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ARTICLE

Factors associated with the adoption of mobile applications (Apps) for the management of dairy herds

Factores asociados a la adopción de aplicaciones móviles (Apps) para la gestión de hatos lecheros

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Abstract: Technology is an important tool to increase a company's performance. Although there is literature related to the adoption of technology in dairy agribusinesses, information regarding the adoption and use of Apps for herd management is scarce. The objective was to explore the factors associated with the adoption of Apps in a sample of dairy agribusinesses. A structural analysis was conducted to evaluate the relationship between internal and external variables of the dairy agribusiness and the process of adoption, appropriation and use of Apps for herd management. The adoption of Apps in dairy herds can be explained by two constructs: Internal motivational factor and external motivational factor, where productivity improvement and receiving technical advice are the variables with the greatest impact.

Keywords: agribusiness, mobile technologies, structural equations, agricultural technology.

Resumen: La tecnología es una importante herramienta para incrementar el desempeño de las compañías. Aunque existe literatura relacionada con la adopción tecnológica en agronegocios lecheros, la información referente a la adopción y uso de Apps para la gestión de hatos es escasa. El objetivo fue explorar los factores asociados a la adopción de Apps en agronegocios lecheros. Se realizó un análisis estructural para evaluar la relación entre las variables internas y externas del agronegocio lechero y el proceso de adopción, apropiación y uso de Apps para la gestión de los hatos. La adopción de Apps en hatos lecheros puede ser explicada mediante dos constructos: Factor de motivación interno y Factor de motivación externo, donde el mejoramiento de la productividad y el recibir asesoría técnica son las variables de mayor impacto.

Palabras claves: agronegocios, tecnologías móviles, ecuaciones estructurales, tecnología agrícola.

Introduction

The use of information and communication technologies (ICT) in organizations can develop competencies and strategies in business models, generating benefits such as increased productivity, cost reduction, financial efficiency, and the entry into new markets (Faisal & Kisman, 2020; Vargas-Ortiz et al., 2019). In the livestock sector, ICT have provided tools that allow workload reduction, facilitates herd management and improves the quality-of-life of the producers (Tse et al., 2018). They are also considered essential for planning and controlling operations in the dairy value chain (Walse, 2016).

The adoption of ICT in production systems has accelerated the use of smartphones in agribusiness management (Chavoshi & Hamidi, 2019). The development of this technology has allowed access to mobile internet and cloud services, which has generated an increase in the number of applications for smartphones (Apps) adopted in the agriculture industry (Rose et al., 2016). It has also facilitated the access in real-time to essential information of

technical parameters which improves decision-making (Debauche et al., 2019; Krell et al., 2021). Although this technology has provided multiple benefits, the existing literature has not fully covered issues related to the adoption of Apps for dairy herd management (Michels et al., 2019). This lack of information in accordance with the specific characteristics of the dairy sector has restricted the investment in technology by the dairy producer (Luvisi, 2016); a reason which could be related to a lower rate of technology adoption in the dairy industry compared to other industries (Russell & Bewley, 2013).

Therefore, it is necessary to study the implications of the adoption of digital technologies, such as Apps, for dairy farmers in terms of reasons for investing (Steeneveld & Hogeveen, 2015), technical efficiency (Steeneveld et al., 2012) or its economic consequences (Bijl et al., 2007), among other issues. The objective of this research was to explore the factors associated with the adoption and use of Apps for dairy herd management.

Theoretical Foundation

Herd management

Dairy herd management is defined as the set of strategies in productive systems with the aim of increasing productivity (Michels et al., 2019). The management process is a necessity in agribusiness, as it increases the benefits of productive activity and long-term sustainability (Rubio, 2011). This allows organizations to adapt to environment changes and maintain competitiveness in the markets (Múnera-Bedoya et al., 2018). Organizational management activities used in dairy herds include animal selection, diet determination, personnel selection, management of technical and economic records, sanitary control, fodder management and technology use in daily tasks (Díaz & León, 2022).

Information and Communication Technologies

ICT have become essential tools for education, entertainment, and organizations, providing strategies oriented to digital literacy and digital skills (Vázquez-López et al., 2021). In the business sector, they have provided benefits such as increased profitability, access to real-time information for decision making and direct communication with other agents in the value chain (Clarke Modet & Co, 2014). In the dairy industry, the use of these technologies has generated a substantial increase in the competitiveness, effectiveness, and efficiency of the sector (Papageorgiou et al., 2020). ICT in dairy herds allow for operational diagnosis, evaluation and early detection, control of the production system, improvement of cows' well-being and producers' quality-of-life (Bovo et al., 2020). The use of ICT in dairy herds increases the adoption of mobile applications for organizational management (García-Villegas et al., 2020).

Mobile applications in the agricultural sector

Mobile applications have allowed improvement in production processes in some labor sectors and change in people's habits (Fonseca-Barrera et al., 2020). They provide users with competencies that improve their communication, reduce the workload, facilitate the process of accessing information and boost creativity (Cárdenas & Cáceres, 2019). In the agricultural sector, Apps have been implemented as tools that allow the collection, analysis, dissemination, and evaluation of data impact, which facilitates decision making in agribusiness (Oteyo et al.,

2021). This generates improvements in productivity and environmental care. The use of Apps in dairy herds has transformed production processes and provided tools for the management of livestock systems, generating competitive advantages in the market (Pérez & Lasso, 2019).

The use of technologies in agriculture as tools in productive activities promotes the optimization of processes in agribusiness (Ahumada et al., 2020). Organizations that adopt technologies in production systems generate competitive advantages in the market and increase business performance, improving the welfare of producers and increasing productivity and the economic performance of the agribusiness sector (Chavas & Nauges, 2020).

Variables associated with the use of mobile applications

The use of mobile applications in dairy herds has provided tools to improve production, administrative and commercial processes in dairy production systems (Pérez & Lasso, 2019). The factors associated with the implementation of these technologies in these are related to internal or external motivations, which influence the behavior of the producer (Conor et al., 2019).

Vieira et al. (2021) and Freitas et al. (2018), found that the health control of the cows, quality control of the milk, the reduction of the costs associated with maintaining the hygienic and sanitary quality of the milk, are factors that motivate the dairy producer to invest in technologies for their production systems. Schulze-Schwering et al. (2022), determined that the use of mobile technologies facilitates data analysis, provides real-time information for decision making and improves business management in the dairy herd, factors that motivate the producer to implement information technologies. Valeeva et al. (2007), determined the importance of farm performance, referring to productivity indicators and increased profitability are factors that motivate the dairy farmer to implement technologies in the production system.

Lam et al. (2011) established that the change in consumer behavior in the implementation of technologies is influenced by third-party financing through bonuses or penalties. Kyaruzi et al. (2019) determined that state support and the necessity to adapt to market demands are factors that influence the adoption of technologies in the agricultural production systems.

Methodology

The research was carried out in four municipalities in the north of the department of Antioquia, Colombia, and took as a sample 45 dairy production systems, selected at convenience according to the intention and availability of the producers to participate in the study. The measurement instrument was composed of two parts; the first allowed a general understanding of the demographics of the participants and the productive characteristics of the dairy agribusiness; using descriptive statistical analysis to determine the mean, median and frequency for the variables of age, years of experience in the dairy sector, years of formal education, distance from the municipal seat, the number of cows in production and the yield in liters of milk per day. Also, variables of possession and use of mobile devices in dairy production systems were evaluated. The second part focused on the factors that producers considered most important when adopting the use of Apps for managing their herds; the variables were assessed using a Likert-type response scale between 1 (Not important at all) and 5 (Very important). The data was collected between May 2020 and December 2021.

The minimum sample size was established from the “10-times rule” in partial least squares structural equation modeling (PLS-SEM), determined with the number of existing paths of the construct with the highest number of observable variables multiplied by 10. For this case,

the factor "internal motivation" was the one with the highest number of relationships, with 4 items, so the sample had to be greater than 40 observations. For this reason, a sample size of 45 observations was recognized as sufficient for an exploratory model, in which the aim was to identify the data structure regarding the phenomenon under study (Alambaigi & Ahangari, 2016; Martínez & Fierro, 2018).

The statistical analysis included exploratory factor analysis, an analysis that establishes the smallest number of latent variables (unobservable variables) that underlies a set of observable variables, by identifying similar factors with a causal link, that explain the order and structure of the data (Goretzko et al., 2021; Watkins, 2018); this method should be used when the researcher has no a priori hypothesis about factors or measured variables (Finch & West, 1997). The "psych" library (Revelle, 2020) of the R-project software (R Core Team, 2020) was used, and subsequently the construction of a structural equation model (SEM), including in each factor only variables with Cronbach's alpha and coefficient omega higher than 0.70 and a factor loading higher than 0.5 (Amirrudin et al., 2021; Novitasari et al., 2021). Convergent validity was determined using the average variance extracted (AVE) with values greater than 0.5. The model fit was validated with a root mean square error of Approximation (RMSEA) less than 0.1 and a comparative fit index (CFI) greater than 0.9 (Cangur & Ercan, 2015), using the "lavaan" library (Rosseel, 2012) from the R-project software (R Core Team, 2020).

Results and Discussion

Dairy farmers were, on average, 44±11 years old, and in turn, had been in the dairy business for 21±16 years (Table 1). Although there are reports of no relationship between age and intent to use the Apps (Palos & Martín, 2016), having a group of producers who are mature and have vast experience in the dairy business favors the productivity of the sector, considering that the knowledge gained through praxis facilitates decision making (Cuartas et al., 2018). However, this practical knowledge has not been complemented with academic training since, on average, dairy farmers have only studied up to the sixth grade; this limits both individual and organizational learning (Pardo & Díaz, 2014). This situation could explain why the dairy industry in Colombia has focused more on survival than on technological and business development (Barrios et al., 2016).

Table 1. Characteristics of dairy farmers and dairy agribusinesses in Northern Antioquia, Colombia.

Item	Mean	Median
Producer's age (years)	44±11	46
Years of experience as a producer in the dairy business	22 ±16	20
Years of formal education received by the producer	6.5±5.3	5
Distance to municipal seat (km)	8.9±4.9	9
Number of cows in production	22±15	16
Production (L d^{-1})	357±36,9	260

Source: the authors.

An average herd production of 357 L d^{-1} was found, a value that suggests that the dairy herds studied were of medium size according to the classification proposed by Lobos et al. (2001). This could favor the intent to adopt new technologies, since Barrios & Oliveira-Ángel (2013) reported that larger herds require greater technological intensity, in contrast to smaller herds. In contrast, Barrios et al. (2016) found no differences regarding herd size in the adoption rate of dairy technologies.

Almost all producers (98%) had a cellphone, but only 80% accessed the internet via this device (Table 2). The use of smartphones in dairy herd management provides potential benefits in production systems, such as timely and informed decision making, improved communication with agents in the value chain, collection of agribusiness information, access to training platforms, among others (Kenny & Regan, 2021). 63% of producers considered the mobile device to be a useful tool for managing technical information, a contradictory result considering that only 7% of the herds studied had systematized management of technical information. Similar results were reported by Barrios et al. (2019) when they found that the Colombian dairy sector has a low frequency of adoption of soft technologies or those related to knowledge management, a situation that puts the producer at a disadvantage compared to the European dairy industry, whose adoption and use of soft technologies exceeds 60% (Michels et al., 2019). The reasons that influence the adoption and use of mobile technologies in agribusiness are the challenges in connectivity in rural areas and the producer's willingness to adopt new technologies (Schulz et al., 2022).

Table 2. Digital profile of dairy agribusinesses in Northern Antioquia, Colombia.

Item	%
The owner has a cellphone	98
The owner accesses the Internet from a mobile device	80
The owner considers the mobile device useful for managing information	63
The property has cellular operator coverage	88
The property has fixed internet service	29
Technical production records are kept	77
Systematized technical records are kept	7

Source: the authors.

When inquiring about the aspects of greatest influence on producers' intent to adopt Apps to improve herd management, it was found that increasing business profitability and improving productivity were the most important, in that order, with means of 4.7±0.7 and 4.6±0.8, respectively (Table 3). The use of new mobile technologies in dairy herds increases when the producer perceives the value of the technology in economic terms (Michels et al., 2019). In addition, mobile applications in dairy herds improve productivity in agribusinesses as well as work efficiency by allowing compilation and quantification of labor input levels (Deming et al., 2018). On the contrary, the variables "adaptation to the environment" and "external financing" were the ones that presented lower mean values with 3.4±1.6 and 3.3±1.7, respectively. It has been shown that the adoption of mobile technologies for the use of digital banking for external financing is influenced by the demographic characteristics of the population, quality of the internet connection, perceived usefulness and ease of use, and the confidence, knowledge and risk perceived by the producer (Atuahene & Boateng, 2015).

In the construction of the final SEM, variables with low statistical significance were eliminated, leaving seven variables grouped into two factors; this allowed for the identification of the structure of the relationships between the variables and the factors formed (Table 3). According to the common characteristics of the variables grouped in each factor, factor 1 was denominated as the one related to aspects of internal motivation for the adoption and use of Apps, while factor 2 included external motivation variables. The model showed satisfactory residual and non-residual fit indicators. The CFI indicator was above 0.95 (0.985), as suggested by Cupani (2012), and the residual indicator RMSEA (0.06) was less than 0.08 as recommended by Bollen (1989).

Table 3. Indicators of internal consistency and validity for factors associated with the use of mobile applications for the management of dairy herds

Factor	Item	Mean	Factorial loading	Average factor loadings	Cronbach's alpha	Coefficient omega	AVE
Internal motivation	Reduction of operating costs	4.4±0.9	0.51	0.76	0.85	0.86	0.61
	Optimization of information management	4.5±1.1	0.68				
	Productivity improvement	4.6±0.8	0.98				
	Increase in business profitability	4.7±0.7	0.84				
External motivation	Receiving external financing	3.3±1.7	0.71	0.76	0.81	0.81	0.58
	Need to adapt to the environment	3.4±1.6	0.75				
	Being a beneficiary of technical assistance	3.8±1.6	0.81				

Source: the authors.

The first factor, "internal motivation", was the reflection of the variables profitability increase, productivity improvement, information management optimization and cost reduction (Figure 1); note the weight of the variables "productivity improvement" and "profitability increase", with standardized factor loadings of 0.98 and 0.84, respectively. This result coincides with that described by Bewley et al. (2015), who described that the perceived benefits of adopting precision technologies in the dairy sector have generally been related to increased system efficiency. Barrios et al. (2020) reported that production cost control is a factor associated with the adoption of technologies in dairy agribusinesses. Gichamba & Lukandu (2012) mention that one of the factors associated with the use of mobile technologies in dairy farming is determined by the increase in productive efficiency in agribusinesses, which generates increases in organizations' income, thus maximizing producers' profits (Fouad et al., 2021).

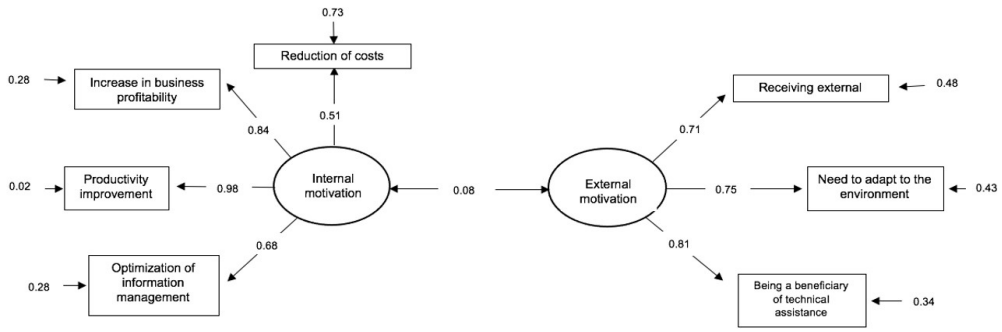

Figure 1. Structural equation model for factors associated with the adoption of Apps for dairy herd management. Source: the authors.

The inclusion of the variables "information management optimization" (factor loading 0.68) and "cost reduction" (factor loading 0.51) in the internal motivation factor denotes how today dairy producers have become aware of the relevance of information traceability and decision making based on data. This aspect will possibly promote the implementation of Information and Communication Technologies ICT and cost analysis in this industry, which has historically presented low implementation of economic diagnostics and information and communication technologies (Barrios & Oliveira-Ángel, 2013; Rodríguez et al., 2015). The use of mobile technologies optimizes economic performance in dairy herds by providing a support system for decision making, based on information obtained from the production system (Jelinski et al., 2020; Michels et al., 2020).

In the second factor, "external motivation", the variable with the highest weight was the "receiving technical advice" (factor loading 0.81), an element that ratifies the importance of the institutional framework for this sector, since technology transfer programs guide the producer to make the right decisions for the intervention of critical points in the operation of their businesses (Cerón-Muñoz et al., 2015). Technical advisory services through mobile technologies increase the adoption rate of mobile applications (Apps) for dairy herd management, by providing tools to producers for problem solution in agribusiness. (Sinha et al., 2018). In turn, "receiving external financing" was the variable with the lowest weight within the construct (factor loading 0.71), which could suggest that dairy farmers do not always access the leverage to finance their technological investments, a situation reported by Rodríguez et al. (2015) who found, for the same region, a credit access rate of 38%.

When inquiring about the potential causes of the low adoption rate of Apps for dairy herd management; the most popular response was lack of sufficient knowledge to use the information generated (47%), followed by the high cost of smartphones (42%) and difficulty in using mobile devices (34%, Table 4). Lack of knowledge and increased perception of insecurity in the use of ICT affect the adoption and use of these technologies by producers; therefore, extension strategies should be implemented to provide training in the use of mobile technologies for dairy herd management (García-Villegas et al., 2020; Singh-Brar et al., 2020).

Table 4. Variables that influence low App use for dairy herd management

Variable	Nº	%
I lack the knowledge to use the generated information	25	47
High cost of smartphones	22	42
Difficulty for using smartphones	18	34
Poor tech support for Apps and mobile devices	16	30
Limited integration with other technologies in the farm	15	29
Conformity with the current approach to information management	13	29
I prefer to wait for improved versions of the available Apps.	9	19

Source: the authors.

Conclusions

The implementation of mobile technologies in dairy production systems is influenced by internal and external factors. Dairy farmers who perceive cost reduction, information management optimization, productivity improvement and increased profitability as internal factors will increase the adoption rate of mobile applications for agribusiness management, which will improve aspects related to dairy herd efficiency. The external motivating factor

is influenced by technical assistance coverage, external financing, and the need to adapt to environment changes. Government policies that aim to implement mobile technologies in dairy herds should provide financial and technical assistance as part of their strategies, which in turn will improve the technological level in agribusiness. Dairy farmers perceive mobile technologies as important and necessary tools for information management, but the implementation of these technologies is not yet widespread. This low adoption of mobile technologies becomes a challenge in terms of the competitiveness required by production systems, given that it is a disadvantage for producers in highly competitive markets.

This study contributes to the state-of-the-art on the use of technologies in a sector in need of research on the adoption of mobile technologies. In the same way, it contributes to decision-making by dairy farmers in a conscious and informed manner about the variables that determine the acquisition of an App for the management of dairy herds.

Public policies aimed at promoting the adoption of mobile technologies in dairy herds must guarantee financial and technical assistance as a support instrument to improve the technological level in agribusiness. Likewise, they should address issues related to the improvement of productive indicators and the increase in the profitability of dairy herds, which may increase the motivation of the dairy farmers towards the implementation of mobile technologies, which will provide them with skills and tools that could facilitate entering new highly competitive markets.

This research limits itself to determine the factors that motivate dairy farm producers to implement mobile technologies in their herds; it did not consider variables related with skills and knowledge in the adoption of technology such as facilitating conditions, performance expectations and the impact of the environment of the producer in the implementation of the technology. It is recommended for future studies in this line of work, to include analyses related to producer satisfaction in the use of this technology, factors that determine the success in the positioning of a dairy farm.

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