Livestock Science 250 (2021) 104591

Contents lists available at ScienceDirect

Livestock Science

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

Dairy farmers' heterogeneous preferences for animal welfare-enhancing flooring properties: A mixed logit approach applied in Sweden

E. Owusu-Sekyere [a,b,*], H. Hansson [a,c], E. Telezhenko [d]

[a] *Department of Economics, Swedish University of Agricultural Sciences, Uppsala, Sweden*
[b] *Department of Agricultural Economics, University of the Free State, Bloemfontein 9300, South Africa*
[c] *Department of Economics, Swedish University of Agricultural Sciences, Uppsala, Sweden*
[d] *Department of Biosystems and Technology, Swedish University of Agricultural Sciences, Uppsala, Sweden*

HIGHLIGHTS

- Heterogeneous preferences exists for dairy farmers' choice of flooring attributes.
- Swedish dairy farmers prefer low slip risk to be the most important floor attribute.
- The next important attribute preferred by the farmers is floor softness.
- Preferences for low abrasive floors are influenced by gender.
- Swedish dairy farmers are willing to pay for floors that improve animal welfare.

ARTICLE INFO

Keywords:
Animal welfare
Dairy cows
Dairy farmers
Floor systems
Latent attitudes
Sweden

ABSTRACT

In this paper, we examine preferences for flooring properties that enhance animal welfare in dairy cattle barns among a sample of Swedish dairy farmers. The findings reveal that respondents differ in their choice of flooring properties that improve farm animal welfare. The findings also show that they consider low-slip risk and the softness of floors to be the most important properties. Findings from a latent variable model revealed that floor packaging and installation, workability and animal welfare are important factors that explain the respondents' preferences for different types of floors. The findings demonstrate that dairy farmers who prefer soft, low-slip and less abrasive floors are influenced by the way the floors are incorporated and installed into the building design, the ease with which other tasks can be performed after installing the flooring and the welfare that the specific flooring provides for the animals. The findings contribute relevant insights that are needed for the promotion and adoption of farm management practices that improve animal welfare.

1. Introduction

European dairy farming is progressively investing in farm management practices that enhance animal welfare (Barkema et al., 2015; Vanhonacker et al., 2008). The drive to improve animal welfare is a consequence of the increasing body of scientific knowledge about animal suffering and the rising public awareness of animal welfare (de Jonge and van Trijp, 2013; Horgan and Gavinelli, 2006; Leonardsson, 2011; Lagerkvist and Hess, 2011). The drive to improve animal welfare is also linked to the potential relationship between animal welfare and productivity and economic performance (Hansson et al., 2018; Norwood and Lusk, 2011). However, it is worth mentioning that an increase in productivity does not necessarily mean improved welfare and vice versa.

Several stakeholders, including veterinarians, consumers and various pressure groups, directly or indirectly contribute to the drive to improve animal welfare (Verbeke, 2009). However, the role of farmers in maintaining and improving animal welfare is crucial (Kauppinen et al., 2010, Kauppinen et al., 2012), but is often not addressed by researchers. In particular, it is the farmers who make the actual decisions concerning what animal welfare measures to adopt, and thereby ultimately determine the living conditions of animals in agricultural production. Because of this, it is important to understand the farmers' decisions and the factors that drive farmers' decision in situations that affect animal welfare (Vanhonacker et al., 2008).

* Corresponding author at: Department of Economics, Swedish University of Agricultural Sciences, P.O.Box 7013, Uppsala SE-75007, Sweden.
E-mail address: enoch.owusu.sekyere@slu.se (E. Owusu-Sekyere).

https://doi.org/10.1016/j.livsci.2021.104591
Received 27 July 2020; Received in revised form 30 April 2021; Accepted 6 June 2021
Available online 10 June 2021

One of the housing management practices that is gaining particular attention from dairy farmers is the type of flooring systems used in alleys and waiting areas in free-stall housing, because animals have direct contact with floors, and this has direct or indirect effects on animal welfare (Bergsten et al., 2015; Platz et al., 2008). Exposure to insufficient bedding and poor walking surfaces in cattle barns have been repeatedly addressed as risk factors for claw disorders and lameness (Barker et al., 2010; Potterton et al., 2012). Claw and leg disorders associated with lameness are considered to be one of the most important animal welfare issues in dairy production , and is the major cause of mortality due to on-farm euthanasia (Alvåsen et al., 2014).

Slippery floors impede the cows' movement and the dissipation of heat (Palmer et al., 2012; Telezhenko et al., 2017). Thus, inappropriate flooring systems may cause both lameness and impair reproduction, contributing to major economic losses in milk production (Hogeveen et al., 2017). Reducing the slipperiness and excessive abrasiveness of alley floors has been shown to provide better welfare for animals as well as better claw health (Rushen and de Passille, 2009; Bergsten et al., 2015). Floor softness is a property that positively affects the welfare and movement of dairy cows. Cows prefer to stand and walk more on softer surfaces (Platz et al., 2008; Telezhenko et al., 2007). Softer floors have also been found to impact claw health (Bergsten et al., 2015; Randall et al., 2018). For instance, Bergsten et al. (2015) found that soft floors reduce the prevalence and severity of sole and white-line haemorrhage in dairy cows. A soft floor is considered to be instrumental for healthy feet and legs (Bergsten et al., 2015; Telezhenko et al., 2008; van Amstel et al., 2004).

Floor hygiene is another important aspect of floor quality, where improved hygiene ensures not only better claw health (Barker et al., 2010) with respect to infections and hygiene-related lesions but also udder cleanliness, which is important for preventing mastitis (Magnusson et al., 2008). When a soft rubber covering is fitted on top of a slatted concrete floor, it decreases drainage and this usually has negative consequences for claw health with respect to hygiene-related lesions (Bergsten et al., 2015).

In general, there are various types of flooring used in free-stall housing for dairy cows. The properties of these floors differ in terms of factors such as price and impact on animal welfare. However, little research has been done on dairy farmers' preferences for flooring solutions that enhance farm animal welfare. Hence, there is a lack of understanding of farmers' preferences for flooring properties that are more animal friendly, as well as how floors with these properties can be promoted to further improve farm animal welfare. In addition, the prevailing knowledge is inadequate to form an understanding of how dairy farmers will respond to different flooring properties, as well as to the factors that hinder or influence the type of flooring they choose. So far, from the perspective of farmers, there is no consensus about what constitutes the ultimate flooring type, where the different components interact to create the optimal solution. The choice of a given type of flooring is ultimately the decision of the farmer, and the choice made by the farmer eventually affects the living conditions of animals in agricultural production. When choosing flooring, farmers need to rely on their own experience as well as the advice of building consultants, equipment retailers, researchers, veterinarians, etc., which may result in conflicting recommendations. In addition, to find the ultimate flooring type for dairy production, where the different components interact in an optimal manner, the attitudes of the dairy farmers must be considered as the farmers' attitudes influence their behaviour (Bruijnis et al., 2013). Indeed, the inclusion of attitudinal and other psychological constructs into choice models has been found to provide a better explanation for the decision-making process (Paulssen et al., 2014). It also helps improve the behavioural content in choice models (Mariel et al., 2015; Paulssen et al., 2014).

The aim of this study is to investigate Swedish dairy farmers' distinct preferences for flooring properties in dairy cattle barns using discrete choice experimental data. Furthermore, we examine how farmer's attitudes towards the functions of the flooring influence their choice of different flooring systems as defined by their properties. In this way, we aim to understand farmers' perspectives regarding the different types of flooring used in dairy cattle housing.

2. Materials and methods

2.1. Empirical model

The dairy farmers' choice of flooring is assumed to be based on random utility theory (McFadden 1974; Norwood and Lusk, 2011). The random utility theory assumes individuals to be rational and preferring products that give them the highest utility (McFadden, 1974). The utility attained by individuals for a given choice is assumed to consist of deterministic and random components (McFadden 1974; Norwood and Lusk, 2011). In this study, we posit that the decision of the dairy farmers in relation to floor types is based on the expected benefits associated with the flooring type. Examples of such expected benefits include the positive effects of improved flooring solutions on production as highlighted in the introduction, possible government investment support for the reconstruction of animal housing in a way that improves animal welfare, and support for improved hoof health for dairy cows; this type of support exists in Sweden.

Following the rational cognitive process of utility maximization, the utility of a specific type of floor chosen by a farmer is assumed to be derived from the sum of utilities the farmer associates with the properties of the floor. When faced with floor choices that have different types of properties, farmers are assumed to choose flooring that will provide them with the highest level of utility[1] (Hensher and Greene 2003; McFadden 1974). We assumed that the utility derived from a given floor type can consist of pecuniary as well as non-pecuniary benefits associated with keeping the dairy herd on a specific type of floor, including benefits associated with enhanced animal welfare. Thus, we assume that a rational dairy farmer *f* chooses flooring alternative *i* in choice scenario *s* when faced with available options$\mathrm{Q_{fs}}$in such a way that utility is maximized. Let $\mathrm{U_{ifs}}$ denote the utility that farmer *f* obtains from choice scenario *s* and $\mathrm{U_{kfs}}$ denote utility for the status quo alternative *k*. Thus the model dictates that the farmer will choose floor scenario *s* if $\mathrm{U_{ifs}} > \mathrm{U_{kfs}}; \forall_k \neq i, k \in \mathrm{Q_{fs}}$. The utility $\mathrm{U_{ifs}}$of option *i* for dairy farmer *f* in choice scenario *s* is expressed as:

$$\mathrm{U_{ifs}} = \mathrm{V_{ifs}} + \nu_{\mathrm{ifs}} \quad (1)$$

Where $\mathrm{U_{ifs}}$is the utility of option *i* for dairy farmer *f* in choice scenario *s*, ν_{ifs} denotes the typical and deterministic utility and $\nu_{\mathrm{ifs}}$is the error term (*i.i.d.*). Under homogeneity assumptions, the representative utility is based on the trade-offs between the properties, and this leads to a multinomial logit model (MNL) expressed as:

$$\mathrm{V_{if}} = \beta_{\mathrm{m}} \cdot \mathrm{Z_{mi}} \quad (2)$$

Where Z_{mi}represents the properties with level m of floor solution alternative i, and β_{m}represents the regression coefficients that are explained as marginal utilities. To account for the differences in preferences for the flooring alternatives, a stochastic component is added to the marginal utilities which results in a mixed logit (MXL) model (Hensher and Greene, 2003) expressed as:

$$\mathrm{V_{if}} = (\beta_{\mathrm{m}} + \lambda_{\mathrm{mf}}) \cdot \mathrm{Z_{mi}} \ (\text{MXL without interactions}) \quad (3)$$

Where Z_{mi}denotes the properties of the flooring alternatives where levels m and β_m represent coefficients explained as marginal utilities,

[1] We refer readers interested in detailed utility maximization and mixed logit approaches to Hensher, D., Greene, W. 2003. The mixed logit model: The State of Practice. Transp. 30, 133–176 ; McFadden, D. 1974. Conditional Logit Analysis of Qualitative Choice Behaviour, in Zarembka, P. (ed.). Frontiers in Econometrics. New York: Academic Press. 105-142.

λ_{mf} is a vector of parameters representing dairy farmers' deviation from the mean marginal utilities. Each dairy farmer attains a given marginal utility expressed as $\beta_{mf} = (\beta_m + \lambda_{mf})$ from the flooring properties. λ_{mf} is assumed to be distributed normally with a zero mean. Also, the correlations across product alternatives and choice scenario *s* are presumed to be zero. The characteristics of the farmer and farm operations (X_{mi}) and floor-related attitudes (ϑ_{lf}) are modelled deterministically as an MXL model with interaction terms. Scores on floor-related attitudinal indicators (φ_{lf}) for latent variables *l* are specified to capture the effects of scores on their resultant latent variable λ_{lk} and expressed as:

$$\varphi_{lf} = \hbar_{lf} \cdot \gamma_{lk} + \mu_{lf} \tag{4}$$

Where φ_{lf} is the score for dairy farmer f on the k^{th} indicator of latent variable γ_l, $\hbar_{lf} \cdot \gamma_{lk}$ is a linear function and the deterministic component, μ_{lf} denotes the measurement error in a given score. μ_{lf} is assumed to be uncorrelated across indicators with *i.i.d.,* and $\hbar_{lf}$ representing the factor loadings, which capture the effects of γ_l on $\hbar_{lf}$. The goodness of fit of Eq. (4) can be tested using measures such as chi-square, root mean square error of approximation (RMSEA), comparative fit index (CFI) and standardized root mean square residual (SRMR) (Bagozzi and Yi, 2012). Following Eq. (4), the floor-related attitudinal constructs are specified so that they may be partly explained by the farm and farmer characteristics and expressed as:

$$\gamma_{lk} = \sum_p \tau_{lp} . x_{pf} + \varsigma_{lf} \tag{5}$$

Where τ_{lp} represents estimated coefficients that capture the effects of the p^{th} dairy farmer or farm characteristic denoted by x_p, ς_{lf} denotes the error term with normal *i.i.d.* assumption and permitted correlation across latent variables. The scores on the floor-related attitudinal indicators (φ_{lf}) are then incorporated into the MXL model as interaction effects together with the farm and farmer characteristics as:

$$V_{if} = \beta_m . Z_{mi} + \left(\sum_t \alpha_{mt} \cdot X_{mi} + \sum_l \lambdabar_{ml} \cdot \varphi_{lf} \right) \cdot Z_{mi} \ (\text{MXL with interactions}) \tag{6}$$

where α_{mt} and $\lambdabar_{ml}$ are vectors of parameters to be estimated for the interactions with the farmer and farm characteristics and the floor-related property variables, respectively. When considering five floor properties with a total of twelve levels (Table 2), the interaction with all the floor-related attitudinal indicators, farm and farmer characteristics could result in several interaction effects in the model. Hence, there is a need to use an interaction variable selection procedure to keep the model manageable. The MXL model accounts for differences at the individual level and calculates mean monetary valuations.

2.2. Sampling and data

The paper used survey data collected from a sample of Swedish dairy farmers using an online survey. The online administration of the questionnaire, compared to pen-and-paper surveys or face-to-face interviews, was considered feasible and efficient in Sweden where about 98% of the population has internet access in the home (Swedish Internet Foundation, 2019).

Inclusion criteria were that the farm i) should specialize in dairy production and ii) should be large enough to provide full-time work for at least the farmer himself/herself. The latter criteria ensured that very small farms, which are kept mostly for lifestyle and recreational reasons, were not included. An initial random sample of 700 individual farms was selected from the official register of farms in Sweden, which is operated by Statistics Sweden, taking the inclusion criteria into account. To ensure confidentiality and respondent anonymity, a market research company collected the data on behalf of the research group, which only received anonymized survey data. Data collection took place in late November and the first half of December 2019.

From the initial sample of 700 dairy farms, we excluded 3 institutional farms (high-school and university farms). The remaining 697 dairy farmers were thus invited to participate in the survey by mail, and follow up was carried out by text message and e-mail. After two additional reminders were sent via text message and email, a total of 246 responses were received (response rate ~35%). However, after excluding incomplete responses from the total number of responses received, 142 responses were viable; the effective response rate was thus ~20.37% (i.e., 142/697).

The questionnaire was divided into three sections. The first section requested information on farmer and farm characteristics, such as the number of years spent in dairy farming, herd size, production system (i.e. conventional, organic), housing system (e.g. tie stalls only, loose housing only or loose housing and tie stalls) and milk output. The second section contained questions relating to farmers' attitudes towards the floors used in alleys and waiting areas, floor packaging, floor workability and the animal welfare associated with different types of flooring. The final section focused on farmers' preferences for and choice of flooring properties in a choice experiment setting.

2.3. Experimental design

The study employed a choice experimental design as not all the dairy farmers had invested in new flooring at the time of the survey. Therefore, in order to create a comparative situation, all the farmers were presented with a hypothetical scenario in a choice experiment that corresponded to what they might encounter in a real-world situation (Norwood and Lusk, 2011). The discrete choice experiment allowed the dairy farmers to choose between different flooring solutions with different combinations of flooring properties. The attributes considered in the choice experiment included risk of slipping, abrasion, softness, manure removal technique, duration of quality maintenance, cost and source of information on flooring, claw and leg health (not included in the present analysis). The properties and their levels are shown in Table 1. Risk of slipping and abrasion attributes have three attribute levels consisting of low, average and high. Softness attribute has two levels (i.e. soft, hard). Manure removal technique attribute has two levels (i.e. mechanical scraper, robotic scraper). The duration of quality maintenance attribute has two levels (i.e. five years, ten years). The cost attribute has three levels including 400 SEK per m^2, 750 SEK per m^2 and 1300 SEK per m^2.

Attributes were obtained from previous studies on the impact of different flooring systems on animal welfare (Telezhenko et al., 2009; Bergsten et al., 2015; Van der Tol et al., 2005) and were further discussed with Swedish animal health and welfare experts. The cost of installation and of manure removal were obtained from construction companies involved in the sale of flooring materials and floor installation as well as from building consultants.

In this study, slip risk and abrasion were effect coded in order not to confound the utility function's grand mean and to account for non-linear effects in the property levels (Hensher et al., 2005). Softness, manure removal and quality maintenance properties and their levels were

Table 1
Flooring properties and levels in choice experiment.

Properties	Levels	Coding
Risk of slipping	Low, Average, High	Effect coded
Abrasion	Low, Average, High	Effect coded
Softness	Soft, Hard	Dummy coded
Manure removal	Mechanical scraper, Robotic scraper	Dummy coded
Duration	Five year (70 SEK per m^2), Ten years (130 SEK per m^2)	Dummy coded
Installation cost (m^2)	400 SEK per m^2, 750 SEK per m^2, 1300 SEK per m^2	Continuous

dummy coded. The choice cards were designed using fractional factorial main effects. The design resulted in 32 possible flooring solutions, and from these, 16 choice sets were generated using a cyclic design with each choice set having options A, B and a "no option" (see sample choice set in Appendix A). The choice sets generated were divided into blocks of four, with each block containing four choice sets. Each respondent was randomly allocated to a block. The choice sets were blocked to reduce the number of choice sets presented to each farmer in the surveys. The choice sets were in Swedish.

3. Results

3.1. Descriptive characteristics of farms and farmers

The definitions and summary statistics of the variables are presented in Table 2. In terms of herd size, the average number of dairy cows, heifers aged one to two years and calves under 12 months were 101, 46 and 55, respectively. The average number of dairy cows observed in this study is consistent with the average dairy herd of 101, as reported by the Swedish Board of Agriculture in 2020 (Agriwise, 2021). The average milk yield of 10,315 kg ECM does not differ significantly from the average milk yield of 10 405 kg ECM reported by the Swedish Board of Agriculture in 2020 (Agriwise, 2021). Twenty-six percent of the dairy farms were certified organic, and the remaining 74% used conventional farming methods. The 26% figure for organic farms is higher than the organic milk production in Sweden, which is 17%, as reported in 2018 (Swedish Board of Agriculture, 2019). Other farm characteristics included in the survey are shown in Table 2.

3.2. Latent variable model results regarding farmers' attitudes towards floor packaging, workability and animal welfare

Table 3 shows the results of the Mimic model which tests how farmers' attitudes towards floors used in alleys and waiting areas relate to their observed indicators and to farm and farmer characteristics. Three latent attitudinal constructs were identified, consisting of floor packaging & installation, floor workability and animal welfare. Details outlining which indicators each construct consists of are presented in the measurement model in Table 3. The descriptive statistics for the indicators floor packaging, floor workability and animal welfare are presented in Appendix B.

The latent attitudinal construct, floor packaging & installation, is defined by indicators consisting of the inclusion of the floor as part of the whole building design (FPI-1) and ease of installation (FPI-2). The construct, floor workability, consists of how well the floor is suited to the general operation of the farm (FWI-1), how easy the floor is to keep clean (FWI-2), how suited the floor is to the manure cleaning technique (FWI-3), how suitable the floor is to being walked on by the animals (FWI-4) and being driven on with motor vehicles (FWI-5), as well as ease of removal or replacement (FWI-6). Finally, the animal welfare constructs consist of how good a grip the floor provides and how it prevents animals slipping (ACI-1), encourages animals to move around (ACI-2), facilitates natural behaviour (ACI-3), promotes good claw health (ACI-4) and guarantees better animal welfare (AC1-5). These latent attitudinal constructs were first explored using principal factor analysis and confirmed using the structural equation modelling approach (MIMIC model).

The hypothesized latent constructs were validated using composite reliability (CR) and average variance extracted (AVE) measures. The CR measures for the three attitudes towards floor packaging & installation, workability and animal welfare were 0.75, 0.76 and 0.77 with an AVE of 0.79, 0.75 and 0.76, respectively. The hypothesized latent constructs are validated by the CR and AVE measures. The MIMIC model's fitness was tested using Chi-square, RMSEA, CFI and SRMR, which is presented in Table 3 below. The Chi-square, RMSEA, CFI and SRMR measures presented below show good model fitness and validity.

The results in Table 3 further indicate that including indicators of the flooring system as part of the whole building design (FPI-1) and ease of

Table 2
Descriptive statistics of farms and farmers.

Variables	Description	Min.	Max.	Mean	Std. dev.
Age	Age of farmer	25	76	51	12
Number of years in dairy farming	Number of years in dairy farming	1	52	24	13
Income from dairy farming	Proportion of farm's total revenue from dairy production (%)	10	100	76	17
Disposable income from dairy farming	Proportion of household's total disposable income (after tax) from dairy production (%)	10	100	65	32
Milk yield	Average milk yield per cow (energy-corrected milk ECM/year) in kg	6,500	13,790	10,315	1,360
Dairy cows	Number of dairy cows	12	450	101	81
Heifers	Number of heifers aged 1-2 years	6	157	46	37
Calves	Number of calves under 12 months	7	702	55	66
		Categories			*%*
Gender	Gender of respondent	Male (1)			78
		Female (0)			22
Agric. education	Whether the dairy farmer has an agricultural education	Yes(1)			53
		No (0)			47
Production system	System of dairy production	Conventional (1)			74
		Organic (0)			26
Housing system	Current dairy housing system used by the farmer	Tie stalls only			22
		Loose housing only			59
		Loose housing and tie stalls			19
Off farm	Whether the dairy farmer has any off-farm employment	Yes (1)			13
		No (0)			87
Flooring problems	Whether the farmer has recorded any floor-related diseases or injuries on the dairy farm	Yes (1)			68
		No (0)			32
Rebuilding of barn	Whether the farmer has rebuilt his or her barn before	Yes (1)			68
		No (0)			32

All the respondents have been classified by Statistics Sweden as being i) specialist dairy farmers and ii) at a minimum full-time farmers.

Table 3
Estimates of the mimic model.

Variables	Floor packaging & installation	Floor workability	Animal welfare
Structural model	Coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)
Age	0.02***(0.00)	0.04**(0.02)	0.06*** (0.02)
Male	0.12**(0.05)	-0.34*** (0.04)	-0.24*** (0.04)
Agric education	0.34***(0.04)	0.19***(0.03)	0.22*** (0.03)
Number of years in dairy farming	-0.05**(0.00)	0.03(0.02)	0.01 (0.02)
Income from dairy farming	-0.03***(0.00)	0.04***(0.08)	0.05*** (0.00)
Disposable income from dairy farming	0.22***(0.04)	0.01**(0.00)	0.17*** (0.05)
Off farm	0.37***(0.05)	0.02 (0.05)	0.05(0.04)
Milk yield	0.12***(0.01)	-0.01 (0.01)	0.01 (0.01)
Floor problems	0.08**(0.04)	0.12***(0.04)	0.19*** (0.03)
Conventional system	0.15***(0.05)	0.15***(0.04)	0.18*** (0.04)
Explained variance	*0.32*	*0.21*	*0.14*
Measurement model			
FPI -1	0.72***(0.09)		
FPI-2	0.57***(0.08)		
FWI-1		0.13***(0.06)	
FWI-2		1.01***(0.02)	
FWI-3		1.05***(0.02)	
FWI-4		0.92***(0.02)	
FWI-5		0.79***(0.01)	
FWI-6		0.74***(0.03)	
ACI-1			0.05*** (0.00)
ACI-2			0.94*** (0.02)
ACI-3			1.07*** (0.01)
ACI-4			0.93*** (0.02)
ACI-5			0.82*** (0.02)
Intercorrelation			
Floor packaging & installation	1		
Floor workability	0.06	1	
Animal welfare	0.09	0.86***	1

† Goodness of fit indicators: RMSEA=0.05, CFI=0.96, TLI=SRMR= 0.02; Chi-square=1.44.
†***, ** indicate significance at 1% and 5% levels.

installation (FPI-2) is significantly and positively correlated to the floor packaging & installation attitudinal dimension. Indicators relating to how well the floor is suited to the general operation of the farm (FWI-1), how easy the floor is to keep clean (FWI-2), how suited the floor is to the manure cleaning technique (FWI-3), how suitable the floor is to being walked on by the animals (FWI-4), as well as being driven on with motor vehicles (FWI-5) and the ease with which it can be removed or replaced in whole or in part (FWI-6), are all significantly and positively correlated to the attitudinal dimension floor workability. Indicators related to how good a grip the floor provides and how it prevents animals slipping (ACI-1), encourages the animals to move around (ACI-2), facilitates natural behaviour (ACI-3), promotes good claw health (ACI-4) and guarantees better animal welfare (AC1-5) were all highly significant and positively correlated to the animal welfare dimension. The significance of all the indicators confirms the contribution of the indicators to the latent constructs.

The results show that age and agricultural education are positively correlated to the attitudinal dimensions floor packaging & installation, workability, and animal welfare. Being a male dairy farmer is negatively correlated to the attitudinal dimensions floor workability and animal welfare, but positively correlated to the attitudinal dimension floor packaging and installation. The experience of the dairy farmers is negatively correlated to the attitudinal dimension floor packaging and installation. Having a higher proportion of farm income from dairy production is positively correlated to the attitudinal dimensions floor workability and animal welfare, but negatively correlated to the attitudinal dimension floor packaging and installation. Having a higher proportion of disposable income from dairy production is positively correlated to the attitudinal dimensions floor packaging & installation, workability and animal welfare. A conventional production system is positively correlated to the attitudinal dimensions floor packaging & installation, workability and animal welfare. The farmers' experience in terms of floor-related diseases and injuries is positively correlated to the attitudinal dimensions floor packaging & installation, workability and animal welfare.

The farm and farmer characteristics explained only 32%, 21% and 14% of the variations in the attitudinal dimensions floor packaging & installation, workability and animal welfare, respectively. The remaining unexplained variance captured by the error terms is significantly distributed between the latent variables as indicated by the error term inter-correlations, particularly workability and animal welfare.

3.2. Variation in preferences for flooring properties

Table 4 presents the mixed logit estimates of dairy farmers' preferences for flooring properties. We tested the suitability of the conditional logit and mixed logit using Akaike information criteria (AIC) and the Bayesian information criteria (BIC), as well as McFadden's pseudo R^2, and found that the mixed logit outperformed the conditional logit model. Therefore, we have presented the results of the mixed logit model. McFadden's pseudo R^2 value of 0.27 was within the acceptable model fitness range of (0.2–0.4) (Hensher et al., 2005). The results in Table 4 do not include interaction terms. A positive utility estimate for a given property level indicates an increase in utility compared with the base category, making the choice of alternative flooring systems that enhance animal welfare more probable, whereas a negative estimate indicates a reduction in utility. Specifically, the results indicate that the marginal utility of floor *costs* (i.e., *installation and maintenance*) is significantly negative, meaning that high costs for installation and maintenance of a floor decreases utility and the likelihood that a farmer will adopt alternative flooring solutions.

The utility estimate for *low-slip risk* is highly significant and positive, suggesting that low-slip risk increases utility and the likelihood that dairy farmers will choose a given flooring solution relative to the *high-slip risk* (base category) floors. In terms of abrasiveness, the results indicate that the marginal utility of *average and high levels of abrasion* is highly significant and negative relative to a low abrasion level. These results imply that utility, and the likelihood that dairy farmers will choose a given flooring solution, decreases if the floor exhibits average

Table 4
Estimates of the mixed logit model without interaction terms.

Properties	Levels	Coeff. estimates	Std. estimates
Risk of Slipping	Low	2.62*** (0.66)	4.38*** (1.04)
	Average	0.82 (0.48)	1.73** (0.87)
Abrasion	Average	-1.10*** (0.41)	-1.54** (0.77)
	High	-1.26*** (0.41)	1.16** (0.58)
Softness	Soft	1.39** (0.58)	3.94*** (1.00)
Manure removal	Robotic scraper	-1.64*** (0.60)	1.64 (0.85)
Duration	Ten years	1.17** (0.49)	2.29*** (0.76)
None		-1.00** (0.00)	0.92*** (0.28)
Cost		-0.002*** (0.000)	
Number of observations			1,704
Log likelihood			-477.47
Pseudo-R^2			0.27
Number of respondents			142

†***, **, show significance at 1% & 5% levels.

to high levels of abrasion.

The marginal utility of *soft* floors is highly significant and positive, implying that soft floors increase utility and the probability that farmers will adopt a given flooring solution. The likelihood of farmers adopting a given flooring solution decreases with the use of a *robotic scraper* as a cleaning device relative to a *mechanical scraper*, as shown by the significantly negative marginal utility estimate. The utility estimate of a *ten-year* duration was significant and positive, suggesting that a *ten-year* duration for a floor increases utility and the likelihood that dairy farmers will adopt a given flooring solution. Finally, the negative and significant estimate for the *none-option* (status quo), i.e., a hypothetical scenario where dairy farmers do not adopt any flooring solution, results in a significant decrease in utility. This suggests the existence of a need to adopt some type of flooring solution. The significant standard deviation estimates for all the properties except the *robotic scraper* indicate the variation in choice for the properties . The significant standard deviation estimates also imply that monetary values attached to the properties cannot be explained as representing the entire samples (Owusu-Sekyere et al., 2014).

To account for the differences preference and marginal utility, we included interaction effects in the MXL model and have presented the results in Table 5. The results in Table 5 reveal that all the properties in the MXL model with interaction terms have the same signs as the model without interaction terms with the exception of *low abrasion*, which is positive but insignificant. Furthermore, all the properties in the interaction model with the exception of the ten-year duration exhibited differences in the preferences as shown by the significant standard deviation estimates. The interaction effects show that the dairy farmer's age and conventional production system negatively affects their preference for floors with a *low-slip risk*. On the other hand, a preference for low-slip risk is positively influenced by a higher income from dairy farming and the construct animal welfare.

Preferences for *less abrasive* floors are positively influenced by male gender, engagement in off-farm activities, and the occurrence of floor-related injuries and diseases. Floor packaging and installation negatively influence a preference for less abrasive floors. Preferences for *soft* floors are positively influenced by a high income from dairy farming. On the other hand, a farmer's age negatively influences preferences for *soft* floors.

Finally, a preference for the use of a *robotic scraper* is negatively influenced by age but positively influenced by the constructs higher income from dairy farming, conventional production system, and floor packaging and installation. The interaction for *ten-year* maintenance and the none-option were not included due to convergence issues.

The average willingness to pay for particular flooring properties is presented in Table 6. The results indicate that, on average, dairy farmers are willing to pay a higher price for *low-slip risk* and *soft* floors, respectively. This is followed by a *ten-year* maintenance period and *average slip risk*, respectively. Furthermore, the dairy farmers are willing to pay a higher premium to switch from a *mechanical scraper* to a *robotic scraper*. Similarly, the dairy farmers are willing to accept compensation for costs associated with switching from *low abrasion* to *average or higher abrasion* levels.

Table 5
Estimates of the mixed logit model with interaction terms.

Main effects	Coefficient estimates	Std. estimates
Low-slip risk	1.64 *** (0.48)	3.62*** (0.68)
Low abrasion	0.13 (0.32)	1.38** (0.61)
Soft	1.43*** (0.56)	2.70*** (0.68)
Robotic scraper	-1.99*** (0.61)	2.84*** (0.93)
Ten years	1.31*** (0.36)	1.24 (0.68)
None	-0.78*** (0.30)	1.03** (0.41)
Cost	-0.002*** (0.000)	
Interaction effects		Coefficient Estimates
Low-slip risk	x Age	-0.04** (0.02)
	x Income from dairy farming	0.02** (0.00)
	x Agric education	-1.08 (0.60)
	x Conventional system	-1.36** (0.65)
	x Floor workability	-1.49 (0.91)
	x Animal welfare	2.05** (1.01)
Low abrasion	x Gender	1.68*** (0.61)
	x Disposable income from dairy farming	-0.04 (0.01)
	x Off farm	0.89** (0.36)
	x Conventional system	-1.11 (0.67)
	x Floor problems	0.55** (0.21)
	x Floor packaging & installation	-0.78** (0.33)
	x Floor workability	0.51 (0.30)
Soft	x Age	-0.05** (0.02)
	x Gender	1.09 (0.64)
	x Conventional system	-1.64 (0.90)
	x Income from dairy farming	0.10*** (0.01)
	x Floor packaging & installation	1.00 (0.59)
Robotic scraper	x Age	-0.08** (0.04)
	x Income from dairy farming	0.04** (0.01)
	x Conventional system	5.66** (2.89)
	x Floor packaging & installation	1.75** (0.89)
Log likelihood		-489.24
Pseudo-R^2		0.22
LR		149.30***
No. of observations		1,704
Respondents		142

†***, **, show significance at 1% & 5% levels.

4. Discussion and conclusions

In this paper, we examine dairy farmers' preferences for alternative flooring solutions that enhance animal welfare in dairy cattle barns. This study uses data collected from a sample of Swedish dairy farmers. This study builds on previous studies that examined different flooring solutions and the characteristics that affect animal welfare (Barker et al., 2010; Franck et al., 2007; Telezhenko et al., 2008; van Amstel et al., 2004) by investigating how flooring properties influence dairy farmers' choice of flooring solution as well as how farm and farmer characteristics influence choices. By doing so, the paper reveals relevant factors that influence the farmers' preferences for flooring solutions that can improve animal welfare. With the use of MIMIC and mixed logit models, the paper highlights sources of variation in preferences for flooring properties that can improve the welfare of dairy cows. Thus, the study contributes to the existing body of knowledge in the following ways: Firstly, we contribute to the knowledge of relevant factors that hinder or influence a dairy farmer's choice of alternative flooring solutions, by using an empirical model that accounts for differences in preferences. In particular, this study is the first comprehensive study to objectively investigate the fundamental features of the most common and appropriate flooring solutions for dairy cows, and to assess farmers' preferences for flooring properties. Secondly, this Swedish dairy-farm case study contributes to an understanding of the demand for housing and

Table 6
Mean willingness to pay estimates of flooring properties.

Properties	Mean WTP (SEK)	95% confidence intervals
Slipperiness		Lower - Upper
Low-slip risk	1196.37	[697.38] - [1695.37]
Average slip risk	376.70	[-15.33] - [768.74]
Abrasion		
Average abrasion	-502.68	[-879.49] - [-125.87]
High abrasion	-577.67	[-1011.07] - [-144.26]
Softness	633.10	[123.61] - [1142.59]
Tenth year	534.05	[71.32] - [996.77]
Robotic scraper	-747.74	[-1294.93] - [-200.56]
None	-456.73	[-699.20] - [-235.67]

Estimates in parenthesis are 95% confidence intervals. NS: Not significant.
Exchange rate in December 2019 (1 SEK: 0.011USD).

management systems that are more animal friendly. As advanced in this section, the study findings also contribute relevant insights that are needed for designing strategies to improve animal welfare as well as targeted recommendations for farmers, particularly in terms of the adoption of farm management practices that can improve animal welfare.

There are several aspects of our findings that are worth discussing further. Findings from the latent variable model reveal the importance of floor packaging and installation, workability and animal welfare in explaining farmers' preferences for alternative flooring solutions. Thus, the findings demonstrate that dairy farmers who prefer flooring solutions with a low slip risk, less abrasion and that are soft are influenced by the way the floors are incorporated and installed in the building design, the ease with which other tasks can be performed after installing the floor and the welfare that the chosen floor provides for the animals. Low-slip risk, less abrasion and soft floors can improve animal welfare (Bran et al., 2019; Telezhenko et al., 2017; Franck et al., 2007). For instance, slippery floors can cause lameness (Bran et al., 2019) and reduce natural locomotion (Telezhenko et al., 2017). Slipperiness is regarded as one of the most undesirable properties of alley floors, as it can cause lameness (Bran et al., 2019) and impair natural locomotion (Telezhenko et al., 2017). In addition, overly abrasive floors can lead to excessive claw horn wear, which also leads to uneven force distribution and thin soles, causing claw lesions and lameness (Telezhenko et al., 2008; van Amstel et al., 2004). Moderate roughness on hard floors is usually desirable compared with hard floors with no roughness, as it increases floor friction and claw grip while allowing for claw horn wear (Franck et al., 2007). Soft floors positively affect the comfort and movement of dairy cows (Platz et al., 2008; Telezhenko et al., 2017).

Important findings also worth discussing are the trade-offs between the flooring properties. From the marginal utility estimates of the flooring properties, dairy farmers seem to perceive *low-slip risk* to be the most important property. This might be due to their understanding of the adverse effects of *high-slip risk* and its consequences on production. For instance, studies by Warnick et al. (2001) and Green et al. (2012) found that lameness, which is associated with slippery floors, can result in significant milk and financial losses. A Swedish study by Oskarsson (2010) found the cost per lame cow could amount to SEK 3,800 in cases of severe sole ulceration that need to be treated by a veterinarian. Traumatic injuries caused by slipping and falling can range from simple lesions on the claws and legs to severe injuries to muscles and nerves, as well as fractures of large bones. All of this can lead to premature culling. Mortality affects about 5% of cattle in Sweden with the average cost of culling being as high as SEK 5,500 (Oskarsson, 2010).

Variations in preferences for the property *low-slip risk* was explained through interaction with age, income from dairy farming, and conventional system of production and animal welfare. In particular, the farmer's age and conventional system of production interacted negatively with preferences for low-slip risk. The aforementioned results suggest that older farmers are less likely to prefer a given floor if they perceive the slip risk to be low or they do not think that the slip risk is important at all, compared with younger farmers. Furthermore, farmers using conventional production methods are less likely to prefer a given floor if they perceive the slip risk to be low or they do not think that the slip risk is important at all, relative to farmers using organic production methods. The negative effect of age on preference for *low-slip risk* could be attributed to the fact that older farmers are accustomed to a system of tie-stalls, and thus the slip risk may not be as relevant. In addition, younger people are expected to have a more positive view of newer technology (Issahaku and Abdulai, 2020). On the other hand, farmers who obtain a high proportion of their income from dairy production and who are strong proponents of animal welfare were found to be more likely to prefer a given floor if they perceive the slip risk to be low.

The next significant property preferred by the farmers in the study is floor *softness*. Floor softness is a property that previous studies (e.g., Telezhenko et al., 2007; Platz et al., 2008) have found to have had a positive impact on the locomotion of dairy cows. Differences in the preference for soft floors is explained by the farmer's age and the proportion of their income that is generated from dairy production. In particular, we found that older farmers are less likely to adopt soft floors.

Furthermore, the findings reveal that farmers perceive the adverse effect of abrasive floors to be serious with significant negative utilities. This is shown by the significantly negative utility estimates for a moderate to high level of abrasion versus a low level of abrasion. This finding is in line with previous studies by Telezhenko et al. (2008) and van Amstel et al. (2004), who observed that too much abrasion due to excessive roughness leads to excessive claw horn wear, which also results in uneven force distribution and thin soles, causing claw lesions and lameness. It is worth mentioning that a *low-abrasion* level was included in the interaction model and was found to be positive relative to a high-abrasion level; this is not a surprising result given that Franck et al. (2007) indicated that some level of roughness (moderate) is usually needed to increase floor friction and claw grip as well as to prevent claw overgrowth by claw horn wear. Preferences for less abrasive floors are positively correlated to the farmers' perception regarding the ease with which other tasks can be carried out on the floor, occurrence of floor-related diseases and injuries, and participation in off-farm activities, as well as male gender.

Finally, the use of a *robotic scraper* as a manure cleaning device is positively correlated to a higher income from dairy farming, a conventional system of dairy production, and the attitudinal dimension, well-packaged and easily installed floors, compared with a mechanical scraper. However, as expected, older farmers have negative preferences for the use of a robotic scraper. The common manure cleaning technique on solid floors is the use of scrapers. The use of robotic scrapers is new technique for manure cleaning on solid floors. Some farmers use bobcats and this is considered as a cheap solution with poorer hygiene. In terms of the monetary value of the flooring properties, the study brings a different perspective in terms of the costs dairy farmers are willing to incur for improvements in flooring systems. Insights gained in this study suggest that, on average, the dairy farmers' place a higher value on flooring solutions with a *low-slip risk*, followed by *soft floors* and *ten-year maintenance* of the installed floors. This finding is contrary to that of Dutch farmers who anticipated positive effects from softer floors, both in terms of health and welfare, but were not willing to pay for it (Bruijnis et al., 2013). In particular, the Swedish farmers were willing to pay approximately USD 167 more for floors with a lower slip risk compared with soft floors. The findings regarding the monetary values attached to the flooring properties can serve as motivation for construction companies and consultants to strive for better flooring designs and solutions that enhance farm animal welfare.

The study has implications for the design of strategies to increase the uptake of flooring solutions that can improve farm animal welfare. The first implication relates to the existence of differences in preferences for alternative flooring solutions defined by their properties (Carlsson et al., 2007). The selected properties have a significant impact on the welfare of dairy cows (Telezhenko et al., 2009). In designing alternative flooring systems, it is often assumed that livestock farmers are homogenous in their understanding of flooring effects on animal welfare, as well as in their choice of flooring systems. Findings in this study suggest that the dairy farmers under consideration here have differing preferences and that the variation in preferences could be attributed to variations in their understanding of the function of different flooring systems, as indicated by the varied marginal utilities for the different properties. This is supported by Bruijnis et al. (2013) who found that Dutch dairy famers' knowledge and understanding of information on cow foot health positively impacted their intention to improve foot health. This finding highlights the need to provide educational information and recommendations to dairy farmers in a way that helps them understand the effects of different floor properties on animal welfare.

The second implication relates to the attitudinal constructs floor packaging and installation, workability and animal welfare. Therefore, the perception of how floors can be incorporated and installed in the building design, the ease with which other tasks can be performed on the floor after installation and the welfare that animals can derive from the floor are highly relevant in the farmers' preferences for flooring solutions that enhance animal welfare. Hence, information about different flooring systems and how they can be incorporated into the building design, the ability to work or perform other tasks (e.g., manure cleaning) on the floor and the welfare the floor provides to animals should be communicated to farmers through reliable channels. In the Swedish context, the floors are packaged as part of the complete building concept. The floor can be supplied in one package with other stall equipment (milking equipment, stall dividers etc.). The floors can also be installed separately from other equipment, building construction. Another implication relates to the negative relationship between agricultural education and low-slip risk flooring. In the case of older farmers, it may be that in the past agricultural programs did not consider types of flooring to be a sufficiently valid or relevant topic, since some of the flooring solutions have only recently been developed (e.g., rubber mats). For the younger farmers, the findings suggest an improvement in agricultural education programs is necessary to highlight farm management practices, such as the effects of different flooring properties on productivity and animal welfare.

Based on the findings of this study, we conclude that dairy farmers in Sweden are willing to adopt flooring systems that enhance animal welfare (i.e., low-slip risk, less abrasion and soft floors). Preferences for flooring that improves animal health and welfare can be promoted through the provision of information on different flooring properties and their functions. Moreover, the likelihood that a farmer will invest in flooring that improves animal welfare depends on certain farm and farmer characteristics, which were discussed in this study. Based on these findings, we suggest that future research related to how education, policies and recommendations to encourage flooring systems that promote animal welfare should incorporate attitudinal factors to explain behavioural change. With insights from this study, strategies to promote animal welfare-enhancing flooring systems can be developed.

CRediT authorship contribution statement

E. Owusu-Sekyere: Conceptualization, Data curtion, Methodology, Formal analysis, Writing – original draft, Software, Validation, Writing – review & editing. **H. Hansson:** Funding acquisition, Supervision, Investigation, Project administration, Conceptualization, Data curtion, Investigation, Resources, Methodology, Writing – review & editing. **E. Telezhenko:** Writing – review & editing, Validation, Methodology, Funding acquisition, Investigation, Project administration.

Declaration of Competing Interest

On behalf of me and my co-authors we declare that there is no conflict of interest.

Acknowledgement

This study was funded by the Swedish Farmers' Foundation for Agricultural Research (SLF), grant no: O-18-20-161, which is gratefully acknowledged.

Appendix A. . Sample choice set

If you were to build a new barn from scratch, or if you were to undertake major reconstruction of your farm, which of the following flooring solutions would you choose? Please note that the flooring solutions may not necessarily be available on the market.

Property	Flooring solution A	Flooring solution B	None Neither A nor B. I will keep my current floor
Slippery risk	High	Average	
Abrasion	Low abrasion	High abrasion	
Softness	Soft	Soft	
Manure removal	Mechanical scraper	Robotic scraper	
Duration	Five years (70 SEK per m^2)	Ten years (130 SEK per m^2)	
Installation costs (m^2)	750 SEK per m^2	400 SEK per m^2	
Source of information on floor, claw and leg health	Building adviser	Floor salesman	
I would choose	[]	[]	[]

This property was not included in the current analysis.

Appendix B. . Descriptive statistics of indicators of attitudinal constructs in the MIMIC model

Floor packaging and installation	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Floor should come as a part of the whole building design (FPI-1)	4(2.8)	10(7.0)	39 (27.5)	60 (42.3)	29 (20.4)
Floor should be easy to install (FPI-2)	11 (7.7)	8 (5.6)	26 (18.3)	55(38.7)	42 (29.6)
Floor workability					
Floor should be well suited to my general operations (FWI-1)	1(0.7)	2 (1.4)	12 (8.5)	45 (31.7)	82 (57.7)
Floor should be easy to clean and keep clean (FWI-2)	1(0.7)	1 (0.7)	14 (9.9)	41 (28.9)	85 (59.9)
Floor should be well suited to my manure cleaning technique (FWI-3)	1(0.7)	1 (0.7)	14 (9.9)	43 (30.3)	83 (58.5)
Floor should be well suited for animals to walk on (FWI-4)	1(0.7)	-	10 (7.0)	36 (25.4)	95 (66.9)
Floor should be well suited for driving on with motor vehicles (FWI-5)	8(5.6)	10 (7.0)	41 (28.9)	36 (25.4)	47 (33.1)
Floor should be easy to remove or replace in whole or in part (FWI-6)	9(6.3)	10 (7.0)	28 (19.7)	45(31.7)	50 (35.2)
Animal welfare					
Floor should provide good grip and prevent animals slipping (ACI-1)	1(0.7)	1(0.7)	5(3.5)	35(24.6)	100(70.4)
Floor should encourage animals to move around (ACI-2)	1(0.7)	1 (0.7)	13 (9.2)	41 (28.9)	86 (60.6)
Floor should facilitate natural animal behaviour (ACI-3)	1(0.7)	1 (0.7)	8 (5.6)	35 (24.6)	97 (68.3)
Floor should promote good claw health (ACI-4)	2(1.4)	-	5 (3.5)	36 (25.4)	99 (69.7)
Floor should guarantee better animal health and welfare (AC1-5)	3 (2.1)	2(1.4)	27 (19.0)	66 (46.5)	44 (31.0)

†Values in the appendix are frequencies and percentages (in brackets).

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