

Scotland's Rural College

Trained-user opinion about Welfare Quality® measures and integrated scoring of dairy cattle welfare

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1 **Interpretive summary**

2 **Trained-user opinion about Welfare Quality® measures and integrated scoring of dairy**

3 **cattle welfare. By de Graaf et al.** Overall welfare assessments can be used for

4 communication with consumers (labelling), as incentive for welfare improvements and as

5 regulative target. Such assessments should be valid, reliable and balance the relative

6 importance of various welfare measures. The Welfare Quality® (WQ) approach is one of the

7 most well-known methods for overall welfare assessment. However, the present study shows

8 that the WQ integration method should be revised if it is to correspond with the opinions of

9 trained users of the WQ protocol for dairy cattle.

10 WELFARE QUALITY® VS. TRAINED-USER OPINION

11 **Trained-user opinion about Welfare Quality® measures and integrated scoring of dairy**

12 **cattle welfare**

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32 **ABSTRACT**

33 The Welfare Quality® (WQ) protocol for on-farm dairy cattle welfare assessment describes
34 27 measures and a step-wise method to integrate values for these measures into 12 criteria
35 scores, grouped further into four principle scores and finally into an overall welfare
36 categorization with four levels. We conducted an online survey to examine whether trained
37 users' opinions of the WQ protocol for dairy cattle correspond with the integrated scores
38 (criteria, principles and overall categorization) calculated according to the WQ protocol. First,
39 the trained users' scores (n = 8 - 15) for reliability, validity and their ranking of the
40 importance of all measures for herd welfare were compared to the degree of actual impact of
41 these measures on the WQ integrated scores. Logistic regression was applied to identify the
42 measures that affected the WQ overall welfare categorization into the 'not classified' or
43 'enhanced' categories for a database of 491 European herds. The smallest multivariate model
44 whilst maintaining the highest % of both sensitivity and specificity for the 'enhanced'
45 category contained six measures, the model for not-classified contained four measures. Some
46 of the measures that were ranked as least important by trained users (e.g. measures relating to
47 drinkers) had the highest influence on the WQ overall welfare categorization. Conversely,
48 measures rated as most important by the trained users (e.g. lameness and mortality) had a
49 lower impact on the WQ overall category. In addition, trained users were asked to allocate

50 'criterion' and 'overall' welfare scores to seven focal herds selected from the database (n =
51 491 herds). Data on all WQ measures for these focal herds relative to all other herds in the
52 database were provided. The degree to which expert scores corresponded to each other, the
53 systematic difference and the correspondence between median trained-user opinion and the
54 WQ criterion scores were then tested. The level of correspondence between expert scoring vs.
55 WQ scoring for 6 of the 12 criteria and for the overall welfare score was low. The WQ scores
56 of the protocol for dairy cattle thus lacked correspondence with trained users on the
57 importance of several welfare measures.

58 **Keywords:** animal welfare, welfare assessment, trained-user opinion, Welfare Quality[®]

59 INTRODUCTION

60 Assessing animal welfare is a highly complex task. Animal welfare is a multidimensional
61 concept, which calls for a multi-criteria assessment using a multitude of welfare-indicators
62 (Mason and Mendl 1993; Fraser et al., 1997). To express the overall welfare status of a group
63 of (farm) animals in one score or index, indicator data should be integrated which requires
64 interpretation and balancing. The lack of a 'gold standard' for animal welfare assessment (i.e.
65 there is no standardized and commonly agreed-on method for assessing the overall welfare
66 status of a group of farm animals) implies that some degree of subjectivity is inevitable when
67 weighting different measures (Spoolder et al., 2003). To be widely accepted, an overall
68 welfare index ought to correspond with society's concept of animal welfare and with the
69 opinion of experts, i.e. people who are seen by society to have adequate knowledge and
70 expertise about animal welfare. However, opinions on the concept of animal welfare may
71 differ between and even within experts and society. For example, producers tend to highlight
72 basic health and functioning of farm animals while non-producers tend to emphasize the need
73 for a natural living environment of farm animals (reviewed by Sørensen and Fraser, 2010). It

74 can be argued that for people without expertise in dairy cattle welfare and the specific welfare
75 measures involved, it is too difficult to adequately balance the importance of different welfare
76 measures. It has been shown that providing detailed information about on-farm collection
77 methods of welfare measures, significantly influences the relative weights they are given by
78 experts (Rodenburg et al., 2008). Therefore, the current study elicited experienced animal
79 scientists on the specific welfare measures involved only.

80 To date, the Welfare Quality[®] (WQ) protocols are most likely the most renowned and
81 comprehensive method for overall welfare assessment of different farm animal species
82 (chickens, pigs and cattle) (Welfare Quality, 2009). Unlike some other welfare assessment
83 protocols, WQ relies predominantly on animal-based measures. Resource-based and
84 management-based measures, in contrast, mostly reflect risk factors for welfare impairments
85 instead of directly measuring welfare (Blokhuis et al., 2003; 2010). The WQ protocols are
86 based on four main welfare principles ('good feeding', 'good housing', 'good health' and
87 'appropriate behavior') which are split into 12 independent welfare criteria (Table 1). Various
88 welfare measures (n = 27 for dairy cows) were selected by animal scientist to assess these
89 welfare criteria, based on validity, reliability and feasibility to perform on-farm. The WQ
90 protocol describes three steps to integrate these welfare measures into an overall final welfare
91 category. Methods of integration aim to be widely acceptable by society and are therefore
92 based upon expert opinion of social and animal scientists and stakeholders (Botreau et al.,
93 2007), depending on the integration step. For interpretation of measures into criteria scores,
94 animal scientists were consulted (n = 6) who were involved in the choice and development of
95 the WQ measures (Botreau et al., 2008). They were asked to score several situations which
96 could occur on-farm per criterion (e.g. for integument alterations within the criterion 'absence
97 of injuries', experts were asked to score 11 hypothetical farms with varying prevalence of
98 hairless patches, wounds and swellings). Calculation of criterion scores is based on expert

99 scoring. For aggregation from criteria to principle scores, social scientists were involved as
100 well, using a similar approach. For the final step, several scenarios for reference profiles were
101 developed to aggregate principle scores into an overall category. These scenarios were tested
102 for 69 European dairy farms (Austrian, German and Italian) to firstly compare their ability to
103 discriminate between farms. Secondly, stakeholders were consulted to assess which scenario
104 was most appropriate and thirdly, the degree to which each scenario matched with the general
105 impression of observers for 44/69 dairy farms was assessed. The four overall categories
106 ('excellent', 'enhanced', 'acceptable' or 'not classified' (Welfare Quality[®], 2009)) were
107 constructed to reflect both the multi-dimensional nature of welfare and the relative importance
108 of the various welfare measures using mathematical operators which limit the amount of
109 compensation which may occur between welfare measures, i.e. when a combination of
110 positive scores compensate for one negative score (Botreau et al., 2009).

111 Recent critical evaluations of the WQ integration methods indicate that in the dairy cattle
112 protocol a few resource-based measures appear to have a disproportionately large influence
113 on integrated scores (Heath et al., 2014; de Vries et al., 2014). For example, the measures for
114 the criterion 'absence of prolonged thirst' (i.e. number, adequate functioning and cleanliness
115 of drinkers) have a relatively large influence on integrated scores, although they are criticized
116 for their low or undocumented validity (Knierim and Winckler, 2009; de Vries et al., 2013; de
117 Jong et al., 2016; Tuytens et al., 2014). In contrast, some of the most pressing welfare
118 problems for dairy cattle as highlighted by epidemiological studies (de Boyer des Roches et
119 al, 2014; Main et al, 2003; Whay et al, 2003) and assessed by experts (i.e. mortality, lameness
120 and mastitis, Lievaart and Noordhuizen, 2011; Nielsen et al., 2014; Whay et al., 2003), had a
121 smaller influence on overall welfare categorization (de Vries et al., 2013; Heath et al., 2014;
122 Buijs et al., 2016) These findings point towards potential discrepancies between the welfare
123 assessment in dairy cattle of certain welfare experts and the WQ scores.

124 The WQ protocols were designed with the intention of modifying and updating assessment
125 methods according to advances in animal welfare science. Currently, a large group of
126 researchers has become familiar with the protocol and many farm visits have been performed
127 by these researchers (further referred to as ‘trained users’), allowing for a thorough evaluation
128 of the impact which measures have on overall welfare categorization. Therefore, analyzing
129 the correspondence between WQ integrated scores and the opinion of such trained users has
130 now become feasible. Hence, the objective of the current study was to analyze
131 correspondence between welfare assessment by trained users and the WQ scores (criterion
132 and overall welfare category). We performed this by examining whether measures which
133 impact WQ categorization most are also those which are deemed most important by trained
134 users.

135 MATERIALS AND METHODS

136 *WQ Protocol*

137 A brief description of the WQ protocol for on-farm dairy cattle welfare assessment is
138 presented below; the full protocol can be found at <http://www.welfarequalitynetwork.net/>. In
139 short, the protocol describes 27 on-farm welfare measures (Table 1) that are subsequently
140 integrated in a 3-step process to arrive at an overall welfare category. First, 27 welfare
141 measures of various scales are combined into scores for 12 welfare criteria on a scale of 0
142 (worst) – 100 (best) (Table 1), using various aggregation methods (for details see Welfare
143 Quality[®], 2009). Second, criteria are integrated into scores for four welfare principles using
144 Choquet integrals, algorithmic operators which ensure that a poor score cannot be fully
145 compensated by a better score in another criterion (Botreau et al., 2008). Principle scores can
146 range from 0 (worst) to 100 (best). The third and final integration step is an outranking
147 procedure from principle scores, arriving at an overall welfare category. Dairy welfare in a

148 herd is considered ‘excellent’ when that herd scores >50 for each principle and >75 on two of
149 them. When a herd scores >15 on each principle and >50 on at least two of them, it is
150 classified as ‘enhanced’. ‘Acceptable’ herds score >5 for all principles and >15 for at least
151 three principles. Herds that do not reach the thresholds for the category ‘acceptable’ are
152 considered ‘not classified’. These reference profiles for overall welfare categorization were
153 based on data from 69 herd assessments in the European Union (Botreau et al., 2009).

154 <Table 1>

155 *Collating WQ Data*

156 Datasets of assessments using the WQ protocol for on-farm dairy cattle welfare were collated
157 from seven European research institutes. Data from 10 countries (Macedonia, The
158 Netherlands, France, Belgium, Scotland, Denmark, Romania, Northern Ireland, Spain and
159 Austria) and 491 herds were used. The collected samples were selected to be representative
160 for 1) small scale dairy herds in Macedonia (n = 12); 2) non-organic and non-tie stall dairy
161 herds in The Netherlands (n = 60) and France (n = 128); 3) random herds with individual
162 Somatic Cell Count data available (SCC, to be able to calculate WQ scores) in Belgium (n =
163 140), Scotland (n = 16) and Denmark (n = 42); 4) typical herds for the regional low-input
164 herding systems in Romania, Northern Ireland and Spain (n = 30); and 5) loose housed dairy
165 herds with at least 20 cows in Austria (n = 65). Integrated WQ scores were calculated from
166 raw data using a custom-made integration procedure programmed in R 3.2.2 (R Foundation
167 for Statistical Computing, Vienna, Austria). The R integration program is available on
168 request. The resulting welfare scores were in agreement with the INRA WQFA webtool
169 (<http://www1.clermont.inra.fr/wq/>), in which WQ measure scores can be entered (for dairy
170 cows, fattening cattle, growing pigs and broilers), and WQ criteria, principle and
171 categorization scores are provided.

172 **Survey**

173 The survey was sent to 31 trained users, partially completed by 14 - 15 (depending on the
174 question) and totally completed by 8 trained users. The survey was sent to animal welfare
175 scientists which the co-authors knew to be experienced in the WQ assessment protocol for
176 dairy cow welfare. These trained users were in turn asked to provide contact details of any
177 additional animal welfare scientists which would be suitable (trained to use the WQ protocol).
178 All trained users who filled out the survey, were not involved in creating the survey. All
179 trained users had experience with the WQ protocol for dairy cattle (i.e. were trained to
180 perform the WQ protocol for dairy cattle and had performed on-farm WQ assessment of dairy
181 herds), were animal scientists and had authored at least 1 peer-reviewed scientific paper about
182 dairy cattle welfare involving the WQ protocol. Trained users were all European and a total
183 of 8 different nationalities was represented (British, Spanish, Macedonian, Dutch, Finnish,
184 Austrian, German and French). Trained users were surveyed on their judgement of the
185 reliability, validity and importance of all WQ measures. In questions based on data from the
186 WQ EU database, they were asked to score the farms for each WQ criteria and to assign an
187 overall welfare score.

188 ***Reliability, Validity and Ranking of all WQ Measures for Dairy Cattle.*** The trained
189 users were asked to indicate how acceptable they judged the reliability and validity of all
190 measures using a tagged visual analogue scale from 0 to 100. Tags were ‘not acceptable
191 (<25)’, ‘just acceptable (25 – 50)’, ‘acceptable (50 – 75)’, and ‘very acceptable (75 – 100)’.
192 ‘Reliability’ was defined in the survey as ‘a combination of inter-observer, intra-observer and
193 test-retest reliability’. ‘Validity’ was defined as ‘the measure measures what it is supposed to’.
194 Trained users were then asked to rank all WQ measures according to importance for the
195 overall welfare status of a herd of dairy cattle from 1 (most important) – 27 (least important).

196 It was mentioned that for ranking, (inter alia) reliability, validity, perceived relevance and
197 prevalence may be considered.

198 ***Expert scoring based on all WQ measurements.*** The trained users were then asked to
199 score overall welfare based on all measures from the WQ protocol. They were shown one
200 figure with box plots for all measures (part of the figure for one criterion: Figure 1). These
201 showed the same herds as in the first figure using the same colored triangles. Trained users
202 were asked to score overall welfare of 7 focal herds using a 0-100 tagged visual analogue
203 scale, with the tags ‘not classified’ (< 20), ‘acceptable’ (20 – 55), ‘enhanced’ (55- 80) and
204 ‘excellent’ (>80). For this purpose, we randomly selected five herds from the ‘acceptable’
205 welfare category and two herds from the ‘enhanced’ category out of the entire dataset. This
206 reflects the distribution of the dataset in which 1.8% of the herds were categorized as ‘not
207 classified’ (9 herds), 62.7% as ‘acceptable’ (308 herds), 35.4% as ‘enhanced’ (174 herds) and
208 none as ‘excellent’.

209 <Figure 1>

210 ***Comparing WQ Criteria Scores Using Trained-user Opinion.*** To assess the degree to
211 which integrated WQ criteria scores correspond to trained-user opinion, the trained users were
212 shown graphs of all measures per criterion separately, showing the distribution of all herds in
213 the database (example of one criterion: Figure 2, data shown in Table 2). The ‘focus herds’
214 were highlighted using triangles in different colors, and tables stated the data for each.
215 Trained users were asked to score the herds for all 11 criteria (excluding the criterion ‘thermal
216 comfort’, as this is not measured on-farm for dairy cattle) on a 0-100 tagged visual analogue
217 scale using the tags ‘not classified (< 20)’, ‘acceptable (20 – 55)’, ‘enhanced (55- 80)’ and
218 ‘excellent (>80)’.

219 <Figure 2>

220 ***Statistical analysis***

221 The statistical analysis was performed in R 3.2.2 (R Foundation for Statistical Computing,
222 Vienna, Austria). The analyzed data (except overall welfare categorization) were considered
223 to be sufficiently normally distributed, based on the graphical evaluation (histogram and QQ-
224 plot) of the residuals.

225 ***Reliability, Validity and Ranking of all WQ Measures for Dairy Cattle.*** To examine the
226 influence of median reliability and validity scores and their interaction on median ranking of
227 all measures, we used a linear mixed regression model with reliability and validity scores as
228 independent variables, and importance rank as dependent variable. A random effect for expert
229 was included in the model to account for the repeated measures.

230 ***Predicting Overall Welfare Categorization Using WQ Measures.*** To analyze which
231 measures affected the WQ overall categorization both into the lowest (not classified) and the
232 highest (enhanced, as no farms were categorized as excellent) categories, welfare categories
233 of the entire European dataset (n = 491) were divided into two binary variables (1=enhanced,
234 0=other for variable 1; and 1=not classified, 0=other for variable 2). Logistic regression was
235 used to identify measures that affected overall categorization both univariate and multivariate.
236 For the latter, a model was built using stepwise forward selection, retaining measures with a P
237 < 0.05 while maintaining the highest R2. Collinearity was checked for measures used within
238 the models. Model outcome was assessed by calculating specificity and sensitivity using the
239 following formulae:

$$\text{Specificity} = \frac{\text{TN}}{\text{TN} + \text{FP}} \quad \text{Sensitivity} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$

240 Where TN = true negatives, FP = false positives, TP = true positives and FN = false
241 negatives. Negatives were those farms categorized as ‘other’ and positives were those farms
242 categorized as either ‘enhanced’ for the first binary variable or ‘not classified’ for the second.

243 ***Comparing WQ Criteria Scores with Trained-user Opinion.*** To assess the systematic
244 difference between the median trained-user opinion score and the WQ criteria scores for each
245 focal herd (n = 7), a paired t-test was performed. To model the correspondence of median
246 scores allocated by the trained users and the WQ criteria scores, a linear model was fitted and
247 the coefficient of determination was calculated. Additionally, the intra-class correlation
248 coefficient (ICC) was calculated to assess the degree of coherence between individual trained-
249 user opinions.

250 **RESULTS**

251 ***Perceived Reliability, Validity and Ranking of WQ Measures***

252 Median validity and reliability scores for all measures were ‘acceptable’ to ‘very acceptable’
253 (i.e. median scores > 50, Table 3). Nevertheless, there was variation in median scores for the
254 various measures, ranging from 60 to 100 and from 50 to 90 for reliability and validity
255 respectively. Highest median ranking was attached to ‘lameness score’ (rank 2), ‘body
256 condition score’ (4), ‘mortality rate’ (7) and ‘integument alterations’ (7). ‘Lameness score’
257 and ‘integument alternations’ received the highest median validity scores (89 and 90,
258 respectively), along with ‘lying outside the lying area’ (89) and ‘tail docking method’ (88).
259 ‘Tied versus loose housing’ (100), measures of drinker space (‘Centimeters of trough per cow
260 (minimum 6 cm), number of water bowls per cow (minimum 0.10) and at least two drinkers
261 available for each cow’ (93) and ‘water flow’ (90) received the highest median reliability
262 scores. The measure ‘Qualitative Behavior Assessment’ (QBA) was given the worst median
263 importance rank (22), the lowest median reliability score (60), and was among the lowest
264 median validity scores (57). Measures of drinker space was given the lowest median validity
265 score (50). ‘Water flow’ was among the lowest ranking measures in terms of importance (20)
266 and among the lowest median validity scores (60) as well. Highest variation in reliability

267 scores between trained users (SD) was found for QBA (32), and lowest variation for ‘Body
268 condition score’(10). For validity scores, highest variation between trained users was found
269 for validity scores of ‘water flow’(28) and lowest for integument alterations (8). For ranking,
270 scores for ‘Tail docking method’, ‘Head butts and displacements’ and ‘Avoidance distance
271 test’ (9) were most variable and scores for ‘Mortality’ and ‘Integument alterations’ were least
272 variable (4).

273

274 <Table 3>

275

276 The importance rank of the measure was negatively associated with both the reliability and
277 validity scores, although validity had a somewhat higher estimate (i.e. higher importance as
278 indicated by a lower ranking was associated with higher reliability and validity scores) ($P =$
279 0.03 for both, estimates -0.66 and -0.74 , respectively, adjusted $R^2 = 0.20$). A very small but
280 significant interaction was found between reliability and validity scores, where they did not
281 strengthen each other’s negative effect on ranking ($P = 0.048$, estimate = -0.009).

282 ***Predicting Overall Welfare Categorization Using WQ Measures***

283 When analyzed univariately, 20 out of 41 measures significantly ($P < 0.05$) affected overall
284 welfare categorization into the ‘enhanced’ category (Table 4), and 11 measures significantly
285 affected categorization into the ‘not classified’ category for the entire European dataset ($n =$
286 491).

287 <Table 4>

288 The multivariable model that had the fewest variables whilst maintaining the highest % of
289 both sensitivity and specificity (67% and 85%, respectively) for the ‘enhanced’ category
290 contained the following measures (from most to least influence): ‘at least two drinkers/cow’,
291 ‘water flow’, ‘% of animals lying outside the lying area’, ‘mean time needed to lie down’

292 'drinker cleanliness', and '% of animals with at least one lesion/swelling' (Table 5). For not-
293 classified, the measures (from most to least influence) 'at least two drinkers/cow', 'number of
294 lean cows', 'QBA-index' and 'number of displacements/cow/h.' contributed to the model
295 with fewest variables but the highest sensitivity (44%) and specificity (100%).
296 <Table 5>

297 *Comparing WQ Overall Welfare Category and Criteria Scores with Trained-user Opinion*

298 For 2 of 5 'acceptable' herds and for 1 of 2 'enhanced' herds, the majority of trained users (n
299 = 8) scored in accordance with WQ (Figure 3). Regarding scores that were not in accordance
300 with WQ, the vast majority were a lower category than the WQ calculation (25 of 29 expert
301 scores). Overall, ICC for overall welfare scores by trained users was 0.5.

302 <Figure 3>

303 The criteria 'absence of injuries', 'absence of pain induced by management procedures',
304 'expression of social behavior' and 'good human-animal relationship' were systematically
305 scored lower by trained users than the WQ score (Table 6). The expert and WQ scores were
306 not significantly related for two criteria: 'absence of prolonged thirst' and 'absence of
307 prolonged hunger' (Table 6). The correspondence between trained users was insufficient (ICC
308 < 0.6) for two criteria, namely 'absence of injuries' and 'absence of disease'. The number of
309 measures within a criterion tended to be negatively related to ICC (P = 0.06, estimate = -
310 0.04).

311 <Table 6>

312 **DISCUSSION**

313 This study gives insight into the relation of integrated scores of the WQ dairy cattle protocol
314 with trained-user opinion. The specific research design imposes some limitations, but also
315 provides challenges for future research. For example, we chose to only select dairy cattle

316 welfare trained users who were trained users of the WQ dairy cattle protocol. This ensured
317 that trained users had a proper knowledge of the protocol and all measures, but limited the
318 number of possible respondents. The results show discrepancies between trained-user opinion
319 and WQ scores.

320 *Trained-user Opinion on Ranking, Reliability and Validity of Measures*

321 The measures that the trained users ranked highest in terms of perceived importance for the
322 overall welfare status of a herd (viz. ‘lameness score’, ‘body condition score’, ‘mortality rate’
323 and ‘integument alterations’) are in agreement with earlier studies in which dairy cattle
324 welfare trained users were asked to score the importance of welfare measures (Nielsen et al.,
325 2014; Lievaart and Noordhuizen, 2011; Whay et al., 2003). Reliability and validity scores
326 both influenced ranking positively (based on the negative relationship between reliability and
327 validity scores and ranking), but did not positively interact. This means that highest ranked
328 measures in the current study did not necessarily receive the highest validity *and* reliability
329 scores. In addition, although the set-up of this study was such that trained users had to
330 consider validity and reliability before ranking, other (unknown) factors appeared to influence
331 the trained users’ opinion on the importance of the various measures for overall herd welfare
332 as well (further supported by the models’ low R^2 of 0.20). This was the case for lameness, for
333 example, which was ranked highest for importance although its reliability was among the
334 lowest.

335

336 Overall, QBA was scored among the lowest by the trained users with regard to reliability and
337 validity (although still within the ‘acceptable’ range) and was ranked lowest on importance
338 for dairy cattle welfare status. The QBA is a method that uses descriptors such as ‘frustrated’
339 or ‘content’, to interpret the behavior and body language of an animal by integrating these
340 details of animal behavior into a qualitative judgment of overall welfare state (Wemelsfelder,

341 2001; Rousing and Wemelsfelder, 2006; Wemelsfelder, 2007). Inter-observer reliability was
342 tested and deemed acceptable for a QBA method using ‘free’ descriptors (i.e. not set but
343 determined by observers themselves) and was validated by correlating results to behavioral
344 observations (Rousing and Wemelsfelder, 2006; Napolitano et al., 2012). The fixed-term-
345 method and specific set of descriptors used in the WQ protocol were tested for inter-observer
346 reliability in a study by Bokkers et al., (2012) and judged as not satisfactory by the authors
347 involved (i.e. Kendall’s coefficient of concordance < 0.7), whereas Wemelsfelder et al. (2009)
348 reported satisfactory observer agreement in beef, dairy cattle and veal calves of those
349 descriptors. In addition, recently published papers demonstrated internal validity by testing
350 correlation between QBA and other behavioral and physiological measures (Coignard et al.,
351 2014; Phythian et al., 2016; Serrapica et al., 2017).

352

353 While some measures scored highest for reliability, they scored lowest for validity, e.g.
354 measures related to the criterion ‘absence of prolonged thirst’ (‘centimeters of trough per
355 cow’), or were ranked lowest on importance for dairy cattle welfare (‘water flow’). Criticism
356 expressed in earlier studies for these measures is related to their resource-based nature and the
357 impact these specific measures have on the WQ integrated scores, while preference generally
358 shall be given to animal-based measures (de Vries et al., 2013; Heath et al., 2014; Buijs et al.,
359 2016). Measuring functioning of water points, water provision and water cleanliness refers to
360 assessing a risk for cows being in a certain welfare state and may therefore in some cases not
361 be the most valid measure of an actual welfare state in dairy cattle, in this case due to
362 prolonged thirst. Additionally, to our knowledge, no actual validity testing of the WQ drinker
363 measures has occurred. This could explain the relatively low perceived validity score attached
364 by the trained users to these measures. Further testing of reliability and validity on certain
365 measures is needed, based on the results of the current study and previous research (Knierim

366 and Winckler, 2009). If from such studies it appears that measures are not sufficiently reliable
367 or valid, then research should be performed to propose improved measures.

368

369 The trained users did not always agree on the relative importance for the overall welfare status
370 of dairy herds of different welfare measures (given the high variations in ranking and
371 reliability and validity scores between trained users). This possibly reflects diverging views in
372 what trained users find most important for dairy cattle welfare, as Fraser et al., (1997) showed
373 in his study on animal welfare conceptualization among animal welfare scientists. This
374 indicates that when using trained-user opinion to determine weights for various measures,
375 such variation should be accounted for when selecting the expert panel. Therefore, it is not
376 likely that an overall welfare score will always perfectly reflect an individual trained users'
377 opinion. Methods to achieve more consensus among trained users exist. Examples are
378 deliberative processes using a workshop like performed by Rodenburg et al. (2008), or more
379 complex processes like a 'Delphi' method with multiple rounds of expert elicitation and
380 feedback (Linstone and Turoff, 1975).

381

382 *Comparison of the measures' impact on overall welfare categorization and trained-user* 383 *opinion*

384 Compared to previous studies (Heath et al., 2014; Buijs et al., 2016), more measures affected
385 both the 'enhanced' and the 'not classified' categorization in the current study. This is likely
386 due to a larger variation in data in the current study which used a much larger (and diverse, as
387 data was collected in more than one country) database compared to both other studies. To
388 specify, the current sample comprised of 491 herds, as opposed to 92 herds and 22 flocks for
389 Heath et al., (2014) and Buijs et al., (2016) respectively. In accordance with Heath et al.
390 (2014) drinker measures had the biggest influence for both the enhanced and not classified

391 models, while in the current study these received some of the lowest ranks and/or validity
392 scores by the trained users. Additionally, the QBA score which scored lowest overall was
393 among the best predictors for the ‘not classified’ categorization. By contrast, although there is
394 often little agreement among trained users on importance of various welfare measures, some
395 measures which are regarded as highly important to cattle welfare by certain welfare trained
396 users, did not have a great influence on the overall welfare status categorization. For example,
397 although ‘lameness score’ and ‘mortality rate’ contributed to the ‘enhanced’ categorization in
398 univariate models, they did not when combined into a multivariable model. These results
399 show that the relative influence of measures on WQ integrated scores may not be in
400 accordance with the trained users’ opinion of this study. We tested this by comparing expert
401 scoring of WQ criteria and overall welfare with calculated WQ scores.

402 ***Comparing WQ Integrated Scores with Trained-user Opinion***

403 ***Overall welfare category.*** For only three out of the seven herds, the majority of trained
404 users scored in accordance with the WQ overall welfare categorization. The two herds that
405 were scored as ‘not classified’ by at least half of the trained users (Herds 3 and 7) both scored
406 badly (i.e. relatively high prevalence) on measures that were ranked as highly important by
407 the trained users, namely lesions/swellings and moderately lame cows.

408 Variation between trained users was shown for the overall welfare scoring, given the
409 relatively low ICCs. This was also shown for criteria scores, where ICCs tended to be lower
410 for criteria which contain the most measures. This can indicate that 1) trained users did not
411 agree on their assessment of overall welfare caused by a different view of animal welfare (as
412 mentioned above) and/or 2) some trained users may have had difficulties in aggregating many
413 welfare measures into one overall score. The latter explanation is supported by that fact that
414 six of the 14 trained users who completed the questions on criterion scores, did not complete
415 the question on overall welfare scores.

416 *Criteria scores.* The criteria ‘absence of injuries’, ‘absence of pain induced by
417 management procedures’, ‘expression of social behavior’ and ‘good human-animal
418 relationship’ were systematically scored lower by trained users than the WQ integrated scores.
419 In the WQ protocol, poor scores have more influence on integrated scores than good scores
420 (Buijs et al., 2016). Therefore, lower scores on each of these criteria would have a major
421 effect on principle scores and overall welfare category.

422 The correspondence between the expert and WQ score for the criterion ‘absence of
423 prolonged thirst’ was extremely low. The finding that the trained users considered some of
424 these measures of relatively poor validity may partly explain this lack of correspondence. It is
425 a strong indication that trained users of the present study did not agree with the way that the
426 criterion score for ‘absence of prolonged thirst’ is calculated in the WQ protocol.

427 Four complementary explanations can be put forward for the poor correspondence
428 between trained users’ scores and WQ integrated scores. First, except for the first step of the
429 integration procedure, WQ consulted a much wider group of stakeholders (including animal
430 scientists, social scientists, producers and retailers.) than we did in the current study. These
431 stakeholders’ views on the relative impact of the various measures on dairy cattle welfare may
432 differ substantially from those of the trained users in the current study. We opted to limit the
433 current study to trained users only, because it could be argued that they are best qualified to
434 assess overall dairy cattle welfare state and the relative importance of the various WQ
435 measures.

436 Second, as the protocol was not yet published when stakeholder opinion was elicited
437 during the WQ project, they could not have gained as much experience in performing the
438 various WQ measures as the trained users in this study. It has previously been shown, that
439 detailed information on welfare measures (e.g. practical implications) can significantly

440 influence relative weight attributed by trained users to these welfare measures (Rodenburg et
441 al., 2008).

442 Third, there was considerable variation between trained users in the present study
443 regarding importance ranking, although there is no information readily available on the degree
444 of variation between the original WQ trained users. The variation in prioritizing certain
445 aspects of welfare in the current group of trained users could arise from different concepts of
446 animal welfare, like Fraser et al., (2008) described as ‘basic health and functioning’, ‘natural
447 living’, and ‘affective states’.

448 Fourth, WQ integration methods likely contribute to differences between trained-user
449 opinion and WQ integrated scores. De Graaf et al., (2016) identified two factors which
450 influence the impact a measure has on the integrated WQ scores, but which seem unintended
451 by the WQ consortium. Namely, 1) the number of integrated measures per criterion or
452 principle, and 2) the various aggregation methods of measures into criteria scores which
453 influence the impact individual measures have on integrated scores. In the present study a low
454 level of correspondence between welfare measures which impact WQ categorization most and
455 which were scored as most important by trained users was found. Also, poor correspondence
456 between trained-user opinion and some criterion scores indicated that this lack of
457 correspondence already starts in the first step of integration.

458 These findings indicate a lack of correspondence between WQ-welfare scores and
459 trained users’ assessment of herd welfare. The opinion of these trained users is the only ‘silver
460 standard’ we have to validate animal welfare integrated scores, since they are arguably best
461 equipped to assess and quantify the welfare of a given herd. Moreover, these trained users
462 may be considered authorities for animal welfare assessment in society, and it is important
463 that scientists who use this method support it. Future research could focus on determining
464 whether the way trained users assess welfare is in correspondence with other stakeholders’

465 assessment. Improvements for WQ may be derived from the observed discrepancies between
466 WQ overall welfare assessment and that of the trained users. In some cases, the trained users
467 scored lower than WQ and in other cases (water provision) they were less stringent. Because
468 WQ allocates more weight to low scores this is likely to have a significant impact on the
469 overall assessment. For example, higher criterion-scores for absence of thirst (following our
470 trained users' opinion) would reduce the impact of this criterion on the overall assessment. On
471 the contrary, lameness should be given more impact since our trained users ranked this as
472 highly important.

473 **CONCLUSION**

474 Trained-user opinion on the most and least important measures for the overall welfare status
475 of a herd did not correspond well with the influence of these measures on the WQ overall
476 welfare categorization. Some of the measures that were ranked as least important for herd
477 welfare by trained users (e.g. measures relating to drinkers) had the highest influence on the
478 WQ overall welfare categorization. On the contrary, measures ranked as most important by
479 the trained users (e.g. lameness and mortality) had a lower impact on the WQ overall
480 category. In addition, results indicate poor correspondence between trained users' scoring and
481 6 of 11 WQ-criteria and the overall welfare category. In both cases, trained users mostly
482 allocated more negative scores, indicating a lower level of welfare. The WQ scores of the
483 protocol for dairy cattle thus lacked correspondence with selected trained users on the
484 importance of several welfare measures.

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488

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619 *Table 1: Principles, the corresponding criteria and measures used in the Welfare Quality®*

620 *assessment protocol for dairy cows*

Principles	Criteria	Measures
Good feeding	Absence of prolonged hunger	Body Condition Score (% very lean animals)
	Absence of prolonged thirst	Availability & cleanliness water
Good housing	Comfort around resting	Lying down duration; collisions during lying down; on edge/outside of lying area; cleanliness
	Thermal comfort	No measure for dairy cattle
	Ease of movement	Free stalls or presence of tethering and exercise
Good health	Absence of injuries	Lameness; integument alterations
	Absence of disease	Respiration/digestive diseases; mastitis; mortality; dystocia, downer cows
	Absence of pain induced by management procedures	Mutilations (dehorning; tail docking; use of anesthetics/analgesics)
Appropriate behavior	Expression of social behavior	Incidence agonistic interactions
	Expression of other behaviors	Access to pasture
	Good human-animal relationship	Avoidance distance at feeding place
	Positive emotional state	Qualitative Behavioral Assessment

621

622 *Table 2: Measure values of each of the seven herds presented to trained users in the survey*

Criteria, measures	Herd #	1	2	3	4	5	6	7
Absence of prolonged hunger								
% of lean cows		0	3	17	5	11	3	24
Absence of prolonged thirst								
Number of water bowls/cow		0.5	0.0	0.0	0.0	0.0	0.6	0.05
Trough length/cow (cm)		0.0	7.9	4.7	28.6	9.0	0.0	0.0
Drinker cleanliness		Yes	Yes	No	Yes	Yes	Yes	Yes
At least 2 drinkers/cow		No	Yes	No	No	Yes	No	Yes
Resting comfort								
Mean time needed to lie down (s)		4.6	4.6	7.5	4.1	6.6	5.4	6.8
% of cows colliding with housing equipment		16	15	72	0	37	8	33
% of cows lying outside of lying area		50	11	0	0	0	35	0
% of cows with dirty flanks		34	55	81	14	67	79	70
% of cows with dirty lower legs		57	37	85	38	20	79	100
% cows with a dirty udder		18	21	77	10	42	48	95
Ease of movement								
Loose (L) or tied (T) housing		T	L	L	L	L	T	L
Absence of injuries								
% of moderately lame cows		0	13	88	0	23	0	84
% of severely lame cows		32	0	12	10	17	27	5
% of cows with at least one lesion		7	12	72	28	13	20	68
% of cows with no lesions but at least one hairless patch		98	18	28	38	21	100	32
Absence of disease								
Number of coughs/cow/minute		0.05	0.00	0.13	0.10	0.06	0.17	0.00
% cows with nasal discharge		59	0	0	0	5	18	0
% cows with ocular discharge		0	0	0	0	0	0	0
% cows with hampered respiration		0	0	0	5	0	0	0
% cows with diarrhea		5	0	0	0	0	0	16
% cows with vulvar discharge		0	0	0	0	0	0	3
% cows with SCC ¹ > 400.000		8	21	25	0	14	8	12
% cows mortality		5	3	4	0	4	3	4
% calvings with dystocia		0	21	0	0	1	6	3
% downer cows		0	6	0	0	0	6	5
Absence of pain induced by management procedures								
Dehorning method, Thermal (T), Caustic paste (P) or None (N)		T	P	P	N	P	P	T
Use of Analgesics		No	Yes	Yes	No	Yes	No	No
Use of Anesthetics		No	Yes	Yes	No	Yes	No	Yes
Expression of social behavior								
Number of Head butts/cow/15 min.		0.8	4.0	0.7	0.0	0.4	0.4	1.0
Number of Displacements/cow/15 min.		0	1.2	0.1	0.0	0.2	0.0	0.8

	min.						
	Expression of other normal behavior						
	Number of hours on pasture	214	180	0	0	0	214 195
	Number of days on pasture	19	9	0	0	0	8 9
	Human-animal relationship						
	% of cows that could be touched	36	55	59	100	55	44 30
	% closer than 50 cm but not touched	11	36	37	0	26	2 35
	% between 50 and 1 m	23	9	9	0	11	14 24
	% > 1 m	30	0	0	0	9	41 11
	Positive emotional state						
	QBA ² score	43	40	8	91	77	66 54

623 ¹Somatic Cell Count

624 ²Qualitative Behaviour Assessment

625 *Table 3: Median (interquartile range) reliability and validity scores and rankings for each WQ*
 626 *measure by trained users*

	Reliability score (n = 15)	Validity score (n = 15)	Ranking (n = 13)
Body condition score	89 (11)	79 (35)	4 (8)
Centimeters of trough per cow (minimum 6 cm), number of water bowls per cow (minimum 0.10) and at least two drinkers available for each cow	93 (15)	50 (34)	13 (6)
Water cleanliness, judged visually	80 (28)	70 (36)	19 (9)
Water flow	90 (33)	60 (40)	20 (15)
Time needed to lie down	75 (38)	78 (21)	9 (7)
Cows colliding with housing	70 (39)	82 (28)	16 (10)
Cows lying outside of lying area	85 (33)	89 (28)	16 (10)
Cleanliness of udders, flanks and lower legs	75 (12)	81 (24)	15 (5)
Tied versus loose housing	100 (6)	84 (28)	11 (13)
Lameness score	69 (36)	89 (11)	2 (2)
Integument alterations	75 (15)	90 (14)	7 (4)
Coughing	69 (44)	75 (35)	19 (13)
Nasal discharge	84 (35)	80 (11)	18 (8)
Ocular discharge	85 (31)	80 (12)	18 (11)
Hampered respiration	88 (36)	86 (12)	21 (12)
Diarrhea	75 (21)	70 (22)	15 (8)
Vulvar discharge	77 (39)	86 (14)	18 (8)
Somatic cell count >400.000	83 (19)	81 (11)	13 (14)
Mortality	79 (47)	81 (16)	7 (6)
Dystocia	79 (37)	80 (17)	13 (10)
Downer cows	79 (47)	81 (16)	15 (14)
Dehorning method	90 (26)	86 (16)	11 (10)
Tail docking method	95 (16)	88 (17)	17 (18)
Head butts and displacements	70 (26)	75 (17)	14 (16)
Access to pasture (number of hours and number of days on pasture)	90 (18)	75 (33)	19 (8)
Avoidance distance test	66 (24)	76 (28)	17 (15)
Qualitative Behavior Assessment	60 (37)	57 (20)	22 (11)

627

628

629 *Table 4: P-values of the univariate logistic regression models examining predictability of*
630 *single measures for a herd to be categorized as 'Enhanced' or 'Not classified' based on the*
631 *collated European dataset (n = 491)*

Criteria, Measures	Enhanced	Not classified
Absence of prolonged hunger		
% of lean cows	<0.001	<0.001
Absence of prolonged thirst		
Number of water bowls	0.070	0.863
Water flow	<0.001	0.505
Trough length/cow (cm)	0.001	0.008
At least 2 drinkers/cow	<0.001	0.006
Drinker cleanliness	<0.001	0.068
Resting comfort		
Mean time needed to lie down	<0.001	0.577
% of cows colliding with housing	<0.001	0.365
% of cows lying outside of lying area	<0.001	0.014
% of cows with dirty flanks	0.101	0.172
% of cows with dirty lower legs	0.023	0.110
% cows with a dirty udder	0.374	0.258
Ease of movement		
Loose or tied housing	<0.001	0.016
Absence of injuries		
% of moderately lame cows	0.002	0.392
% of severely lame cows	<0.001	0.096
% of cows with at least one lesion/swelling	<0.001	0.014
% of cows with at least one hairless patch	0.141	0.075
Absence of disease		
Number of coughs/cow/minute	0.168	0.350
% cows with nasal discharge	0.092	0.165
% cows with ocular discharge	0.044	0.426
% cows with hampered respiration	0.293	0.385
% cows with diarrhea	0.386	0.546

% cows with vulvar discharge	0.588	0.936
% cows with SCC >400.000	0.130	0.014
% cows mortality	<0.001	0.189
% calvings with dystocia	0.619	0.841
% downer cows	0.742	0.423
Absence of pain induced by management procedures		
Method dehorning	0.130	0.021
Use of analgesics during/after dehorning	0.618	0.540
Use of anesthesia during dehorning	0.759	0.110
Method tail docking	0.150	0.974
Use of analgesics during/after tail docking	0.011	0.008
Use of anesthesia during tail docking	0.025	0.010
Expression of social behavior		
Head butts/cow/15 min.	0.033	0.759
Displacements/cow/15 min.	0.615	0.159
Expression of other normal behavior		
Number of hours on pasture	0.467	0.153
Number of days on pasture	0.810	0.454
Human-animal relationship		
% of cows that could be touched	0.711	0.188
% of cows that can be approached < 50 cm but not touched	0.012	0.379
% of cows that can be approached by 50 – 1 m	0.253	0.924
% of cows that can't be approached (> 1 m)	0.011	0.547
Positive emotional state		
QBA index score	0.079	<0.001

633 *Table 5: P-values and model estimates of measures in the multivariate logistic regression*
 634 *models predicting a herd to be categorized as 'Enhanced' or 'Not classified' based on the*
 635 *collated European dataset (n = 491)*

Outcome variables	Enhanced model		Not classified model	
	Estimate	P-value	Estimate	P-value
Number of lean cows	-	-	1.8	<0.001
Water flow	1.1	<0.001	-	-
At least 2 drinkers/cow	2.4	<0.001	-3.7	0.007
Drinker cleanliness	0.6	<0.001	-	-
Mean time needed to lie down	-0.7	<0.001	-	-
% of cows lying outside of lying area	-0.9	<0.001	-	-
% of cows with at least one lesion/swelling	-0.5	<0.001	-	-
Number of displacements/cow/h.	-	-	0.7	0.043
QBA index score	-	-	-1.6	0.002

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637 *Table 6: Systematic t-test P-value, Linear Regression R² and ICC of WQ integrated scores and trained*
 638 *user median scores (n =14) for the focus herds (n = 7) for each WQ criterion*

Criteria	Median (IR) ¹ WQ score	Median (IR) ¹ expert score	Systematic t- test P-value	Regression R ²	ICC
Absence of prolonged hunger	67 (39)	50 (75)	0.475	0.237	0.6
Absence of prolonged thirst	20 (97)	50 (71)	0.737	0.007	0.7
Comfort around resting	27 (20)	25 (33)	0.181	0.880**	0.8
Freedom of movement	100 (33)	90 (90)	0.125	1.000***	1.0
Absence of injuries	28 (19)	18 (29)	0.006	0.926***	0.5
Absence of disease	40 (32)	42 (34)	0.296	0.903**	0.4
Absence of pain induced by management procedures	58 (18)	10 (50)	0.023	0.521*	0.8
Expression of social behavior	84 (24)	58 (50)	0.020	0.869**	0.6
Expression of other normal behavior	73 (78)	60 (78)	0.828	0.978***	0.9
Good human-animal relationship	54 (37)	52 (50)	0.023	0.984***	0.7
Positive emotional state	54 (32)	50 (37)	0.901	0.997***	0.8

639 ¹IR = Interquartile Range

640 *P < 0.05

641 **P < 0.01

642 ***P < 0.001

643 **Figures**

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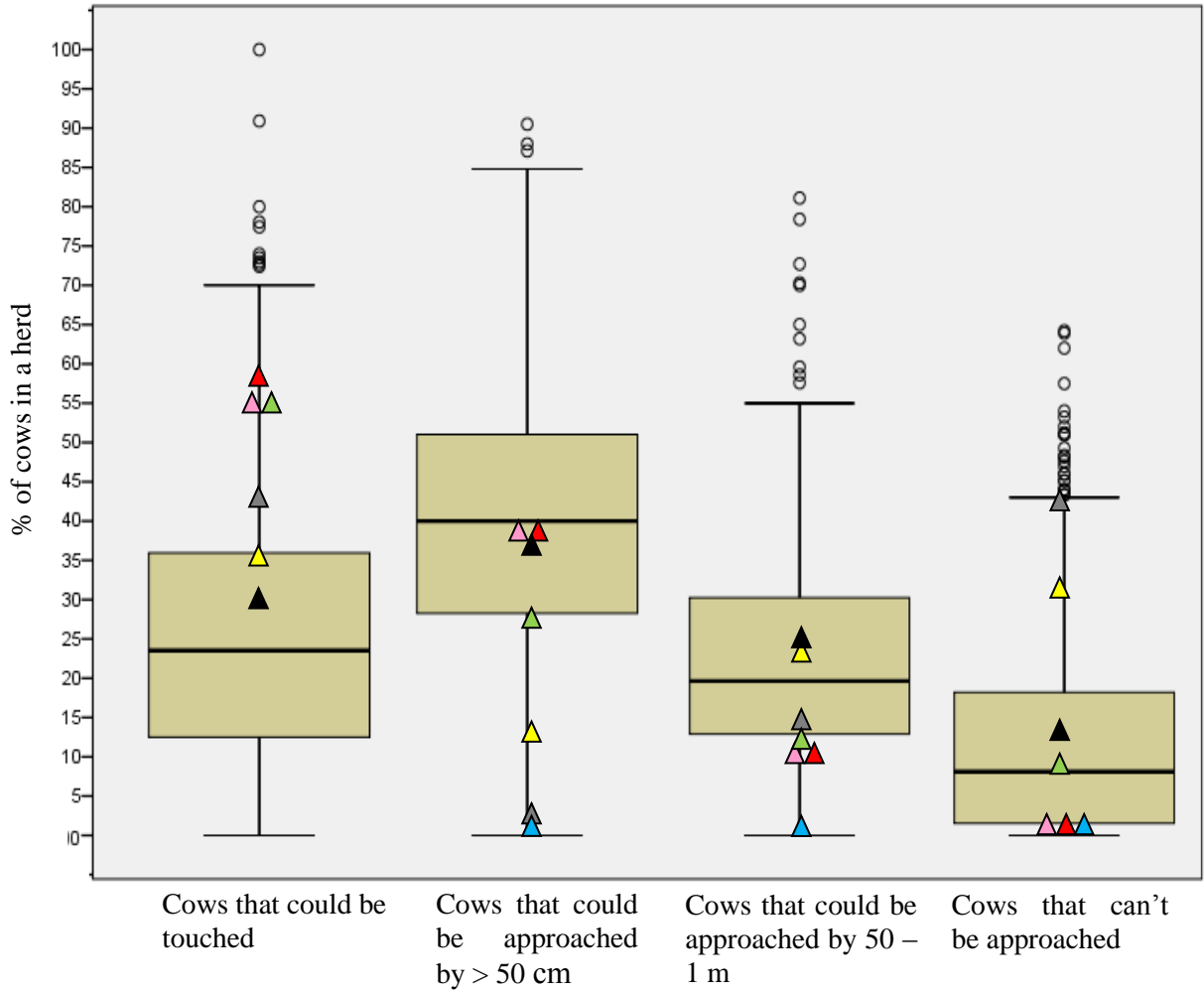
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662 de Graaf, Figure 1

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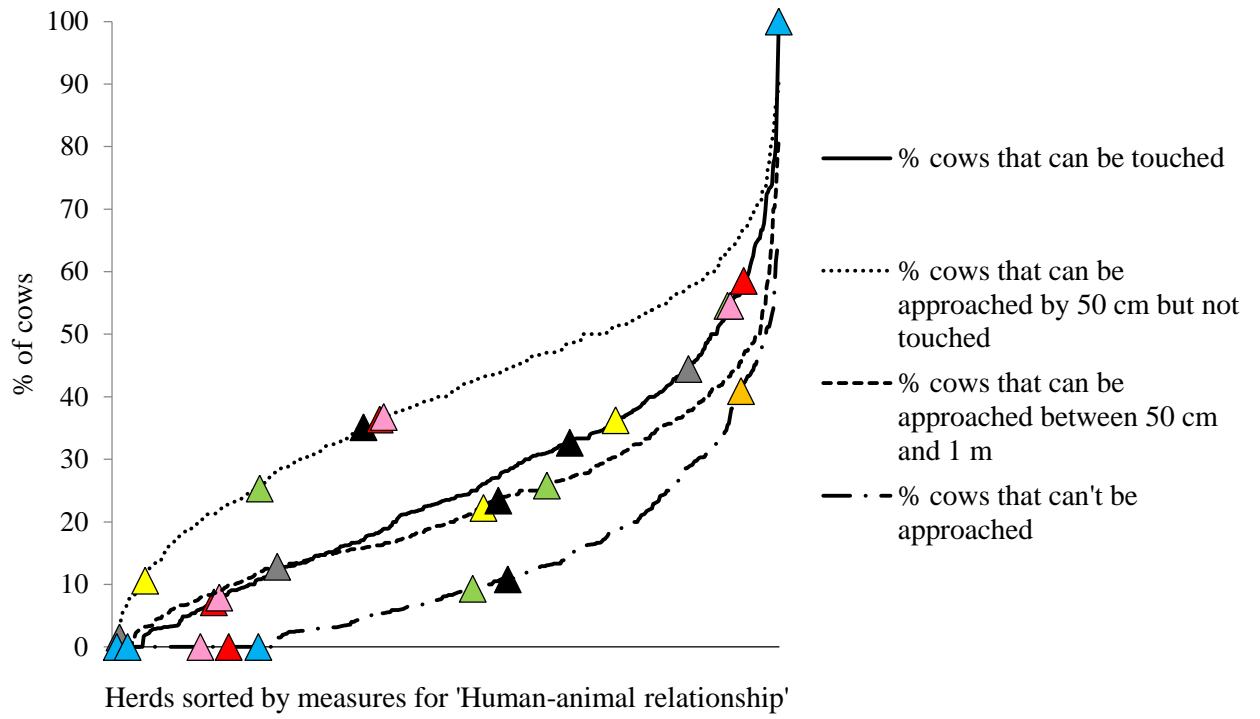
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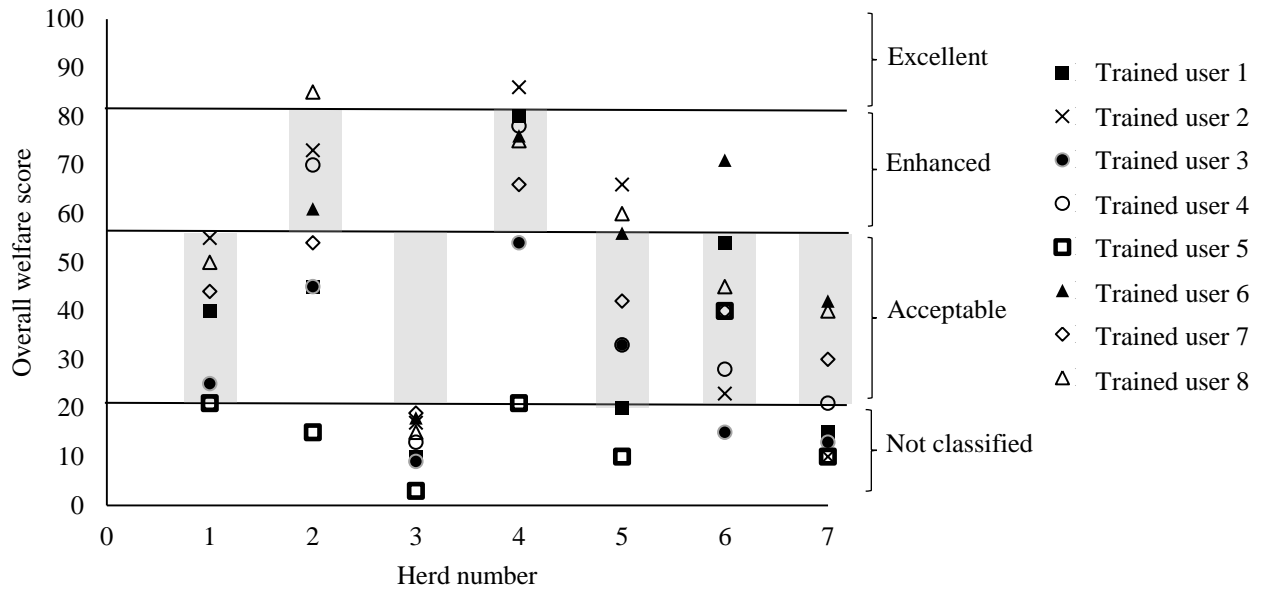
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674 de Graaf , Figure 2



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676 de Graaf, Figure 3

677 **Figure captions**

678 **Figure 1** Example boxplot figure from the survey among trained users, portraying the
679 distribution of all herds in the database (n = 491) for the measures of the ADF, within the
680 criterion 'Human-animal relationship'. Colored triangles mark the seven focus herds.

681

682 **Figure 2** Example figure from the survey among trained users, portraying the distribution of
683 all herds in the database (n = 491) for the measures of the Avoidance Distance at the the Feed
684 rack test (ADF), within the criterion 'Human-animal relationship'. Colored triangles mark the
685 seven focus herds.

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687 **Figure 3** Overall welfare score for all seven focus herds by eight trained users, grey boxes
688 indicate WQ overall welfare category

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