0 – 100 days in milk	101 – 200 days in milk	>200 days in milk
Productive characteristics			
Milk yield, kg/d	31.6 $\pm$ 0.69	34.6 $\pm$ 0.52	34.0 $\pm$ 0.62
Fat, g/kg	37.5 $\pm$ 0.70	36.8 $\pm$ 0.80	34.8 $\pm$ 0.60
Protein, g/kg	32.2 $\pm$ 0.20	32.7 $\pm$ 0.40	32.9 $\pm$ 0.30
Milk urea N, mg/L	346 $\pm$ 9.6	366 $\pm$ 6.1	387 $\pm$ 5.6
Somatic cell counts, $\times 10^3$ mL	210 $\pm$ 44.6	198 $\pm$ 30.1	207 $\pm$ 38.3
Live body weight, kg	622 $\pm$ 12.8	662 $\pm$ 12.0	700 $\pm$ 9.4
Number of lactations	2.06 $\pm$ 0.170	2.39 $\pm$ 0.170	1.86 $\pm$ 0.150
Health related characteristics			
Locomotion score	2.17 $\pm$ 0.050	2.08 $\pm$ 0.040	2.12 $\pm$ 0.040
Body condition score	3.07 $\pm$ 0.030	2.95 $\pm$ 0.020	3.10 $\pm$ 0.020
Udder hygiene score	1.65 $\pm$ 0.090	1.87 $\pm$ 0.080	2.03 $\pm$ 0.860

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466 **Table 2.** Agonistic interactions recorded for 5 consecutive days in 205 dairy cows

Agonistic interactions	Group 1 (n = 77)	Group 2 (n = 63)	Group 3 (n = 65)
At the water troughs	232	178	147
At the feed bunks	800	630	685
Total interactions	1032	808	832
Social rank, number of cows			
Dominant	21	21	20
Intermediate	29	18	25
Subordinate	27	24	20

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469 **Table 3.** Correlations between different parameters for animals with at least 5 encounters

Parameters	Correlation (R)	P-value
Parity and locomotion score	0.464	<0.001
Milk yield and body weight	0.445	<0.001
Milk yield and somatic cell count	- 0.101	0.308
Body condition score and locomotion score	- 0.016	0.824
Social rank and parity	0.339	<0.001
Social rank and milk protein content	0.293	<0.001
Social rank and body weight	0.276	<0.001
Social rank and milk urea content	0.242	<0.001
Social rank and milk yield	0.191	<0.001
Social rank and body condition score	0.126	0.095
Social rank and udder hygiene score	0.096	0.083
Social rank and locomotion score	0.056	0.518
Social rank and somatic cell count	-0.023	0.738
Social rank and milk fat content	- 0.126	0.056

470 Correlations were analysed using Pearson (parametric data: social rank, milk composition and milk  
 471 yield) or Spearman (non-parametric data: locomotion score, body condition score, udder hygiene  
 472 and dominance level) tests.

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477 **Table 4.** Distribution of locomotion score (LS), body condition score (BCS) and udder hygiene score  
 478 (UHS) of lactating cows in relation to their social rank and Chi-square analysis

Items	Social rank							
	Dominant		Intermediate		Subordinate		All herd	
	n	%	n	%	n	%	n	%
LS								
LS 1	0	0	1	1	0	0	1	0.5
LS 2	54	89	63	84	62	90	179	88
LS 3	7	11	10	13	7	10	24	11
LS 4	0	0	1	1	0	0	1	0.5
LS 5	0	0	0	0	0	0	0	0
Cows <sub>total</sub>	61		75		69		205	
BCS								
BCS 2.50	1	2	1	1	2	4	4	3
BCS 2.75	13	21	18	24	16	22	47	22
BCS 3.00	22	35	34	45	33	45	89	42
BCS 3.25	13	23	14	19	16	26	43	22
BCS 3.50	9	15	8	11	2	3	19	9
BCS 3.75	3	5	0	0	0	0	3	2
Cows <sub>total</sub>	61		75		69		205	
UHS								
UHS 1	17	29	32	43	26	37	75	37
UHS 2	28	45	27	36	28	41	83	41
UHS 3	15	24	16	21	14	19	45	21
UHS 4	1	2	0	0	1	3	2	1
Cows <sub>total</sub>	61		75		69		205	
LS	Dominant	Intermediate	Subordinate	$\chi^2$				
LS 1	0	1	0			Chi-square	3.94	
LS 2	54	63	62			Degrees of freedom	6	
LS 3	7	10	7	0.68		P-value	0.689	
LS 4	0	1	0					
LS 5	0	0	0					
BCS	Dominant	Intermediate	Subordinate	$\chi^2$				
BCS 2.50	1	1	2			Chi-square	14.3	
BCS 2.75	13	18	16			Degrees of freedom	10	
BCS 3.00	22	34	33	0.16		P-value	0.155	
BCS 3.25	13	14	16					
BCS 3.50	9	8	2					
BCS 3.75	3	0	0					
UHS	Dominant	Intermediate	Subordinate	$\chi^2$				
UHS 1	17	32	26			Chi-square	4.3	
UHS 2	28	27	28			Degrees of freedom	6	
UHS 3	15	16	14	0.63		P-value	0.634	
UHS 4	1	0	1					

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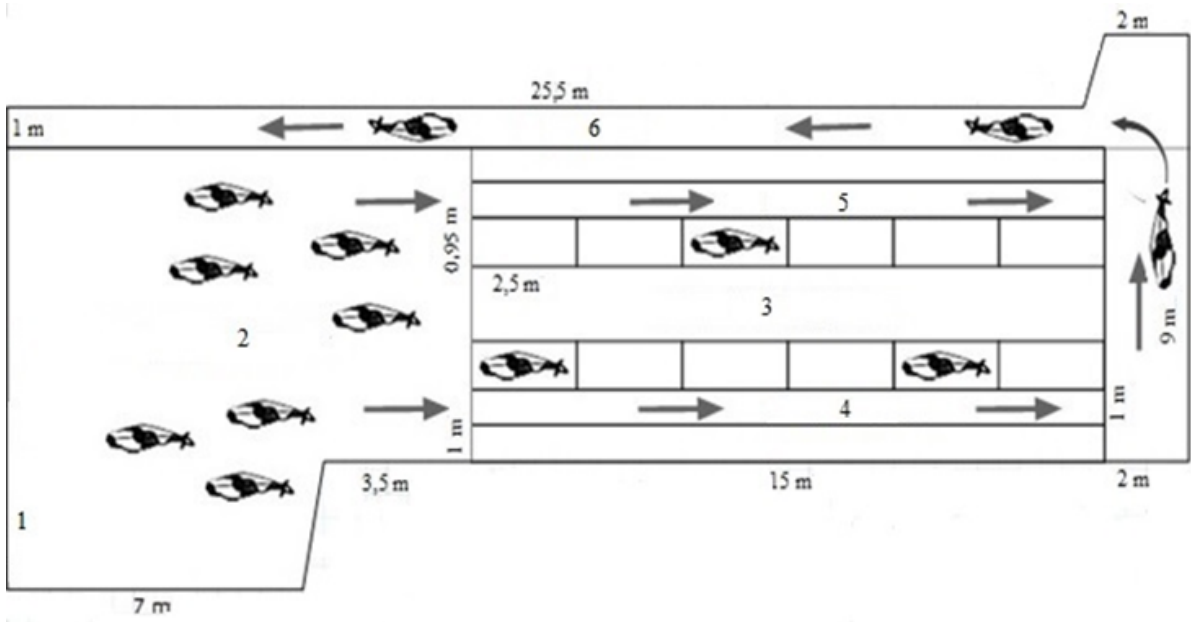
481 **Table 5.** Productive characteristics, social rank, and average order of entrance to the milking  
 482 parlour from stable and no stable cows (mean  $\pm$  standard deviation)

Parameters	Stable cows	No stable cows	<i>P</i> -value (G)	<i>P</i> -value (S)	<i>P</i> -value (G×S)
Waiting area					
Milk yield, kg/d	34.1 $\pm$ 0.67	32.3 $\pm$ 0.73	0.008	0.036	0.316
Fat, g/kg	36.0 $\pm$ 0.90	37.0 $\pm$ 0.70	0.155	0.362	0.818
Protein, g/kg	32.0 $\pm$ 0.30	32.0 $\pm$ 0.30	0.223	0.328	0.837
Milk urea N, mg/L	378 $\pm$ 6.7	351 $\pm$ 8.8	0.007	0.005	0.293
Somatic cell count, $\times$ 10 <sup>3</sup> /ml	169 $\pm$ 34.9	186 $\pm$ 33.4	0.291	0.994	0.396
Social rank	0.5 $\pm$ 0.02	0.5 $\pm$ 0.02	0.786	0.203	0.210
Order of entrance <sup>1</sup>	4.6 $\pm$ 0.28	4.7 $\pm$ 0.16	<0.001	0.637	0.799
Milking parlour					
Milk yield, kg/d	34.6 $\pm$ 0.61	33.7 $\pm$ 0.68	0.079	0.283	0.312
Fat, g/kg	36.5 $\pm$ 0.80	37.1 $\pm$ 0.70	0.489	<0.001	0.622
Protein, g/kg	32.4 $\pm$ 0.30	32.0 $\pm$ 0.30	0.153	0.491	0.860
Milk urea N, mg/L	371 $\pm$ 7.4	365 $\pm$ 8.5	0.005	0.618	0.569
Somatic cell count, $\times$ 10 <sup>3</sup> /ml	190 $\pm$ 37.9	202 $\pm$ 33.7	0.423	0.928	0.065
Social rank	0.5 $\pm$ 0.22	0.5 $\pm$ 0.24	0.703	0.619	0.644
Order of entrance <sup>1</sup>	6.9 $\pm$ 0.37	5.2 $\pm$ 0.18	<0.001	<0.001	<0.001

483 G = probability of lactation stage effect; S = probability of stability effect.

484 <sup>1</sup>Based on the different numbers of animals from Groups 1, 2 and 3, the positions in the order of  
 485 entrance to the waiting area and milking parlour were standardized from 1 to 9.

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 488 **Figure 1.** Layout of the 2 × 6 parallel milking parlour. 1-entrance, 2-waiting area, 3-operator's pit,  
 489 4-right alley, 5-left alley, 6-exit alley.  
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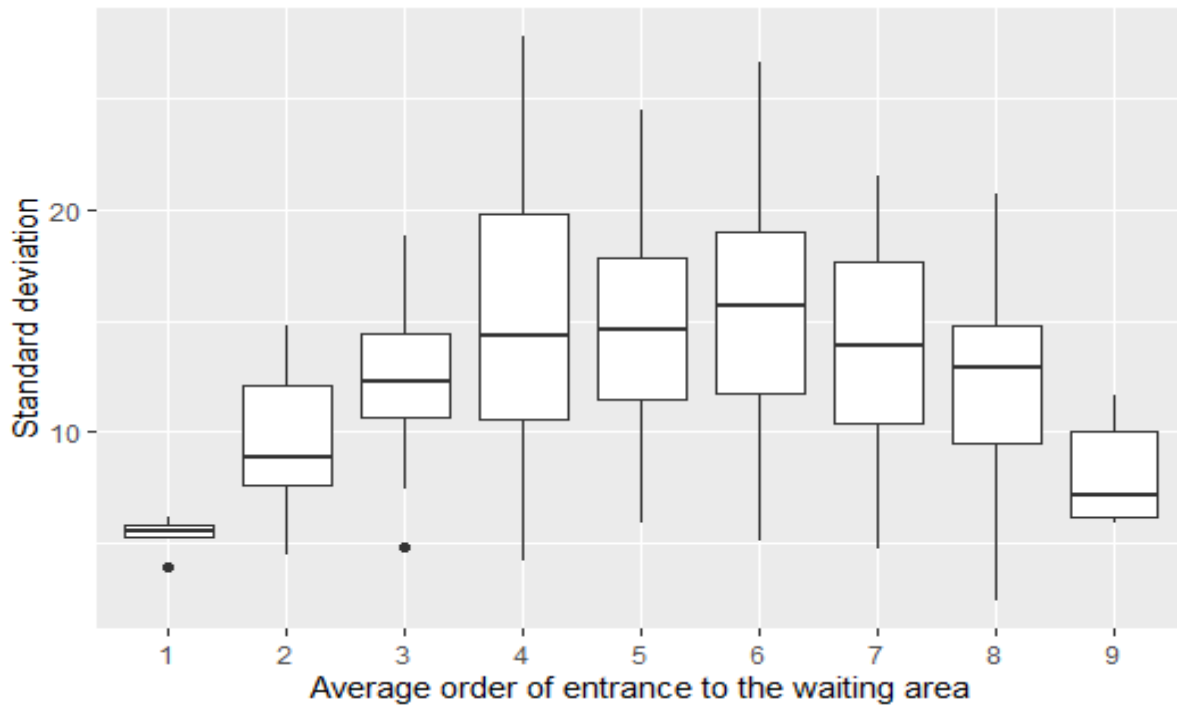
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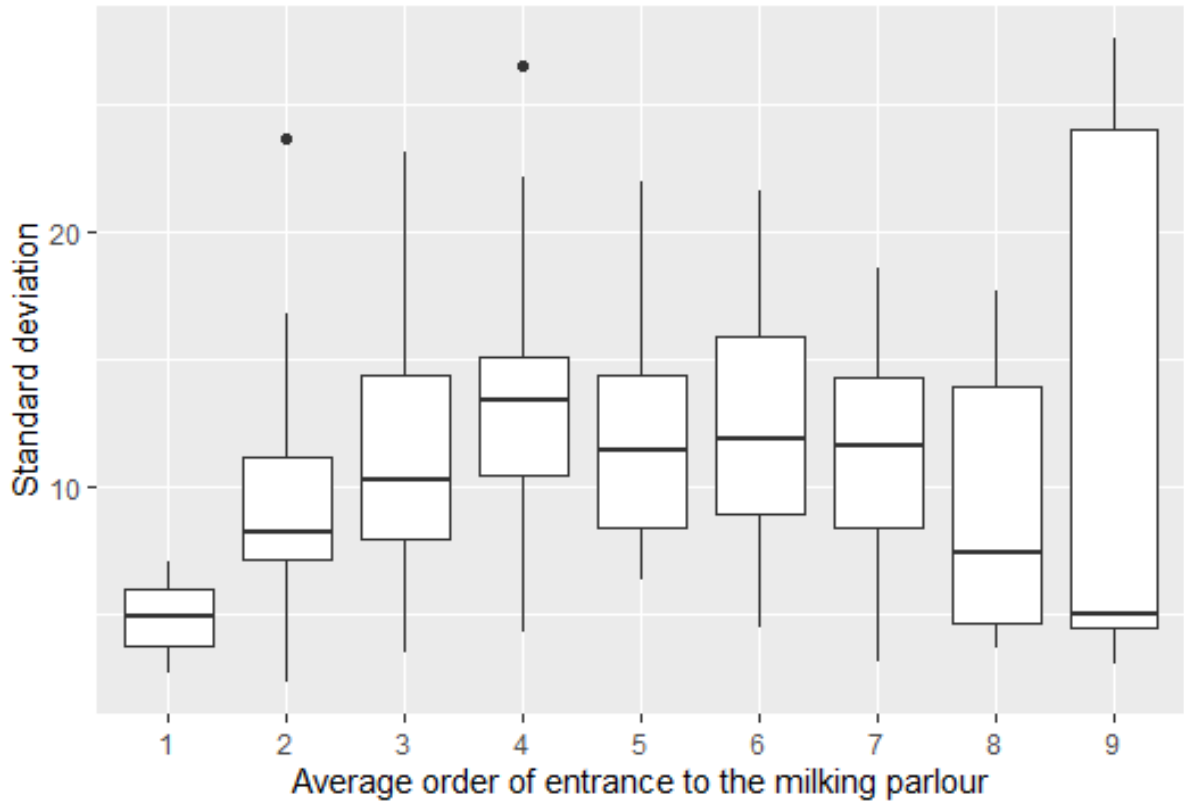
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513 **Figure 2.** Notched Box Plots from average order of entrance to the waiting area and milking  
 514 parlour

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