Research in Veterinary Science 142 (2022) 31–42

Contents lists available at ScienceDirect

Research in Veterinary Science

journal homepage: www.elsevier.com/locate/rvsc

Attitudes and personality of farm managers and association with cow culling rates and longevity in large-scale commercial dairy farms

Triin Rilanto [a,*], Dagni-Alice Viidu [a], Tanel Kaart [a], Toomas Orro [a], Arvo Viltrop [a], Ulf Emanuelson [b], Eamonn Ferguson [c], Kerli Mõtus [a]

[a] Institute of Veterinary Medicine and Animal Sciences, Estonian University of Life Sciences, Estonia
[b] Department of Clinical Sciences, Swedish University of Agricultural Sciences, Sweden
[c] School of Psychology, University of Nottingham, United Kingdom

ARTICLE INFO

Keywords:
Dairy cows
Culling
Farm manager
Personality
Productive lifetime

ABSTRACT

The farmer has the central role in determining cow culling policies on their farm and thus affecting cow longevity. The present study aimed to examine farm managers' satisfaction, attitudes, personality traits and analyse the associations with dairy cow culling and longevity in large commercial dairy farms.

Farm managers of 116 dairy herds rearing at least 100 cows in freestall barns were included. A questionnaire for the farm managers registered personal background information of respondent and included statements capturing their satisfaction, opinions and attitudes regarding dairy cow culling and longevity, farming in general, and a Ten Item Personality Inventory scoring. For each herd, the last 12 months cow culling rate (CR, excluding dairy sale) and herd mean age of culled cows (MAofCC) was obtained from the Estonian Livestock Performance Recording Ltd. A K-mean clustering algorithm was applied to subgroup farm managers based on their attitudes, opinions and personality traits.

The yearly mean herd CR was 33.0% and MAofCC was 60.6 months. Farm managers' were mostly dissatisfied with cow longevity and culling rates in their farms. Dissatisfaction with culling rates and longevity, priority for producing high milk yields over longevity and production-oriented attitude was associated with high culling rates and poor longevity. Farm managers' personality had an effect on herd culling rates and their attitudes explained one third of the variability of culling rates and longevity.

Explaining the economic consequences of high culling rates and decreased longevity, improving the visibility of these parameters together with benchmarking could bring these issues into focus.

1. Introduction

Longevity generally represents the period from birth to culling (Schuster et al., 2020). Nowadays, the average longevity of dairy cows in modern commercial conditions ranges from 4.5 to 6 years (Dallago et al., 2021; De Vries, 2017; Knaus, 2009; Rushen and de Passillé, 2013), which is far below their biological capacity of roughly 20 years (De Vries and Marcondes, 2020). Longevity of a dairy cow is determined by culling which is a departure of cows from the herd because of sale, slaughter, salvage, or death (Fetrow et al., 2006). In cases of low culling rates cow longevity is usually high (De Vries, 2017). Cow culling is the result of a combination of different factors such as cow health, milk yield, and reproductive efficiency but is also influenced by the availability of replacement heifers, market conditions, and also the desire to improve herd genetic merit (De Vries, 2017). Culling is a major cost for dairy farms but is also an essential part in managing herd productivity. According to Boulton et al. (2017) the cost of heifer rearing was repaid in the first two lactations, i.e. about 3.6 years, whereas for the profitability, dairy cows should produce at least four lactations (Knaus, 2009). As mature cows have higher milk yields compared to young cows (ELPR, 2019) higher longevity is related to a higher proportion of higher-yielding cows in the herd, therefore lower culling rates are generally economically more favourable (Groenendaal et al., 2004).

Culling reasons have changed over the last decades, shifting more towards disease-related reasons while less cows are culled voluntarily based on farmers' decision (Compton et al., 2017; Dallago et al., 2021; Rushen and de Passillé, 2013). Due to incorporating different parameters into the models, previous studies have revealed variable optimum

* Corresponding author.
E-mail address: Triin.Rilanto@emu.ee (T. Rilanto).

https://doi.org/10.1016/j.rvsc.2021.11.006
Received 12 August 2021; Received in revised form 11 November 2021; Accepted 16 November 2021
Available online 24 November 2021

culling rates for dairy herds ranging 25–28% with the lowest possible being 20% (Allaire, 1981; De Vries, 2017; Rogers et al., 1988a; Van Arendonk, 1985). However a high rate of involuntary culling is economically most costly to the farm (Orpin and Esslemont, 2010; Rogers et al., 1988b). Culling rates of dairy herds have not increased during the last decades (Compton et al., 2017), however, cow longevity has constantly declined worldwide entailing economic consequences and environmental impacts on the sector but also indicating deteriorating health and welfare of cows and increasing social concerns (Broom, 1991; Clark et al., 2016; Dallago et al., 2021; Hare et al., 2006; Hristov et al., 2013; Rushen and de Passillé, 2013; Schuster et al., 2020). Although longevity of dairy cows contributes to sustainability of dairy production (Bergeå et al., 2016) there is a lack of current studies that determine the economically optimal productive lifespan of dairy cows (De Vries and Marcondes, 2020). There is also high variation on what dairy farmers think as optimum or targeted longevity both in terms of how longevity is expressed and regarding what they think of as possible to achieve (Bergeå et al., 2016).

The majority of research to date has focused on reasons and risk factors for culling and longevity. The identified risk factors mostly belong to the groups of animal factors (e.g. milk yield or occurrence of diseases and success of reproduction), as well as farm housing conditions, feeding and management factors (Chiumia et al., 2013; Haine et al., 2017; Rilanto et al., 2020; Weigel et al., 2003). The genetic trend of productive life is increasing, however simultaneously with improving knowledge and improvements in genetics, cow longevity shows a decreasing trend (De Vries, 2017; Van Pelt et al., 2016). This may occur due to low prioritization of longevity, insufficient communication of these limiting factors to farmers' community or due to factors arising from the farmers' desire or ability to implement necessary changes. Although replacement policies have an important influence on the economic performance of the dairy herd, the culling decisions often include subjectivity, intuition, and individual thresholds of the decision maker (Bergeå et al., 2016; Lehenbauer and Oltjen, 1998). While human decision-making is a complex process the personal demographic characteristics, previous experiences, values, priorities, attitudes and personality-related factors in addition to economic, cultural and family influences have an essential roles in their actions (Adler et al., 2019; Lai et al., 2019; Ritter et al., 2017). The effect of farmers' intrinsic factors, such as attitudes and personality on farming outcomes could arise from the direct human-animal relationship and this concept has often been used to explain the effects of humans on animals. Also, the indirect effect of human influences on animals might occur through management decisions determining the conditions for animals (Adler et al., 2019). Farm management is a series of complex processes, which require decision-making while taking into account many economic and social factors. According to Breuer et al. (2000) consecutive relationships exist between the attitude and behaviour of the stockperson and the latter influencing productivity of commercial dairy cows. While we cannot deny the importance of biological factors, it is possible that in order to improve the longevity of dairy cows, the problem needs to be addressed by analyzing and influencing farmer's decisions and justifications (Bergeå et al., 2016). Several studies have concluded the present association between farmers' attitudes and cattle health such as udder health and mastitis (DeLong et al., 2017; Jansen et al., 2009; Schewe et al., 2015; van den Borne et al., 2014), but also calf mortality (Santman-Berends et al., 2014), welfare parameters and milk production (Fukasawa et al., 2017; Hanna et al., 2009; Kielland et al., 2010). Limited information can be found in the literature on factors associated with farmers' personality and attitudes influencing dairy cow culling and longevity, especially in large commercial farms; however, a better understanding on how the mind-set and personality of dairy farm managers affecting culling and longevity would aid in providing tailored advice and support strategies (Adler et al., 2019).

Estonian dairy cow population includes about 85,000 cows and around 87% of the dairy cow population were reared in large herds with more than 100 cows in year 2019 (ELPR, 2019). The average milk yield of Estonian dairy cows was 10,114 kg in 2019 (ELPR, 2019), taking second place in the EU (Eurostat, 2019). According to the recent study of Rilanto et al. (2020) cows were mostly culled due to "feet/claw disorders", "udder disorders", "metabolic and digestive disorders", and "fertility problems" in Estonian dairy herds suggesting that majority of the culls occur due to health issues or infertility. The majority of the large Estonian dairy farms are loose-housed open-air barns using modern equipment and technology and are managed by hired labour. Large-scale dairy farms are mostly owned by shareholders and are managed daily by farm managers who is usually not a farm owner. A conceptual distinction of the farm managers of large commercial dairy herds from traditional farmers with the ownership status of mostly small-scale farms is present. Due to farm managers' lower involvement in direct activities with animals compared to the traditional farmer, the effect towards animals is probably more influenced by their decisions on farming guided from the farm goals. Similarly to prevailing global trend, the average productive lifetime of culled cows has decreased also in Estonia. The mean age of culled cows shortened from 1113 to 1057 days between years 2013 and 2019, respectively (ELPR, 2016, 2019). Estonian dairy herds represent a model of modern extensive high-yielding commercial farms managed as business enterprises. Due to the above-mentioned characteristics and intensification of the global dairy industry (Barkema et al., 2015), studies conducted in Estonian dairy population could offer wider interest and importance. The present study aimed to explore farm managers' satisfaction, attitudes, and opinions on dairy cow culling and longevity and to analyse the associations between farm managers' attitudes and personality traits and cow culling and longevity in large commercial dairy farms.

2. Materials and methods

2.1. Questionnaire

In order to collect information about farm managers' describing their satisfaction, opinions and attitudes about dairy cow culling and longevity, and farming in general, as well as personality characteristics, a questionnaire was developed by the authors in spring 2019. The theoretical considerations for developing the questionnaire was based on previously published literature that have revealed that stockpersons' sociodemographic profile, values (Tarabla and Dodd, 1990), empathy and attitude towards cows, and job satisfaction (Fukasawa et al., 2017; Hanna et al., 2009) affected farming outcomes. Also, it was assumed that satisfaction with farming and farming outcomes, attitudes towards farming in general, the goals and success, quality of life, openness and production oriented behaviour (Willock et al., 1999), leadership skills (Oyinlade, 2008), personal empathy (Batchelder et al., 2017), perceived effect and control over the problem (Bergevoet et al., 2004; Jansen et al., 2009; Moss-Morris et al., 2002), and personality (Gosling et al., 2003) could influence cow culling rates and longevity. The questionnaire included a cover letter explaining the aim of the study, the possible application of the study results and details about filling the questionnaire. Also, it was stated that filling the questionnaire was voluntary and that all the data would be handled and published in an anonymous and generalized way. The study permission was applied from the Research Ethics Committee of the University of Tartu (study permit number 292/T-18, date of release 15.04.2019). The questionnaire included questions from the following themes: "respondents demography and experience" (age, gender, level of education, position in the farm, number of years of working experience in total and in the current farm), "satisfaction with cow culling and longevity" (number of statements $n = 5$), "importance of longevity" ($n = 5$), "attitude towards high milk yield" ($n = 6$), "influence of youngstock availability" ($n = 2$), "genetic considerations" ($n = 3$), "attitudes towards farming" ($n = 2$), "self-satisfaction" ($n = 4$), "self-confidence" ($n = 5$), "leadership skills" ($n = 5$), "attitudes towards employees" ($n = 5$), "empathy and attitudes towards cattle" ($n = 3$),

"openness and innovative attitudes" ($n = 7$), "quality of life" (n = 4), "empathy" (n = 4), and "impact of socio-economic factors" ($n = 4$). The exact statements are listed in Tables 1 and 2. Also, a Ten Item Personality Inventory (TIPI) scoring (Gosling et al., 2003) was included to assess personality characteristics of the farm managers. For statements in blocks 1–13 (Table 2) and TIPI, farmers were asked to respond in a 7-point Likert scale specifying the extremes (1 = "completely disagree" and 7 = "completely agree") and the middle answer (4 = "neither agree nor disagree"). The answer categories under theme "empathy" (Table 2, block 14) ($n = 4$ statements) were 1 = "does not describe me well" to 7 = "describes me very well". A 7-point scale was applied to record the answers under the theme "impact of socio-economic factors" (block 15, Table 2) specifying the extremes and the middle answer (1 = "not important at all", 4 = "so and so" and 7 = "very important"). The questionnaire was pre-tested in three farm managers by conducting cognitive interviews in order to find out whether the statements were clear and unambiguous to the respondents followed by necessary corrections. The contacting researcher explained the objectives and methodology of the study to the farm manager and clarified whether the farm met the inclusion criteria or not. It was emphasised that a person eligible for filling out the questionnaire was the main person responsible for daily activities and decisions made on the farm (mostly called farm manager). In case the herd did not meet the inclusion criteria, a new herd was randomly selected from the sampling frame. The questionnaire was sent to the farm manager by post and was asked to be completed by the date of the farm visit in which it was returned to the investigator. In case the questionnaire was not completed by that time, it was asked to be returned by post by providing a prestamped envelope. A reminder of completing and returning the questionnaire was sent by e-mail within a month after the farm visit.

2.2. Herd recruitment

The inclusion criteria for the study were the herd size of at least 100 cow-years at the time of recruitment, a freestall barn for cows and no intention to cease production in the near future. Considering the available resources as well as the size of the study population, we targeted 120 herds to be included in the present study. A list of herds meeting the herd size criterion was obtained from the Estonian Livestock Performance Recording Ltd. (ELPR). The herd definition in this study was a dairy unit(s) of cows managed as one operation together with associated youngstock unit(s). The sampling frame included 182 herds whereas some owners (companies) might have more than one separate cow barns in different locations (handled as separate herds in the present study) with common or separate youngstock units. Due to ELPR having no information about the cow housing system, a random sample of 120

Table 1
Descriptive statistics of numerical farm and respondent variables, and their Spearman correlation coefficients with herd cow culling rate (CR) and mean age of culled cows (MAofCC); $n = 116$.

Variable	Mean ± SD (min, max)	Correlation with	
		CR	MAofCC
Farm characteristics			
Herd size (number of cows)	514.4 ± 368.6 (92, 2275)	0.27*	−0.17
Herd milk yield (kg)	10,309.3 ± 1200.1 (5983, 13,155)	0.20*	−0.15
Respondent			
Age of the respondent (years)	46.4 ± 13.0 (24.0, 74.0)	−0.02	0.04
Number of years of working experience with cattle	21.8 ± 12.3 (1.3, 54.0)	−0.14	−0.02
Number of years of working experience in the current farm	12.4 ± 11.0 (1.0, 39.0)	−0.07	−0.003

* $p \leq 0.05$.

Table 2
Statements reflecting farm manager's attitudes and opinions, Big-Five personality domains evaluated in a 7-point Lickert scale and Spearman correlation coefficients with herd culling rate (CR) and mean age of culled cows (MAofCC); $n = 116$.

Block	Statement	Mean ± SD (min…max)	Correlation with	
			CR	MAofCC
Farm manager's attitude and opinions				
1 - Satisfaction with culling and longevity				
	I am satisfied with the cow longevity in our farm.	3.0 ± 1.5 (1…7)	**−0.53***	**0.37***
	I am satisfied with my role in herd culling management.	5.1 ± 1.7 (1…7)	**−0.21***	−0.10
	I am satisfied with the cow culling rate (including mortality and slaughter) in our farm.	3.4 ± 1.8 (1…7)	**−0.37***	**0.22***
	I would like to do more voluntary /economic culling.	5.2 ± 1.9 (1…7)	0.11	−0.10
	High culling rate of young cows is a problem in our farm.	4.1 ± 1.8 (1…7)	**0.17#**	−0.11
2 - Importance of longevity				
	Improving cow longevity is profitable to the farm.	6.3 ± 1.0 (4…7)	−0.04	0.09
	Cow longevity is more important than high milk yield.	4.2 ± 1.5 (1…7)	**−0.21***	0.05
	Long cow longevity refers to good health and welfare of cows.	6.6 ± 0.8 (1…7)	0.07	−0.00
	We aim for longer lifespan in our breeding programme (e.g. breed selection and longevity traits).	5.5 ± 1.5 (1…7)	−0.01	−0.05
	There are more important problems than a short lifespan of the cows in our farm.	4.2 ± 1.8 (1…7)	0.12	0.02
3 - Attitude towards high milk yield				
	Herd milk yield is higher when cows stay longer in the herd.	4.7 ± 1.6 (1…7)	−0.12	0.09
	High milk yield of cows is determining shorter lifespan.	4.9 ± 1.6 (1…7)	0.00	−0.05
	I am motivated to keep the cows' productive life short because young replacement cows produce more milk.	1.7 ± 1.1 (1…6)	−0.10	0.04
	I am motivated to prolong cows' lifespan because older cows have higher milk yields.	5.4 ± 1.6 (1…7)	−0.02	−0.02
	Our farm is trying to be among the highest producing farms.	5.0 ± 1.8 (1…7)	**0.18***	**−0.17#**
	High milk production is largely achieved at the expense of cow welfare.	5.3 ± 2.0 (1…7)	0.05	0.10
4 - Influence of youngstock availability				
	I have to cull cows more than I wish due to surplus of heifers.	1.9 ± 1.5 (1…7)	−0.03	0.00
	Culling policies in our farm are dependent on the availability of replacement heifers.	3.9 ± 2.4 (1…7)	0.04	0.07
5 - Genetic considerations				
	With increasing cow longevity the genetic improvement of the herd slows down.	3.9 ± 1.7 (1…7)	0.09	**−0.17#**
	Genetics that favour the longevity of cows is important in ensuring long lifespan of cows.	6.2 ± 1.1 (3…7)	−0.02	−0.02
	We aim for higher cow culling rates because we want to improve the herd genetic merit with accelerated change of generations.	2.2 ± 1.4 (1…7)	−0.03	0.00
6 - Attitudes towards farming				
		2.9 ± 1.6 (1…7)	0.01	0.09

(continued on next page)

Table 2 (*continued*)

Block	Statement	Mean ± SD (min…max)	Correlation with	
			CR	MAofCC
	Farming is important to the society.			
	The position of farm manager is valued.	3.6 ± 1.6 (1…7)	−0.07	0.11
7 - Self-satisfaction				
	I recommend young persons to become a farm manager.	5.0 ± 1.7 (1…7)	−0.00	0.09
	I generally enjoy my work.	5.9 ± 1.3 (2…7)	**−0.13**#	0.03
	I am good in my work.	4.8 ± 1.2 (2…7)	0.05	−0.00
	I am acknowledged and respected by the farm staff.	5.3 ± 1.1 (1…7)	−0.11	0.01
8 - Self-confidence				
	The competence of the farm manager is important to ensure the longevity of the cows.	6.6 ± 0.7 (4…7)	−0.11	0.03
	There is not much point in planning as new problems appear unexpectedly.	3.0 ± 1.7 (1…7)	0.08	**0.13**#
	In case of problems in the farm I am able to work constructively and find a solution.	5.4 ± 1.1 (2…7)	0.02	−0.04
	I am good in guiding and supporting my subordinates to succeed in their activities.	5.2 ± 1.1 (1…7)	**−0.24***	0.06
	I make unpopular decisions if needed.	5.7 ± 1.4 (1…7)	0.03	−0.05
9 - Leadership skills				
	I have targets to manage the farm.	5.9 ± 1.2 (3…7)	**0.14**#	**−0.12**#
	It is important to follow production records continuously.	6.5 ± 0.9 (4…7)	**0.13**#	**−0.18***
	Before I take important decisions I consider all the arguments.	6.0 ± 1.1 (3…7)	**0.13**#	−0.01
	I enjoy the teamwork.	6.2 ± 1.3 (1…7)	**0.19***	**−0.20***
	I try to listen the arguments of both parties and find a compromise in the case of a conflict.	6.3 ± 1.0 (1…7)	0.10	**−0.15**#
10 - Attitudes towards employees				
	Motivated and educated farm staff is an important factor for having good cow longevity.	6.7 ± 0.7 (4…7)	−0.09	−0.00
	Dedicated and motivated staff is the main assumption for good farming outcomes.	6.9 ± 0.3 (5…7)	0.09	−0.08
	There is not much I can do to motivate farm employees to work better.	3.5 ± 1.8 (1…7)	0.11	**−0.14**#
	I do not expect the staff of my farm to strive because of low salaries.	2.3 ± 1.7 (1…7)	0.03	0.00
	I am generally satisfied with the work of my staff.	5.6 ± 1.2 (2…7)	**−0.14**#	−0.05
11 - Empathy and attitudes towards cattle				
	Cattle are intelligent animals.	6.4 ± 0.9 (3…7)	**0.13**#	−0.03
	Cattle feel physical pain as humans do.	6.8 ± 0.6 (3…7)	**0.25***	0.07
	Cattle are able to feel stress.	6.8 ± 0.9 (1…7)	0.01	**−0.12**#
12 - Openness and innovative attitudes				
	It is important to keep myself up-to-date with the newest information about farming.	6.7 ± 0.7 (3…7)	**0.12**#	**−0.22***
	Keeping the farm up-to-date is important.	6.5 ± 0.9 (2…7)	0.02	0.06
	I like to try new management practices and products in my farm.	5.6 ± 1.3 (2…7)	−0.06	−0.03
	Modern record keeping systems/data management programmes are unimportant in farming.	1.9 ± 1.7 (1…7)	−0.07	0.05
	It is important to visit other farms to look at their methods.	6.1 ± 1.2 (1…7)	0.01	−0.06
	It is important to keep my knowledge up-to-date.	6.8 ± 0.6 (4…7)	−0.06	−0.05
	It is important to be aware of the new farming/animal products in the market.	6.5 ± 0.8 (4…7)	0.04	**−0.13**#
13 - Quality of life				
	Improving the quality of my life is important.	6.2 ± 1.1 (1…7)	−0.04	−0.03
	I value my health more than success at work.	4.9 ± 1.8 (1…7)	−0.00	−0.08
	It is important to have other interests outside farming.	5.4 ± 2.0 (1…7)	−0.05	−0.03
	It is important to spend time with family and friends.	6.2 ± 1.4 (1…7)	−0.02	0.03
14 – Empathy				
	If someone is upset, it affects me too.	4.7 ± 1.8 (1…7)	**−0.15**#	0.10
	I can help others cope with bad emotions.	5.1 ± 1.3 (1…7)	0.08	−0.06
	I often share my feelings with other people.	3.2 ± 1.7 (1…7)	−0.08	**−0.13**#
	Before criticizing others, I try to put myself in their situation.	5.3 ± 1.6 (1…7)	0.07	0.02
15 - Impact of socio-economic factors				
	Our culling policies are dependent on milk price.	2.7 ± 2.1 (1…7)	0.01	**0.14**#
	Our culling policies are dependent on the possibilities to sell heifers.	2.8 ± 2.1 (1…7)	−0.08	−0.00
	Our culling policies are dependent on the price of feeds.	2.2 ± 1.7 (1…7)	−0.12	**0.16**#
	Our culling policies are dependent on the availability of employees.	2.2 ± 1.7 (1…7)	−0.10	**0.15**#
Big-Five personality domains				
	Extraversion	4.1 ± 1.4 (1…7)	**0.22***	−0.07
	Agreeableness	5.6 ± 1.1 (2.5…7)	**0.16**#	−0.06
	Conscientiousness	6.0 ± 0.9 (3.5…7)	0.09	−0.03
	Emotional Stability	5.5 ± 1.2 (2…7)	**0.24***	−0.02
	Openness to new experiences	5.7 ± 1.1 (2.5…7)	0.11	−0.03

Variables with $p \leq 0.2$ are presented in bold face and were used in following multivariable statistical analyses.

* $p \leq 0.05$,

$p \leq 0.2$.

farms was taken from the list of herds by using a random number generator in Stata® MP14.2 (StataCorp, Texas) and the farms were contacted individually by phone. Altogether, 169 herds were contacted before the final sample of 120 herds was reached. All farm visits were conducted between August 2019 to July 2020 and all questionnaires were obtained by August 2020.

2.3. Data handling

The questionnaire data was digitalized using the electronic survey tool LimeSurvey (LimeSurvey GmbH) by the first two authors and all answers were exported in the Excel format. To reveal possible errors in data insertion, five randomly selected answers of the written questionnaire and digitalized data were compared. For each herd, the data of the year preceding the farm visit was collected from the ELPR. This included the number of cows in the herd and the 305-day average cow-level milk yield recorded exactly a year before the farm visit and at the date of the visit as well as the number and age of lactating and dry cows culled

(excluding selling) during the year preceding the farm visit. The average number of cows in the herd and average milk yield over the year before the farm visit was calculated by taking the average of the respective numbers recorded at the farm visit and one year before. The herd cow culling rate (CR) was calculated as the proportion of culled cows (including cows that were slaughtered for meat, died or were euthanized on-farm but excluding cows that were sold for dairy purposes) of the average number of cows in the herd. The mean age of the culled cows was calculated (MAofCC) and is referred also as "longevity" hereafter. The respective ELPR data were merged with the questionnaire data.

Four completed questionnaires were excluded from the data analysis due to farm managers' short (less than one year) work experience on the particular farm assuming their negligible impact on a year-based cow culling rates and longevity in these farms.

Farm and questionnaire data were aggregated into four meaningful blocks. Block "Farm characteristics" included two variables - herd size (average number of cows) and herd average 305-day milk yield (kg). Block "Respondents demography and experience" comprised information about the age, gender, level of education, position, total work experience with cattle, and working experience in the current farm. Third block "Farm manager's attitudes and opinions" consisted of 64 statements that belonged to 15 meaningful themes. Five personality domains created based on TIPI were aggregated into block "Big-Five personality domains" (extraversion, agreeableness, conscientiousness, emotional stability and openness to experiences) using a scoring method developed by Gosling et al. (2003) (Tables 1 and 2, Supplementary Tables 1 and 2).

There were in total 31 (0.4%) missing answers among 116 respondents and 69 questions (from blocks "Farm manager's attitude and opinions" and "Big-Five personality domains"). Thirteen (11.2%) respondents had at least one missing answer (with an average of 2.4 and maximum of nine missing answers). The maximum number of missing answers per question was two while 44 (63.8%) of the questions were fully answered. In order to use the maximum amount of information in data analysis and not to lose herds or questions due to the few missing values, a multiple imputation of missing values was performed using the random forest algorithm in R package missForest (Stekhoven and Bühlmann, 2012).

2.4. Statistical analyses

The relationships between variables were studied with Spearman rank correlation analysis. The selection of variables from blocks "Farm manager's attitudes and opinions" and "Big-Five personality domains" for subsequent statistical analyses were conducted based on their correlations with CR and MAofCC. To not omit the variables with a relatively weak association, but potentially useful in common patterns analysis, a liberal p-value of <0.2 was chosen as the selection criterion (Dohoo, 2009).

In order to generate farm managers' subgroups based on their attitudes, opinions and personality traits, a k-mean clustering algorithm was applied on preselected variables. Separate analyses were performed with variables more correlated with CR (20 variables with $p < 0.2$ in correlation analysis) and with variables more strongly correlated with MAofCC (17 variables). The R package NbClust (Charrad et al., 2014), which also allows to determine the relevant number of clusters, was used. The best number of clusters was three both for variables more strongly correlated with CR and for variables more strongly correlated with MAofCC. The CR and MAofCC in the three clusters were compared with analysis of variance followed by Tukey post-hoc test for pairwise comparisons, and variable values in the three clusters were compared with Kruskal-Wallis test.

Finally, to reveal the relative importance of variables from different blocks to CR and MAofCC, the variance partitioning analysis was performed using R package vegan (Oksanen et al., 2020). For this analysis the respondents' gender, education and position were coded as dummy variables and the partitioning of the total variance of CR and MAofCC was done by partial regression of farm characteristics (number of cows and average milk yield), respondent-specific traits (gender, age, work experience, education and position), selected farm managers' attitudes and opinions and all Big-Five personality domains. The inclusion of all farm managers' attitude and opinions questions as well as considering only questions that were more strongly correlated with CR or MAofCC in correlation analysis ($p \leq 0.05$), left the proportions of effects in variance partitioning analysis almost equal.

All figures were constructed with R version 4.0.3 (R Core Team, 2020) and results were considered statistically significant at $p \leq 0.05$.

3. Results

3.1. Farm and farm manager characteristics

The average herd size of the finally included 116 herds was 514.4 cows (median 448.8) and the average 305-days milk yield per cow was 10,309.3 kg (median = 10,393.0) a year before the farm visit. The yearly mean herd CR was 33.0% (med = 33.0, min = 15.5, max = 61.3) and the mean age of culled cows was 60.6 months (med = 59.6, min = 47.0, max = 88.5) (Table 1 and Fig. 1).

Among all respondents, 52 (45.6%) worked in a position named "farm manager (in Estonian *farmi juhataja*)", 35 (30.7%) stated to work as "animal husbandry managers (in Estonian *loomakasvatusjuht)*" and 27 (23.7%) were categorized as "other" meaning that in addition to the farm managers' duties respondents also kept some other positions in the farm, e.g. were farm owners, veterinarians or AI-technicians, executive directors, overseer or breeding specialists. Irrespective of the name of the position, all respondents considered themselves responsible for daily decision-making and management of the farm and are thus called farm managers hereafter. The average age of farm managers was 46.4 years (med = 47.0), the average work experience was 21.8 years (med = 20.0) and the average work experience in the current farm was 12.4 years (med = 8.0). In total, 78.4% ($n = 91$) of farm managers were women and 55.3% ($n = 63$) had higher education (Table 1 and Supplementary Table 2).

The herd size was positively correlated with the average milk yield ($\rho = 0.38$, $p < 0.001$) and negatively with the age and current work experience of farm manager ($\rho = -0.18$, $p = 0.068$ and $\rho = -0.22$, $p = 0.017$, respectively).

The farms with higher CR had on average lower MAofCC ($\rho = -0.40$, $p < 0.001$). Also, the CR was slightly higher and the MAofCC slightly lower in larger herds and in herds with higher milk yields ($\rho = 0.27$, $p = 0.003$ and $\rho = -0.17$, $p = 0.077$ for farm size and $\rho = 0.20$, $p = 0.032$ and $\rho = -0.15$, $p = 0.100$ for average milk yield) (Table 1). Descriptive statistics of the associations between farm managers' overall characteristics and farm size and milk yield are presented in Supplementary material (Supplementary Figs. 1 and 2). There were no statistically significant differences in CR and MAofCC depending on farm managers' gender, education level or position (Supplementary Table 2).

3.2. Farm managers' attitudes towards farming, employees and cattle

Respondents generally felt that farming is unimportant to society and thought that the position of farm manager is low valued (mean score (MS) = 2.9 and MS = 3.6, respectively). Farm managers stated they generally enjoy their work (MS = 5.9) and gave, on average, satisfactory assessment about their job proficiency (MS = 4.8).

Farm managers generally thought their competence is important in ensuring the longevity of cows (MS = 6.6). Most of the farm managers thought they were good in guiding and supporting their subordinates to succeed in their activities (MS = 5.2) and stated they like teamwork (MS = 6.2). In general, farm managers considered their employees important in achieving farm goals as well as cow longevity (MS = 6.9 and 6.7, respectively). The respondents gave inconsistent answers to the

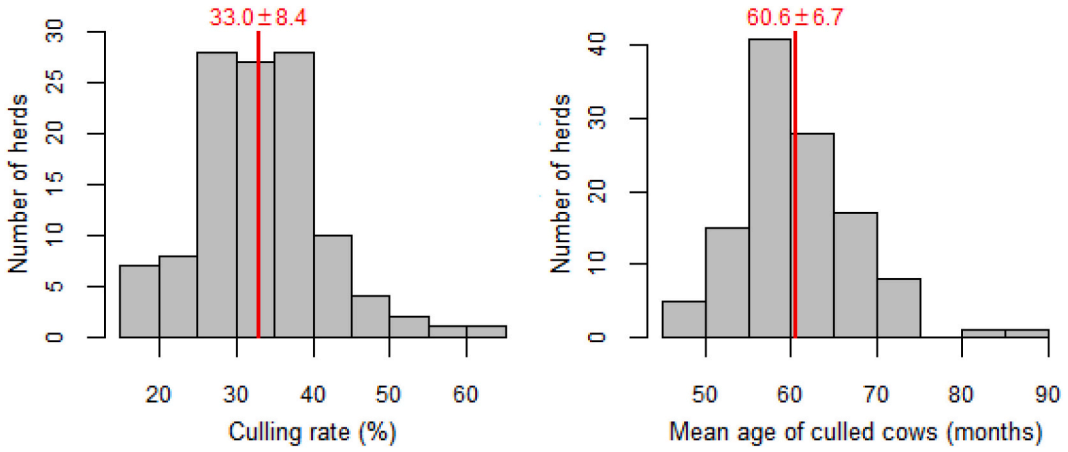

Fig. 1. Distribution of herds (n = 116) according to cow culling rate (CR) (excluding selling) and mean age of culled cows (MAofCC) in a year preceding the farm visit conducted between August 2019 to July 2020; the red line shows the mean ± standard deviation. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

statement "There is not much I can do to motivate farm employees to work better" (MS = 3.5).

The impact of external factors on culling appeared to be generally modest as most of the respondents disagreed that milk price (MS = 2.7), possibilities to sell heifers (MS = 2.8), feed price (MS = 2.2) and availability of employees (MS = 2.2) affect their culling policies (Table 2 and Supplementary Fig. 3).

3.3. Farm managers' satisfaction, attitudes and opinions on dairy cow culling and longevity

Farm managers generally disagreed with the statements "I am satisfied with the cow longevity and cow culling rates in our farm" (MS = 3.0 and MS = 3.4, respectively) and would like to do more voluntary culling (MS = 5.2). Respondents mostly shared the opinion that improving cow longevity is profitable to the farm (MS = 6.3) but had rather doubtful view whether longevity is more important than high milk yield (MS = 4.2). The majority of the respondents stated that long cow longevity refers to the good health and welfare of cows (MS = 6.6). Respondents mostly agreed that genetics that favour the longevity of cows is important in ensuring the long lifespan of cows (MS = 6.2) and stated they aim for a longer lifespan in their breeding programme (e.g. selection of cattle breed and for longevity traits) (MS = 5.5). Generally, farm managers considered high milk yield as a limiting factor in longevity (MS = 4.9) and rather agreed that high milk production is largely achieved at the expense of cow welfare (MS = 5.3) (Table 2 and Supplementary Fig. 3).

Majority of the respondents disagreed that they have to cull cows more than they wish due to surplus of heifers (MS = 1.9). Respondents mostly disagreed with the statement "We aim for higher cow culling rates because we want to improve the herd genetic merit with accelerated change of generations" (MS = 2.2) (Table 2 and Supplementary Fig. 3).

3.4. Association between farm managers' attitudes and opinions and herd cow culling rate and longevity

Herd CR correlated negatively with farm managers' satisfaction with cow longevity in their farm ($\rho = -0.53$, $p < 0.001$), with satisfaction with culling rates ($\rho = -0.37$, $p < 0.001$) and with their role in herd culling management ($\rho = -0.21$, $p = 0.025$). CR was higher in herds in which farm manager stated they aim to be among the highest producing herds ($\rho = 0.18$, $p = 0.049$) and lower in herds where farm managers valued cow longevity over high milk yield ($\rho = -0.21$, $p = 0.023$). Farm managers who tended to be more extraverted and had higher score for emotional stability traits had higher CR in their farms ($\rho = 0.22$, $p = 0.017$ and $\rho = 0.24$, $p = 0.010$, respectively) (Table 2 and Supplementary Fig. 4).

Variables that were associated with higher MAofCC were higher level of satisfaction with cow longevity ($\rho = 0.37$, $p < 0.001$) and with cow culling rates ($\rho = 0.22$, $p = 0.018$). Herd MAofCC tended to be lower in farms where farm manager stated they aim to be among the highest producing farms ($\rho = -0.17$, $p = 0.068$) and declared that with increasing cow longevity the genetic improvement of herd slows down ($\rho = -0.17$, $p = 0.074$). Farm managers emphasizing the importance of following production records ($\rho = -0.18$, $p = 0.048$), enjoying teamwork ($\rho = -0.20$, $p = 0.031$) and considering important to have the newest information about farming available ($\rho = -0.22$, $p = 0.019$) had lower MAofCC in their herds (Table 2 and Supplementary Fig. 4).

3.5. Farm managers' clusters and association with herd culling rate and longevity

There were 20 and 17 farm manager's attitudes and opinions variables having p-value <0.2 in Spearman rank correlation analysis with CR and MAofCC, respectively (Table 2). The k-mean clustering performed separately with these two groups of variables indicated that the optimal number of clusters was three in both analyses. Despite the relatively weak pairwise correlations with CR or MAofCC it appears that the clusters formed by group of variables characterized farms with different CR or MAofCC on the mean level. In addition, there was a fairly strong agreement between the most inferior clusters – farms where the pattern of managers' attitude and opinions corresponded to the highest CR on an average were almost the same as in clusters where the pattern of farm manager's attitudes and opinions corresponded to the lowest MAofCC (Fig. 2).

The more precise comparison of farm managers' attitudes and opinions in CR clusters revealed that in the cluster of farms with on average the highest CR (cluster 3, Fig. 3) farm managers were less satisfied with the cow longevity and culling rate, and with their role in herd culling management. They also confirmed the problem of high culling rate of young cows in their farms and valued less the improvement of cow longevity than milk yield. The farm managers in the cluster of farms with the lowest CR (cluster 1, Fig. 3) stated more often that they do not aim to be among the highest producing farms. They also had less target-driven management style, valued less the importance to follow production records continuously, the need to consider all arguments before taking important decisions and the importance of the availability of the newest information about farming. Additionally, they enjoyed the teamwork less, were more affected by others upset and showed less

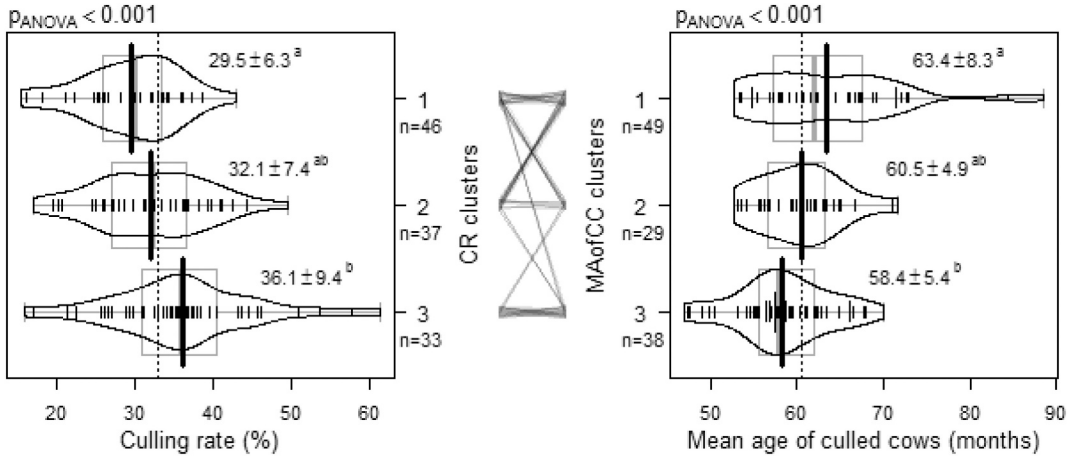

Fig. 2. Distribution of culling rate (CR) and mean age of culled cows (MAofCC) in three clusters. K-mean cluster analysis was performed separately for CR and MAofCC based on variables from blocks "Farm manager's attitudes and opinions" and "Big-Five personality domains" having *p*-value <0.2 in Spearman rank correlation analysis (Table 2). The distributions are presented in form of violin plots, where small vertical lines denote single farms, strong black vertical lines denote means by clusters and dotted line marks the overall mean, and are numerically presented as mean ± standard deviation (different superscript letters indicate statistically significantly different clusters according to the Tukey post-hoc test); p_{ANOVA} above the figures indicates the statistical significance of cluster effect according to the analysis of variance); grey squares in background denote the inter quartile range and strong grey lines show medians. The lines between CR and MAofCC clusters denote the location of single farms (there is a strong concordance in the worst 3rd cluster of both CR and MAofCC, while the first two clusters are more mixed).

extraversion, agreeableness and emotional stability.

The comparison of farm managers' attitude and opinions in MAofCC clusters revealed, that in the cluster of farms with the highest age of culled cows on average (cluster 1, Fig. 4) the farm managers were more satisfied with cow longevity and culling rate in their farm, they stated more often that they do not aim to be among the highest producing farms and that there is not much point in planning. The farm managers of best longevity herds also valued less the setting of goals and targets in farm management, the teamwork and compromises and the importance of the newest information about farming and animal products.

3.6. Importance of different factor groups to herd culling rates and longevity

The role of different variable groups explaining the variability of CR and MAofCC is visualised in Fig. 5. The results of variance partitioning analysis showed, that for both CR and MAofCC the selected farm managers' attitudes and opinions described more than 1/3 of the total variability ($R^2 = 38.2\%$ for CR and $R^2 = 33.4\%$ for MAofCC). The farm characteristics (herd size and average milk yield), and general respondent-specific traits described only 5.5% and 4.2% of the variability of CR, respectively, and most of these effects were already considered by farm managers' attitudes and opinions – the proportions of variance of CR described only by farm and respondent were 0.3% and 1.2%, respectively. The effect of Big-Five personality domains on CR was almost twice that of farm or respondent effects ($R^2 = 9.0\%$), and about half of this effect was specific to personality domains alone. The effects of farm and respondent traits on MAofCC were in the same magnitude ($R^2 = 6.8\%$ and $R^2 = 5.6\%$, respectively) as on CR but the uniqueness of respondent traits was slightly bigger (2.1%). The effect of Big-Five personality domains on MAofCC was marginal and mostly covered by the effect of general respondent-specific traits.

4. Discussion

Dairy farmers have a central role in determining cow longevity specifically appointing the time and reason a cow is culled (Dallago et al., 2021). The present study revealed that dissatisfaction with cow culling rates and longevity, prioritizing high milk yields over longevity and production-oriented management style were the characteristics of farm managers that had highest cow culling rates and poorest longevity in their farms. Due to the large herd sizes and replacing human work with technology, there is reduced interaction between humans and animals (Raussi, 2003). As farm managers are responsible for daily management and decisions relating to herd health and production, their attitudes have direct, as well as indirect, effects on animals. Common to other sectors, large production farms are managed according to production targets and this is reflected in the attitude of the questioned farm managers. According to Breuer et al. (2000) a sequential relationship exists between attitudes and behaviour of the manager and the productivity of their dairy cows. In previous studies, the association between farmers´ attitudes and behaviour to production outcomes was mostly analyzed in smaller herds in which farmers have closer contact with their cattle (Bergeå et al., 2016; Bruijnis et al., 2013; Jansen et al., 2009; Kauppinen et al., 2013; van den Borne et al., 2014). Due to the contextual discrepancies of the roles of managers in large commercial farms compared to family-owned smaller cattle holdings, it is difficult to extrapolate these previous findings to large commercial farms.

The distribution of herd CR and longevity measured as the MAofCC were comparable to that reported in many other countries in the last decade (Bergeå et al., 2016; Chiumia et al., 2013; De Vries, 2017; Hadley et al., 2006; Haine et al., 2017; Nor et al., 2014; Schuster et al., 2020). Although analyzing the association between herd parameters (herd size and level of milk yield) and cow culling rates and longevity was not the primary interest of this study these factors were included as background information. According to the correlation analysis, CR was somewhat higher in larger herds and in case of a higher level of milk yields, however, the MAofCC was not significantly affected by these factors. Similarly, previous studies have concluded that larger herds have higher culling rates, especially among higher-producing cows and possibly due to less individual attention, as cows in larger herds are more often culled due to health problems (Hadley et al., 2006; Rilanto et al., 2020; Weigel et al., 2003).

4.1. Farm managers' attitudes and opinions on dairy cow culling and longevity

Farm managers were mostly dissatisfied with their herd cow culling rates and longevity and would like to do more voluntary culling. This indicates that farmers have less control over culling management and

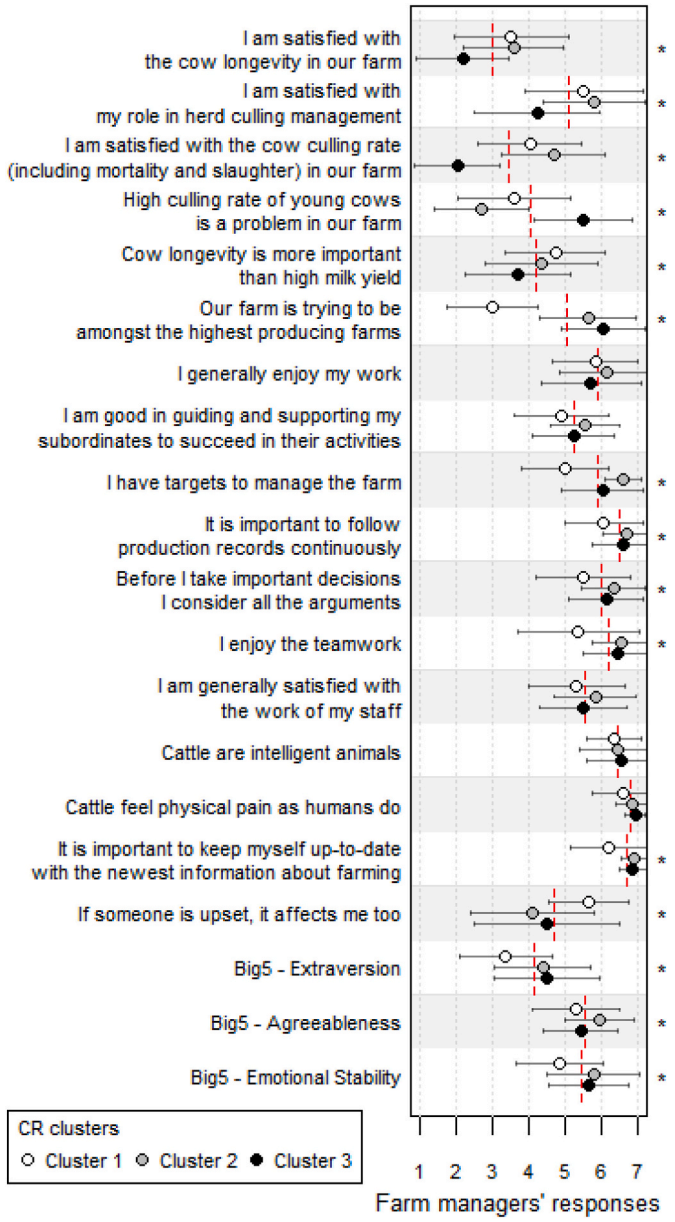

Fig. 3. Mean (± standard deviation) of selected variables in three clusters analyzed in the association with cow culling rate. The variables for k-mean cluster analysis were selected according to their correlation with culling rate (CR; for correlations see Table 2) and the clusters were ordered according to the CR: the average CR values in the 1st, 2nd and 3rd cluster were 29.5%, 32.1% and 36.1%, respectively. The red dotted lines mark the overall means and the stars (*) in the right of the plot denote the variables with statistically significant difference between clusters (Kruskal-Wallis test). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

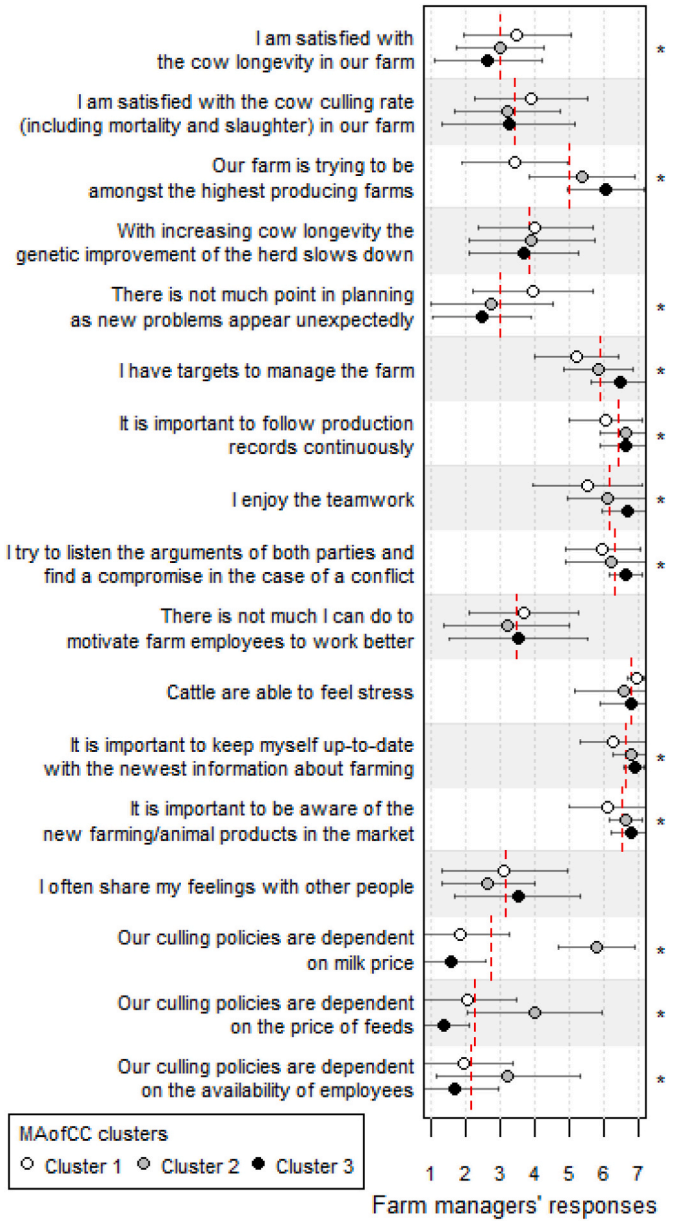

Fig. 4. Mean (± standard deviation) of selected variables in three clusters analyzed in the association with mean age of culled cows. The variables for k-mean cluster analysis were selected according to their correlation with mean age of culled cows (MAofCC; for correlations see Table 2) and the clusters were ordered according to the MAofCC: the average MAofCC values in the 1st, 2nd and 3rd cluster were 63.4, 60.5 and 58.4 months, respectively. The red dotted lines mark the overall means and the stars (*) in the right of the plot denote the variables with statistically significant difference between clusters (Kruskal-Wallis test). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

this is a concern for them (Van Arendonk, 1985). Farm managers mostly agreed that improving cow longevity is profitable to the farm and the persistency of cows was considered to reflect good health and welfare. Still, the majority of the farmers did not prioritize cow longevity over high milk yields in their farms. One reason for this could be that they had inconsistent views regarding the harmful effect of high milk yield on the persistency and overall welfare of cows. As good health and welfare of cows are important preconditions for achieving high production levels farm managers might consider other factors more important in culling than high milk yield. This means that farmers might not see high milk yield as a predisposing factor for prevailing diseases and disorders of cows that eventually will lead to culling.

Encouraging higher milk yield might also derive from the milk pricing system in Estonia, where the pricing is mostly based on the volume of milk whereas the mark-up or discount for fat is about 10 times and for protein 2–4 times lower than the market price of milk fat and protein (Maaleht, 2021). As a consequence, the milk yield of Estonian dairy cows has increased drastically during the last decades (Estonian Livestock Performance Recording Ltd, 2019), meaning that farmers' mentality in achieving high milk yield is prevailing and rooted. In the media and by different cattle breeders' organizations, the herds are ranked and the overall success of the farms in Estonia is mostly assessed

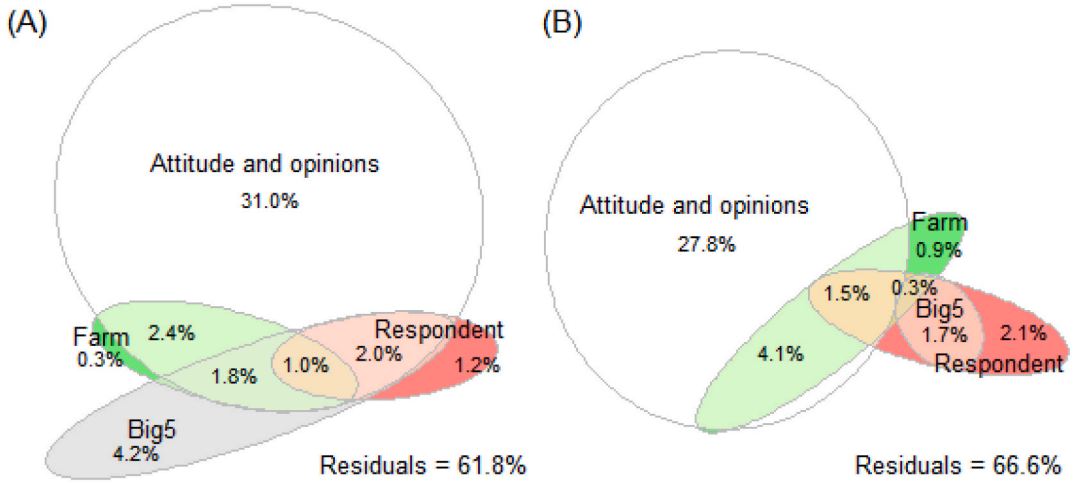

Fig. 5. Results of variance partitioning analysis fitted with Euler diagram. The numerical values present and the size of ellipses and their intersections visualize the percentages of (Panel A) culling rate and (Panel B) mean age of culled cows variance accounted for by farm characteristics (number of cows and average milk yield), respondent-specific traits (gender, age, work experience, education and position), selected farm managers' attitudes and opinions (20 and 17 questions with $p < 0.2$ in correlation analysis with culling rate and mean culling age, respectively) and all Big-Five personality domains.

based on their production parameters, e.g. the level of milk yield, milk protein and fat production and somatic cell count (Äripäev, 2020; Estonian Agricultural Registers and Information Board, 2021; ELPR, 2020, 2019). This economic and social pressure might motivate farmers to invest into the high production capacity in their farms and to prioritize this over cow resilience. Low visibility of longevity values in farm management or milk-recording system data compared to other production data (e.g. milk yield, somatic cell counts etc) could result in a vague focus on longevity, also acknowledged in Sweden (Bergeå et al., 2016). Clear animal health and longevity standards together with benchmarking developed by the dairy industry itself could motivate farmers to value and improve longevity (Rushen and de Passillé, 2013). Also, due to the production-oriented nature of farm managers, there is a need to clarify the economic value of longevity and to optimize the farm goals related to production parameters. Further studies could possibly clarify whether the criteria used in the milk-pricing model have an effect on longevity.

Respondents mostly agreed that genetics that favour the longevity of cows is important in ensuring a long lifespan and roughly two-thirds of the farm managers stated they aim for a longer lifespan in their breeding programme by the selection of cattle breeds and longevity traits. According to the Animal Breeders' Association of Estonia (EABA), farm managers often state that offspring persistency is important when selecting breeding bulls but the final selection is often made based on bull milk yield breeding value or according to specific traits, e.g. position and length of teats that are important especially in robotic milking systems (EABA personal communication, 2021). Prioritizing high milk yield breeding values over longevity traits by dairy farm managers might also result from relatively low heritability of the lifespan score (Pritchard et al., 2013). Also, it should be acknowledged that next to favourable genetic selection for milk yield, there is relatively low genetic control over some non-yield traits, e.g. fertility referring to the importance of environmental factors to overcome the antagonism of milk yield and longevity (Hansen, 2000). As suggested by Knaus (2009), to improve cow longevity, dairy cattle breeding programs should focus more on selection for traits associated with longevity and lifetime performance and reduce the emphasis on selection for lactation performance.

According to farm managers' responses, we can conclude that higher culling rates are not the result of a desire to speed up the change of generations to improve herd genetic potential. As dairy farmers did not confirm the problem of having surplus heifers, the phenomenon reported in other studies of heifers prematurely pushing cows out of the herd counteracting longevity (Bergeå et al., 2016; De Vries and Marcondes, 2020) is rarely the case in Estonian farms. The cattle export market is well developed in Estonia (European Commission, 2017) and selling dairy heifers is an important additional income source for our farmers (Viira et al., 2015) meaning that surplus heifers are rather sold than used for accelerated replacement of cows.

The impact of external factors, e.g. milk price, feed cost, availability of employees and possibility to sell heifers on culling decisions was generally low by farm managers' opinion. Estonian dairy sector has experienced several crises during the last years. The two-years „milk crisis"from 2014 to 2016 in which the milk price was below 300 €/t, being one of the lowest among EU countries (European Commission, 2021) resulted in culling of roughly 10% of Estonian dairy cow population (Estonian Livestock Performance Recording Ltd, 2016). Also, a heavy draught that occurred in summer 2018 caused serious difficulties with dairy farms' feed supplies. It is possible that farms that were in production during the study were the ones that overcame these crises and were thus economically most sustainable and less sensitive to external influences.

4.2. Farm managers' clusters and association with herd cow culling rate and longevity

This study revealed farm managers' subgroups that differed on their farm culling rates and longevity. The level of satisfaction with culling rate and longevity of cows also reflected in the respective measures of the farms meaning that farm managers acknowledge the situation regarding cow culling rates and longevity in their farms. The other aspects included in forming the subgroups revealed that farm managers of the highest culling and shortest longevity herds could be characterized as production and target-oriented, collaborative, open-minded and innovative. All these parameters are more characteristic of an intensive production system. According to Ritter et al. (2017) acknowledging the problem and taking the responsibility for it are important assumptions when implementing necessary changes. Due to identified dissatisfaction and the overall open-minded nature of the farm managers of inferior longevity farms, there are possibly favourable grounds for changing the priorities and motivations. As further studies could clarify specific motives of the farm management board for prioritizing cow health and resilience over high milk yield in the farms, we propose that as a first step, next to production parameters, herd indicators reflecting cow health and longevity should be better highlighted in farm production records together with benchmarking. Revealing the economic

profitability of cow persistency could emphasize the benefit of longevity. Also, implementing cow-based decision-support tools could optimize culling decisions by predicting cows for future profitability (Groenendaal et al., 2004; Orpin and Esslemont, 2010; Sorge et al., 2007) and aid to optimize longevity.

The personality of the farm managers was associated with herd culling rates but had no association with longevity. Farm managers were more extraverted in farms with higher culling rates but also with somewhat higher emotional stability than those from farms with lower CR. To some extent, emotional stability is associated with calmness and low levels of stress, whereas those who are more extroverted are reward-seeking (Beus et al., 2015; Depue and Collins, 1999; Smillie and Jackson, 2006). Indeed, this combination of stable extraversion is associated with positive affect and a more positive outlook (Anglim et al., 2020; DeNeve and Cooper, 1998; Robbins et al., 2010). Due to this positive outlook, a sense of reward, and positive affect farmers with low emotional stability and higher extraversion may perceive more benefits to culling and hence have higher culling rates. Still, further studies are needed to reveal a clear understanding of the behaviour patterns of people with different personalities.

4.3. Influence of different factor groups to herd culling rate and longevity

According to the variance partitioning analysis, roughly one-third of the variance in herd CR and MAofCC was described by farm managers' attitudes and opinions. Still, it is impossible to say whether this is causative or the farm conditions and outcomes influence their attitudes. Especially evident in CR analysis, respondents' background characteristics (age, education and working experience) had a negligible explanatory capacity of herd CR and these traits were mostly overlapping with their attitudes and opinions. The Big-Five personality domains had a higher influence in herd CR analysis than respondents' background characteristic which indicates there might be different thresholds for culling across farmers with different personality traits.

Farm characteristics (farm size and average milk yield) described only a minor part of the variability of the CR and longevity, and interestingly most of these characteristics were overlapping with farm managers' attitudes and opinions. It is anticipated that the attitudes and opinions of farm managers are somewhat determined by the farm goals and policies which might partly be summarized in these two farm characteristics.

4.4. Study limitations

Similar to many other studies analyzing the impact of farmer attitudes and personality on cattle health, welfare and productivity, our study concentrated on the measured outcomes CR and MAofCC instead of farmers' behaviour affected by the attitudes (Adler et al., 2019). Still, several studies have shown that also the farmers' attitudes, over and above farmers' behaviour, explain the variation in cattle health and production outcomes (Jansen et al., 2009; van den Borne et al., 2014). Farm managers differed in the duration of working experience in a particular farm meaning that their possible impact on herd CR and MAofCC is unequal. Also, we lack knowledge about their actual daily contact with animals and specific responsibilities on the farms. The study findings might also include reverse causality possibly most evident in the block of statements about satisfaction with longevity and culling rates, i.e. shorter longevity and higher culling rates induce dissatisfaction. For these reasons, we avoid concluding any causal inferences and promote further studies that would reveal the individual contribution of farm managers on the herd cow culling rates and longevity and aid to clarify the causal pathway between attitude and behaviour of the managers and the studied farming outcomes.

5. Conclusions

The present study revealed that farm managers' attitudes explain considerable proportion of herd culling rates and longevity. As farm managers have a pivotal role in herd culling decisions, their personality also affects herd culling rates. Although cow longevity was considered profitable by most farm managers, it did not outweigh the importance of achieving high milk yield. Dissatisfaction with culling rates and longevity, priority for producing high milk yields over increased longevity and production-oriented attitude were the characteristics of farm managers having highest culling rates and poorest cow life expectancy. Due to the production-oriented management style, there is a need to explain the economic return of longevity and discuss the compromise between milk yields and cow resilience. In order to improve the visibility of health and longevity measures, the respective indices should be better outlined in production records together with benchmarking. External motivators for improving cow persistency, e.g. social agreement of farming goals and recognition of cow persistency, as well asbreeding targets that emphasize the health and resilience of the next generation besides the increased milk yield could alter the mentality of the farm management board which is an important precondition for any changes. Due to high level of dissatisfaction with culling rates and longevity, farm managers' of large Estonian dairy farms are probably willing to tackle this problem and including different stakeholders, joint discussion about the importance, obstacles and options to increase cow longevity are encouraged.

Funding

This work was supported by an Estonian Research Council Grant (PSG268).

Declaration of Competing Interest

None.

Acknowledgments

The authors are grateful to all farmers who were involved in this study. We are very grateful to Estonian Livestock Performance Recording Ltd. for providing the data. Consent for this study was obtained from the University of Tartu Ethics Committee for Human Research (Protocol nr 292/T-18, date 15.04.2019).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rvsc.2021.11.006.

References

Adler, F., Christley, R., Campe, A., 2019. Invited review: examining farmers' personalities and attitudes as possible risk factors for dairy cattle health, welfare, productivity, and farm management: a systematic scoping review. J. Dairy Sci. 102, 3805–3824. https://doi.org/10.3168/jds.2018-15037.

Allaire, F.R., 1981. Economic consequences of replacing cows with genetically improved heifers. J. Dairy Sci. 64, 1985–1995. https://doi.org/10.3168/jds.S0022-0302(81)82801-9.

Anglim, J., Horwood, S., Smillie, L.D., Marrero, R.J., Wood, J.K., 2020. Predicting psychological and subjective well-being from personality: a meta-analysis. Psychol. Bull. 146, 279–323. https://doi.org/10.1037/bul0000226.

Animal Breeders' Association of Estonia, 2021. Animal Breeders' Association of Estonia - Breeding Bulls. URL. https://pullid.etky.ee/?set_lang=en (accessed 21.03.21).

Äripäev, 2020. Selgusid 2019. aasta parim piimakarja- ja lihaveisekarjakasvataja. https://www.pollumajandus.ee/uudised/2020/02/20/selgusid-2019-aasta-parim-piimakarja-ja-lihaveisekarjakasvataja (accessed 5.05.21).

Barkema, H.W., von Keyserlingk, M.A.G., Kastelic, J.P., Lam, T.J.G.M., Luby, C., Roy, J. P., LeBlanc, S.J., Keefe, G.P., Kelton, D.F., 2015. Invited review: changes in the dairy industry affecting dairy cattle health and welfare. J. Dairy Sci. 98, 7426–7445. https://doi.org/10.3168/jds.2015-9377.

Batchelder, L., Brosnan, M., Ashwin, C., 2017. The development and validation of the empathy components questionnaire (ECQ). PLoS One 12, e0169185. https://doi.org/10.1371/journal.pone.0169185.
Bergeå, H., Roth, A., Emanuelson, U., Agenäs, S., 2016. Farmer awareness of cow longevity and implications for decision-making at farm level. Acta Agric. Scand. A Anim. Sci. 66, 25–34. https://doi.org/10.1080/09064702.2016.1196726.
Bergevoet, R.H.M., Ondersteijn, C.J.M., Saatkamp, H.W., Van Woerkum, C.M.J., Huirne, R.B.M., 2004. Entrepreneurial behaviour of dutch dairy farmers under a milk quota system: goals, objectives and attitudes. Agric. Syst. 80, 1–21. https://doi.org/10.1016/j.agsy.2003.05.001.
Beus, J.M., Dhanani, L.Y., McCord, M.A., 2015. A meta-analysis of personality and workplace safety: addressing unanswered questions. J. Appl. Psychol. 100, 481–498. https://doi.org/10.1037/a0037916.
Boulton, A.C., Rushton, J., Wathes, D.C., 2017. An empirical analysis of the cost of rearing dairy heifers from birth to first calving and the time taken to repay these costs. Animal 11, 1372–1380. https://doi.org/10.1017/S1751731117000064.
Breuer, K., Hemsworth, P.H., Barnett, J.L., Matthews, L.R., Coleman, G.J., 2000. Behavioural response to humans and the productivity of commercial dairy cows. Appl. Anim. Behav. Sci. 66, 273–288. https://doi.org/10.1016/S0168-1591(99)00097-0.
Broom, D.M., 1991. Animal welfare: concepts and measurement. J. Anim. Sci. 69, 4167–4175. https://doi.org/10.2527/1991.69104167x.
Bruijnis, M., Hogeveen, H., Garforth, C., Stassen, E., 2013. Dairy farmers' attitudes and intentions towards improving dairy cow foot health. Livest. Sci. 155, 103–113. https://doi.org/10.1016/j.livsci.2013.04.005.
Charrad, M., Ghazzali, N., Boiteau, V., Niknafs, A., 2014. Nbclust: an R package for determining the relevant number of clusters in a data set. J. Stat. Softw. 61, 1–36. https://doi.org/10.18637/jss.v061.i06.
Chiumia, D., Chagunda, M.G.G., MacRae, A.I., Roberts, D.J., 2013. Predisposing factors for involuntary culling in Holstein-Friesian dairy cows. J. Dairy Res. 80, 45–50. https://doi.org/10.1017/S002202991200060X.
Clark, B., Stewart, G.B., Panzone, L.A., Kyriazakis, I., Frewer, L.J., 2016. A systematic review of public attitudes, perceptions and Behaviours towards production diseases associated with farm animal welfare. J. Agric. Environ. Ethics 29, 455–478. https://doi.org/10.1007/s10806-016-9615-x.
Compton, C.W.R., Heuer, C., Thomsen, P.T., Carpenter, T.E., Phyn, C.V.C., McDougall, S., 2017. Invited review: a systematic literature review and meta-analysis of mortality and culling in dairy cattle. J. Dairy Sci. 100, 1–16. https://doi.org/10.3168/jds.2016-11302.
Dallago, G.M., Wade, K.M., Cue, R.I., McClure, J.T., Lacroix, R., Pellerin, D., Vasseur, E., 2021. Keeping dairy cows for longer: a critical literature review on dairy cow longevity in high milk-producing countries. Animals 11, 808. https://doi.org/10.3390/ani11030808.
De Vries, A., 2017. Economic trade-offs between genetic improvement and longevity in dairy cattle. J. Dairy Sci. 100, 4184–4192. https://doi.org/10.3168/jds.2016-11847.
De Vries, A., Marcondes, M.I., 2020. Review: overview of factors affecting productive lifespan of dairy cows. Animal. 14, s155–s164. https://doi.org/10.1017/S1751731119003264.
DeLong, K.L., Lambert, D.M., Schexnayder, S., Krawczel, P., Fly, M., Garkovich, L., Oliver, S., 2017. Farm business and operator variables associated with bulk tank somatic cell count from dairy herds in the southeastern United States. J. Dairy Sci. 100, 9298–9310. https://doi.org/10.3168/jds.2017-12767.
DeNeve, K.M., Cooper, H., 1998. The happy personality: a meta-analysis of 137 personality traits and subjective well-being. Psychol. Bull. 124, 197–229. https://doi.org/10.1037/0033-2909.124.2.197.
Depue, R.A., Collins, P.F., 1999. Neurobiology of the structure of personality: dopamine, facilitation of incentive motivation, and extraversion. Behav. Brain Sci. 22, 491–517. https://doi.org/10.1017/s0140525x99002046.
Dohoo, I.M.W.S.H., 2009. Veterinary Epidemiologic Research, 2nd ed. VER Inc., Charlottetown.
Estonian Agricultural Registers and Information Board, 2021. Maaelu Edendamise Sihtasutus kuulutab välja 2020. aasta parimad karjakasvatajad. https://www.pria.ee/uudised/maaelu-edendamise-sihtasutus-kuulutab-valja-2020-aasta-parimad-karjakasvatajad (accessed 3.5.21).
Estonian Livestock Performance Recording Ltd, 2016. Results of Animal Recording in Estonia 2016. https://www.epj.ee/assets/tekstid/aastaraamatud/aastaraamat_2016.pdf (accessed 14.3.21).
Estonian Livestock Performance Recording Ltd, 2019. Results of Animal Recording in Estonia 2019. https://www.epj.ee/assets/tekstid/aastaraamatud/aastaraamat_2019.pdf (accessed 14.3.21).
Estonian Livestock Performance Recording Ltd, 2020. Newsletter of Estonian Livestock Performance Recording Ltd. https://www.epj.ee/assets/tekstid/piimaveised/piimaveised_58_veebi.pdf (accessed 3.5.21).
European Commission, 2017. TRAde Control and Expert System (TRACES). https://ec.europa.eu/food/sites/food/files/animals/docs/traces_report_annual_2017_move_cattle_eng.pdf (accessed 5.4.21).
European Commission, 2021. Milk market observatory. https://ec.europa.eu/info/food-farming-fisheries/farming/facts-and-figures/markets/overviews/market-observatories/milk_en (accessed 14.3.21).
Fetrow, J., Nordlund, K.V., Norman, H.D., 2006. Invited review: culling: nomenclature, definitions, and recommendations. J. Dairy Sci. 89, 1896–1905. https://doi.org/10.3168/jds.S0022-0302(06)72257-3.
Fukasawa, M., Kawahata, M., Higashiyama, Y., Komatsu, T., 2017. Relationship between the stockperson's attitudes and dairy productivity in Japan. Anim. Sci. J. 88, 394–400. https://doi.org/10.1111/asj.12652.
Gosling, S.D., Rentfrow, P.J., Swann, W.B., 2003. A very brief measure of the big-five personality domains. J. Res. Pers. 37, 504–528. https://doi.org/10.1016/S0092-6566(03)00046-1.
Groenendaal, H., Galligan, D.T., Mulder, H.A., 2004. An economic spreadsheet model to determine optimal breeding and replacement decisions for dairy cattle. J. Dairy Sci. 87, 2146–2157. https://doi.org/10.3168/jds.S0022-0302(04)70034-X.
Hadley, G.L., Wolf, C.A., Harsh, S.B., 2006. Dairy cattle culling patterns, explanations, and implications. J. Dairy Sci. 89, 2286–2296. https://doi.org/10.3168/jds.S0022-0302(06)72300-1.
Haine, D., Delgado, H., Cue, R., Sewalem, A., Wade, K., Lacroix, R., Lefebvre, D., Arsenault, J., Bouchard, É., Dubuc, J., 2017. Contextual herd factors associated with cow culling risk in Québec dairy herds: a multilevel analysis. Prev. Vet. Med. 144, 7–12. https://doi.org/10.1016/j.prevetmed.2017.05.014.
Hanna, D., Sneddon, I.A., Beattie, V.E., 2009. The relationship between the stockpersons personality and attitudes and the productivity of dairy cows. Animal 3, 737–743. https://doi.org/10.1017/S1751731109003991.
Hansen, L.B., 2000. Consequences of selection for milk yield from a geneticist's viewpoint. J. Dairy Sci. 83, 1145–1150. https://doi.org/10.3168/jds.S0022-0302(00)74980-0.
Hare, E., Norman, H.D., Wright, J.R., 2006. Survival rates and productive herd life of dairy cattle in the United States. J. Dairy Sci. 89, 3713–3720. https://doi.org/10.3168/jds.S0022-0302(06)72412-2.
Hristov, A.N., Ott, T., Tricarico, J., Rotz, A., Waghorn, G., Adesogan, A., Dijkstra, J., Montes, F., Oh, J., Kebreab, E., Oosting, S.J., Gerber, P.J., Henderson, B., Makkar, H.P.S., Firkins, J.L., 2013. SPECIAL TOPICS-mitigation of methane and nitrous oxide emissions from animal operations: III. A review of animal management mitigation options. J. Anim. Sci. 91, 5095–5113. https://doi.org/10.2527/jas.2013-6585.
Jansen, J., van den Borne, B.H.P., Renes, R.J., van Schaik, G., Lam, T.J.G.M., Leeuwis, C., 2009. Explaining mastitis incidence in Dutch dairy farming: the influence of farmers' attitudes and behaviour. Prev. Vet. Med. 92, 210–223. https://doi.org/10.1016/j.prevetmed.2009.08.015.
Kauppinen, T., Valros, A., Vesala, K.M., 2013. Attitudes of dairy farmers toward cow welfare in relation to housing, management and productivity. Anthrozoos 26, 405–420. https://doi.org/10.2752/175303713X13697429463718.
Kielland, C., Skjerve, E., Østerås, O., Zanella, A.J., 2010. Dairy farmer attitudes and empathy toward animals are associated with animal welfare indicators. J. Dairy Sci. 93, 2998–3006. https://doi.org/10.3168/jds.2009-2899.
Knaus, W., 2009. Dairy cows trapped between performance demands and adaptability. J. Sci. Food Agric. 89, 1107–1114. https://doi.org/10.1002/jsfa.3657.
Lai, J., Widmar, N.J.O., Wolf, C.A., 2019. Dairy farm management priorities and implications. Int. Food Agribus. Manag. Rev. 22, 15–30. https://doi.org/10.22434/IFAMR2018.0010.
Lehenbauer, T.W., Oltjen, J.W., 1998. Dairy cow culling strategies: making economical culling decisions. J. Dairy Sci. 81, 264–271. https://doi.org/10.3168/jds.S0022-0302(98)75575-4.
Maaleht, 2021. Eesti lehmad lüpsavad liiga lahjat piima. Uutmoodi hinnaarvestus aitaks hädast välja. https://maaleht.delfi.ee/artikkel/93059205/eesti-lehmad-lupsavad-liiga-lahjat-piima-uutmoodi-hinnaarvestus-aitaks-hadast-valja (accessed 22.4.21).
Moss-Morris, R., Weinman, J., Petrie, K., Horne, R., Cameron, L., Buick, D., 2002. The revised illness perception questionnaire (IPQ-R). Psychol. Health 17, 1–16. https://doi.org/10.1080/08870440290001494.
Nor, N.M., Steeneveld, W., Hogeveen, H., 2014. The average culling rate of Dutch dairy herds over the years 2007 to 2010 and its association with herd reproduction, performance and health. J. Dairy Res. 81, 1–8. https://doi.org/10.1017/S0022029913000460.
Oksanen, J., Blanchet, F.G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P.R., O'Hara, R.B., Simpson, G.L., Solymos, P., Stevens, M.H.H., Szoecs, E., Wagner, H., 2020. vegan: Community Ecology Package. R package version 2, pp. 5–7.
Orpin, P., Esslemont, R., 2010. Culling and wastage in dairy herds: an update on incidence and economic impact in dairy herds in the UK. Cattle Pract. 18, 163–172.
Oyinlade, A.O., 2008. A method of assessing leadership effectiveness. Perform. Improv. Q. 19, 25–40. https://doi.org/10.1111/j.1937-8327.2006.tb00355.x.
Pritchard, T., Coffey, M., Mrode, R., Wall, E., 2013. Understanding the genetics of survival in dairy cows. J. Dairy Sci. 96, 3296–3309. https://doi.org/10.3168/jds.2012-6219.
Raussi, S., 2003. Human-cattle interactions in group housing. Appl. Anim. Behav. Sci. 80, 245–262. https://doi.org/10.1016/S0168-1591(02)00213-7.
R Core Team, 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Vienna, Austria. URL. https://www.R-project.org/.
Rilanto, T., Reimus, K., Orro, T., Emanuelson, U., Viltrop, A., Mõtus, K., 2020. Culling reasons and risk factors in Estonian dairy cows. BMC Vet. Res. 16, 173. https://doi.org/10.1186/s12917-020-02384-6.
Ritter, C., Jansen, J., Roche, S., Kelton, D.F., Adams, C.L., Orsel, K., Erskine, R.J., Benedictus, G., Lam, T.J.G.M., Barkema, H.W., 2017. Invited review: determinants of farmers' adoption of management-based strategies for infectious disease prevention and control. J. Dairy Sci. 100, 3329–3347. https://doi.org/10.3168/jds.2016-11977.
Robbins, M., Francis, L.J., Edwards, B., 2010. Happiness as stable extraversion: internal consistency reliability and construct validity of the Oxford happiness questionnaire among undergraduate students. Curr. Psychol. 29, 89–94.
Rogers, G.W., Van Arendonk, J.A.M., McDaniel, B.T., 1988a. Influence of production and prices on optimum culling rates and annualized net revenue. J. Dairy Sci. 71, 3453–3462. https://doi.org/10.3168/jds.S0022-0302(88)79951-8.

Rogers, G.W., Van Arendonk, J.A.M., McDaniel, B.T., 1988b. Influence of involuntary culling on optimum culling rates and annualized net revenue. J. Dairy Sci. 71, 3463–3469. https://doi.org/10.3168/jds.S0022-0302(88)79952-X.

Rushen, J., de Passillé, A.M., 2013. The importance of improving cow longevity. In: Cow Longevity Conference. Tumba, Sweden, pp. 3–21.

Santman-Berends, I.M.G.A., Buddiger, M., Smolenaars, A.J.G., Steuten, C.D.M., Roos, C. A.J., Van Erp, A.J.M., Van Schaik, G., 2014. A multidisciplinary approach to determine factors associated with calf rearing practices and calf mortality in dairy herds. Prev. Vet. Med. 117, 375–387. https://doi.org/10.1016/j.prevetmed.2014.07.011.

Schewe, R.L., Kayitsinga, J., Contreras, G.A., Odom, C., Coats, W.A., Durst, P., Hovingh, E.P., Martinez, R.O., Mobley, R., Moore, S., Erskine, R.J., 2015. Herd management and social variables associated with bulk tank somatic cell count in dairy herds in the eastern United States. J. Dairy Sci. 98, 7650–7665. https://doi.org/10.3168/jds.2014-8840.

Schuster, J.C., Barkema, H.W., De Vries, A., Kelton, D.F., Orsel, K., 2020. Invited review: academic and applied approach to evaluating longevity in dairy cows. J. Dairy Sci. 103, 11008–11024. https://doi.org/10.3168/jds.2020-19043.

Smillie, L.D., Jackson, C.J., 2006. Functional impulsivity and reinforcement sensitivity theory. J. Pers. 74, 47–84. https://doi.org/10.1111/j.1467-6494.2005.00369.x.

Sorge, U.S., Kelton, D.F., Lissemore, K.D., Sears, W., Fetrow, J., 2007. Evaluation of the dairy comp 305 module "cow value" in two Ontario dairy herds. J. Dairy Sci. 90, 5784–5797. https://doi.org/10.3168/jds.2006-0813.

Stekhoven, D.J., Bühlmann, P., 2012. Missforest-non-parametric missing value imputation for mixed-type data. Bioinformatics 28, 112–118. https://doi.org/10.1093/bioinformatics/btr597.

Tarabla, H.D., Dodd, K., 1990. Associations between farmers' personal characteristics, management practices and farm performance. Br. Vet. J. 146, 157–164. https://doi.org/10.1016/0007-1935(90)90008-Q.

Van Arendonk, J.A.M., 1985. Studies on the replacement policies in dairy cattle. II. Optimum policy and influence of changes in production and prices. Livest. Prod. Sci. 13, 101–121. https://doi.org/10.1016/0301-6226(85)90014-4.

van den Borne, B.H.P., Jansen, J., Lam, T.J.G.M., Van Schaik, G., 2014. Associations between the decrease in bovine clinical mastitis and changes in dairy farmers' attitude, knowledge, and behavior in the Netherlands. Res. Vet. Sci. 97, 226–229. https://doi.org/10.1016/j.rvsc.2014.06.017.

Van Pelt, M.L., De Jong, G., Veerkamp, R.F., 2016. Changes in the genetic level and the effects of age at first calving and milk production on survival during the first lactation over the last 25 years. Animal 10, 2043–2050. https://doi.org/10.1017/S1751731116001282.

Viira, A., Omel, R., Värnik, R., Luik, H., Maasing, B., Põldaru, R., 2015. Competitiveness of the Estonian dairy sector, 1994–2014. J. Agric. Sci. 26, 84–105.

Weigel, K.A., Palmer, R.W., Caraviello, D.Z., 2003. Investigation of factors affecting voluntary and involuntary culling in expanding dairy herds in Wisconsin using survival analysis. J. Dairy Sci. 86, 1482–1486. https://doi.org/10.3168/jds.S0022-0302(03)73733-3.

Willock, J., Deary, I.J., McGregor, M.M., Sutherland, A., Edwards-Jones, G., Morgan, O., Dent, B., Grieve, R., Gibson, G., Austin, E., 1999. Farmers' attitudes, objectives, behaviors, and personality traits: the Edinburgh study of decision making on farms. J. Vocat. Behav. 54, 5–36. https://doi.org/10.1006/jvbe.1998.1642.