INFOGRAPHICS AS A MEANS OF COMMUNICATING AND DISSEMINATING TECHNOLOGIES IN SMALL-SCALE DAIRY FARMS FROM CENTRAL MEXICO †

[INFOGRAFÍAS COMO MEDIO DE COMUNICACIÓN Y DIFUSIÓN DE TECNOLOGIAS EN SISTEMAS DE PRODUCCIÓN DE LECHE EN PEQUEÑA ESCALA DEL CENTRO DE MÉXICO]

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SUMMARY

Background. The information and communication technologies are considered important for the rapid and efficient communication and dissemination of information among farmers, which can facilitate the diffusion of technologies. **Objective**. To identify the most relevant technologies to dairy farmers and to analyse farmers' perception of the information contained in the infographics shared via WhatsApp™. **Methodology.** To collect the data, a questionnaire was applied to 108 dairy farmers from central Mexico. Farmers were grouped using multivariate statistics such as factor and cluster analysis. The four most important technologies to farmers were identified and infographics of maize silage, artificial insemination (AI), concentrate feeding, and heat-service were designed and distributed via WhatsApp™™. A Chi-Square test was conducted to analysed the dichotomous responses about farmers' perception of receiving and sending infographics via WhatsApp™. The infographics were also evaluated using a five-point Likert type scale and Kruskal-Wallis test was used to analyse the data. **Results**. Four factors that explain 73.3% of the cumulative variance were identified. Four groups were identified. Group 1 had the largest farm size, group 2 had the most available family labour, group 3 had the youngest farmers with better schooling, and group 4 had the highest level of technical assistance. Farmers in groups 1 and 2 found the infographics on maize silage and AI to be informative and well-understood. Farmers in group 3 found the concentrate feeding infographic to be informative, but 73% reported that pH and ruminal acidity were terms difficult to understand. Meanwhile, 87% of farmers in group 4 found the heat-service infographic to be unimportant, but easy to comprehend. **Implications.** The research contributed to identifying the usefulness of infographics in communicating information on technologies important to farmers. It also identified areas of interest achieved through their use in extension services. **Conclusions.** It is concluded that the infographics and WhatsApp™ are very useful tools for sharing information and communication of technologies. Therefore, the combination of these tools could improve extension services for dairy farmers in rural areas.
Key words: Innovations; digital technologies; rural areas; extension services.

RESUMEN

Antecedentes. Las tecnologías de información y comunicación son consideradas importantes para la comunicación y difusión de información entre productores de manera rápida y eficaz, lo que puede facilitar la difusión de tecnologías entre productores. **Objetivo.** Identificar las tecnologías más importantes para los productores de leche y analizar la percepción de los productores de la información contenida en las infografías compartidas vía WhatsApp™. **Metodología**. Para colectar los datos, sé aplicó un cuestionario a 108 productores de leche del centro de México. Los productores se agruparon utilizando estadística multivariada como el análisis factorial y de conglomerados. Las cuatro tecnologías más importantes para los productores fueron identificadas y se diseñaron infografías sobre ensilado de maíz, inseminación artificial (IA), alimentación con concentrado y celo-servicio, que se distribuyeron vía WhatsApp™. El análisis de Ji-Cuadrada fue utilizado para analizar las respuestas dicotómicas de la percepción de los productores de recibir y enviar infografías vía WhatsApp™®. Las infografías

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también se evaluaron mediante una escala tipo Likert de cinco puntos y los datos fueron analizaron a través de Kruskal-Wallis. **Resultados.** Se identificaron cuatro factores que explican el 73.3% de la varianza acumulada. Cuatro grupos fueron identificados. El grupo 1 tenía el hato de mayor tamaño, el grupo 2 disponía de mayor disponibilidad de mano de obra familiar, el grupo 3 contaba con los productores más jóvenes con mejor escolaridad, y el grupo 4 tenía el nivel más alto de asistencia técnica. Los productores de los grupos 1 y 2 encontraron que la infografía de ensilado de maíz e IA son informativas y fácil de entender. Los productores del grupo 3 consideraron que la infografía de alimentación con concentrado es informativa, pero el 73%, reportó que pH y la acidez ruminal fueron términos difíciles de entender. Mientras tanto, el 87% de los productores del grupo 4 considero que la infografía de celo-servicio no era importante, pero fácil de comprender. **Implicaciones.** La investigación contribuyó en identificar la utilidad de las infografías para comunicar información sobre tecnologías importantes para los productores. Además de identificar áreas de interés logradas a través de su uso en servicios de extensión. **Conclusiones.** Se concluye que las infografías y el WhatsApp™ son herramientas que permiten compartir información y la comunicación de tecnologías. Por lo tanto, la combinación de estas herramientas pudría mejorar los servicios de extensión hacia productores de leche en áreas rurales.
Palabras clave: Innovaciones; tecnologias digitales; areas rurales; servicios de extensión.

INTRODUCTION

It is estimated that 10 percent of the world's population is involved in milk production, with 150 million households keeping livestock for milk production (FAO, 2022) and producing almost 753 million tonnes of milk (FAOSTAT, 2021). In developed countries, dairy farms are mostly small family farms (Blanco-Penedo *et al.,* 2019); however, in low- and middle-income countries, 80 to 90 percent of milk production comes from small-scale farms (FAO, 2022). Small-scale dairy farms are crucial for generating employment in rural areas (FAO, 2022) and are the primary source of family income (Martínez-García *et al*., 2016). However, these farmers face challenges in adopting new technologies due to economic constraints, lack of knowledge, and inadequate technical advice. Additionally, some technologies are considered unimportant for the farm (Martínez-García *et al.,* 2016; Blanco-Penedo *et al.,* 2019).

Previous studies mention that the usefulness and importance that farmers perceive of technologies are factors that influence adoption (Juárez-Morales *et al.,* 2017), in addition to a tendency towards those that have immediate benefits, are easy to implement (Martínez-García *et al.,* 2015), require low levels of investment (Martínez-Garcia *et al.,* 2016), have financial incentives or there is greater certainty that the technology will improve productive and economic outcomes (Barnes *et al.,* 2019).

Information and Communication Technologies (ICTs) and telecommunications services have become increasingly important in the daily lives of the population in recent years, not only as a form of entertainment, but also as tools that can promote social development (García-Villegas *et al.,* 2021), or help to improve the performance of smallholder farms (Bateki *et al*., 2021). The most widely used ICT among farmers is the smartphone, which is important for communication and rapid dissemination of information (García-Villegas *et al*., 2021), because it supports and simplifies many tasks of daily life (Sha *et al*., 2019). Therefore, it is considered as an important tool in daily work (Bonke *et al*., 2018), and it is one of the most accepted and adopted tool for providing information related to agriculture and livestock (Rathod *et al*., 2016).

Smartphone applications have improved crop management (Bonke *et al*., 2018) and dairy herd management (Michels *et al*., 2019; Bateki *et al*., 2021), supported the collection of socio-economic-production data (Daum *et al*., 2021), and simplified the communication process between farmers and government agencies (Kenny and Regan, 2021). WhatsApp™ is a common smartphone instant messaging application at no additional cost (Ortiz *et al*., 2018), and is considered as an essential driver of smartphone use (Sha *et al*., 2019). Previous studies mention that lack of internet signal is not a problem for using WhatsApp™; farmers often send or receive messages via WhatsApp™, and these are received when the signal is restored (Garcia-Villegas *et al*., 2020).

Few studies have quantified the contribution of smartphone applications to farmers' lives. However, the existing studies have mainly focused on crops (Bateki *et al*., 2021), communication of information to improve milk production (Rathod *et al*., 2016), and it has been recommended the dissemination of information on veterinary topics to small-scale dairy farmers through infographics (Garcia-Villegas *et al*., 2021). Infographics are visual representations of data intended to convey information quickly and clearly (Joshi and Gupta, 2021). They are considered an effective means of communicating information without biasing the reader's interpretation (Lee *et al*., 2022). Their use has increased in the last decade, due to the wider and easier access to technology; and they have the potential to provide information to thousands of people in a short period of time (Joshi and Gupta, 2021). However, infographics have not been used to disseminate information about important technologies to small-scale dairy farmers. Therefore, this study aims to share infographics through smartphones and the WhatsApp™ application in rural areas. As a result, the following research questions arise: What are the most important technologies for small-scale dairy farmers? And what is the farmers' perception of the information contained in infographics of important technologies shared via WhatsApp™? Thus, the objective of this research was to identify the most important technologies to the small-scale dairy farmers from the municipality of Aculco, State of Mexico and to analyse farmers' perception of the information contained in the infographics of important technologies shared via WhatsApp™ message.

MATERIALS AND METHODS

Study area

The study was conducted in the State of Mexico, which has a population of seventeen million inhabitants, making it the most populated region in the country (INEGI, 2019). The State of Mexico contributes with an annual production of 445,000 litres of milk, which represents 3.6% of the national production. The work was carried out in the municipality of Aculco, which has an annual production of 31,000 litres of milk, representing 7% of the production of the State of Mexico (SIAP, 2021).

Aculco is located in the northwest of the State of Mexico, between the coordinates 20° 00'- 20° 17' North, and 99° 40' - 100° 00' West, at an altitude of 2,440 meters above sea level, with a semi-cold and sub-humid climate (Sainz-Sánchez *et al*., 2017). A total of 90% of the farms in Aculco are characterised as small-scale, with 3 to 35 cows in production plus their replacements, with surface areas of less than 10 hectares (ha) in size, where the main labour force is the family. The cows in production are milked by hand twice a day, with an average milk production of 13 litres (L) per cow per day (Martínez-García *et al*., 2016).

Survey design

Two paper-and-pencil surveys were designed to gather information. The first survey was divided into four sections: characteristics of the farmer and their family, characteristics of the farm, agricultural technologies used, and technical assistance services. The second structured survey was designed to assess the reception, delivery, content, and usefulness of the infographics. Preliminary testing of the surveys was conducted with ten farmers in October 2021. To improve the surveys, some questions were added, modified, or deleted.

Farmers identification and data collection

The study area comprised 900 small-scale dairy farms (Sainz-Sánchez *et al*., 2017). This technique is useful when the researcher wants to contact people with similar characteristics who are likely to know one another (Vogt and Burke, 2016). A non-probabilistic snowball sampling method was used to select 108 farmers who owned between 3 to 35 cows and had access to a smartphone. The sample size represented 12% of farmers in the study area. To collect the data, two final surveys were conducted face-to-face with 108 farmers between November 2021 and March 2022. The interviews were conducted in the farmers' homes during their free time and in the shed during milking. The duration of the interviews ranged from 45 to 90 minutes. In order to avoid bias of the collected information, the interviews were conducted by only one interviewer, using the same procedure and dynamic with all farmers.

Data analysis

Grouping of small-scale dairy farms

The general characteristics of the participating farmers were analysed using descriptive statistics and percentages. Dairy farmers were grouped using multivariate statistics; however, prior to conducting the analyses, a data exploration was conducted to identify missing data and outliers (Field, 2013). To identify the relationship among the 14 variables that were initially selected, a Factor Analysis (FA) was performed, using principal component analysis (PCA) as the extraction method (Field, 2013); however, variables with communalities greater than 0.5 were retained (García-Villegas *et al*., 2020). The final analysis was performed on 11 variables (Table 1). The Kaiser-Mayer-Olkin index value of 0.5 or higher was used as a criterion to meet the parsimony and interpretability conditions of principal component analysis (PCA). Orthogonal rotation of maximum variance (Varimax) was used to facilitate the interpretation of the factors obtained. The factor loadings obtained from the PCA analysis were used to perform the hierarchical cluster analysis using Ward's method as an agglomerative algorithm to measure the similarity between subjects and group them using the Euclidean distance (Martínez-García *et al*., 2015). The dendrogram and the Euclidean distance association plot were used to determine the number of most significant groups (García Villegas *et al*., 2020). The non-parametric Kruskal-Wallis test was used to compare the groups with respect to the 11 variables analysed (Table 2), as the variables did not show a normal distribution. A pairwise comparison test was used to identify differences among groups (Field, 2013). To analysed the data, IBM SPSS statistics 22 version was used.

Importance of the groups of technologies and each technology

To determine the importance of each technology group (43 in total), including management (9), feeding (7), agricultural practices (9), fodder (10), health, and reproduction (8) (Table 3), the following question was asked. "How important is technology group X... to you on your farm? The importance of each technology (Table 4) was also determined by the questions, "How important is technology X... to you on your farm? Responses to both questions were recorded using a five-point Likert-type scale ranging from 1=not important to 5=very important (Martínez-García *et al*., 2015). Kruskal-Wallis analysis was used to compare the perceived importance of each group of technologies and the importance of each technology among groups of farmers. Differences among groups were identified using a pairwise comparison test (Field, 2013). In addition, the highest median was used to select the most important technologies for each farmer group. Thus, four technologies were considered to create the infographics: maize silage for group 1, artificial insemination for group 2, concentrate feeding for group 3, and heat-service for group 4.

Design and distribution of the infographics of the most important technologies

The infographics depict the most important technologies used by farmers, including maize silage, artificial insemination, concentrate feeding, and heat-service (Figures 1, 2, 3, and 4, respectively). The four digital infographics were designed by the authors of the paper. The final version of each one was considered after a general discussion among them. The four infographics were piloted with four farmers to validate de design and technical accuracy before to deliver these to the farmers; Therefore, the infographics were designed to be easily comprehensible, with drawings and familiar images to aid farmers' understanding (Evans *et al*., 2017). The visual presentation was intended to maintain farmers' attention and increase the adoption of technology on farms (Rose *et al*., 2016). The infographics were shared with farmers as recommended by García-Villegas *et al*. (2020). Four WhatsApp™ groups were formed based on the identified groups of farmers using cluster analysis. The maize silage infographic was sent to group 1, artificial insemination to group 2, concentrate feeding to group 3, and heat-service to group 4. All four infographics were sent in image format to each identified group via a message.

Farmers' perception of receiving and sending infographics via WhatsApp™

To evaluate farmers' perceptions of receiving and sending the four infographics shared via WhatsApp™, we considered the following statements: the infographics contained important information, some information was not understood, the infographics were difficult to share on WhatsApp™, and farmers agreed to receive information through infographics via WhatsApp™ (see Table 5). The responses were captured through dichotomous responses (yes/no). A Chi-Square test (P<0.05) was performed to compare the perception of the four statements among groups of farmers. Differences among groups were identified with the z-test and Fisher test with Bonferroni adjustment (*P*<0.05).

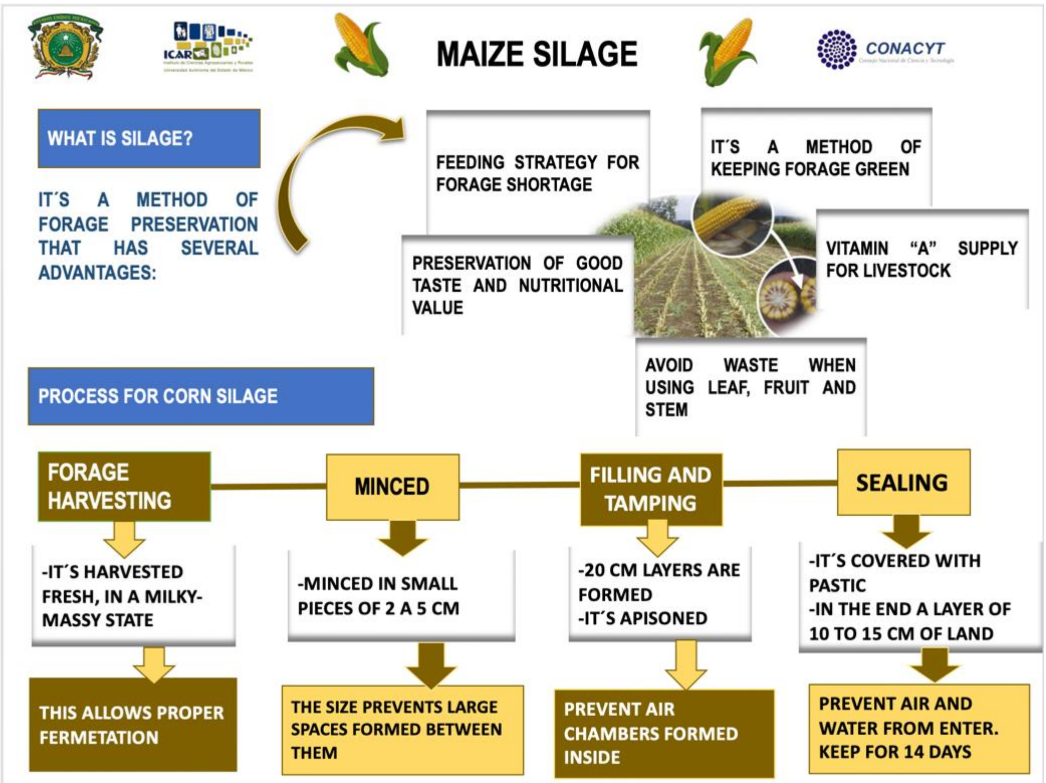

Figure 1. Digital infographic of maize silage.

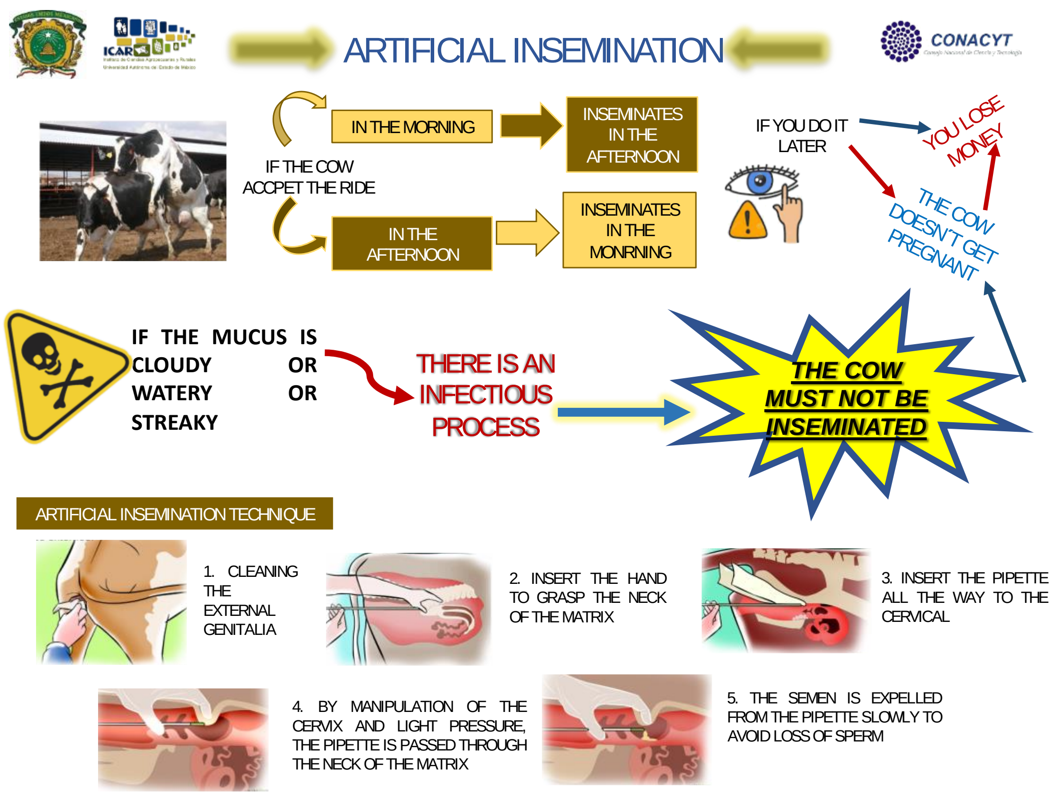

Figure 2. Digital infographic of artificial insemination.

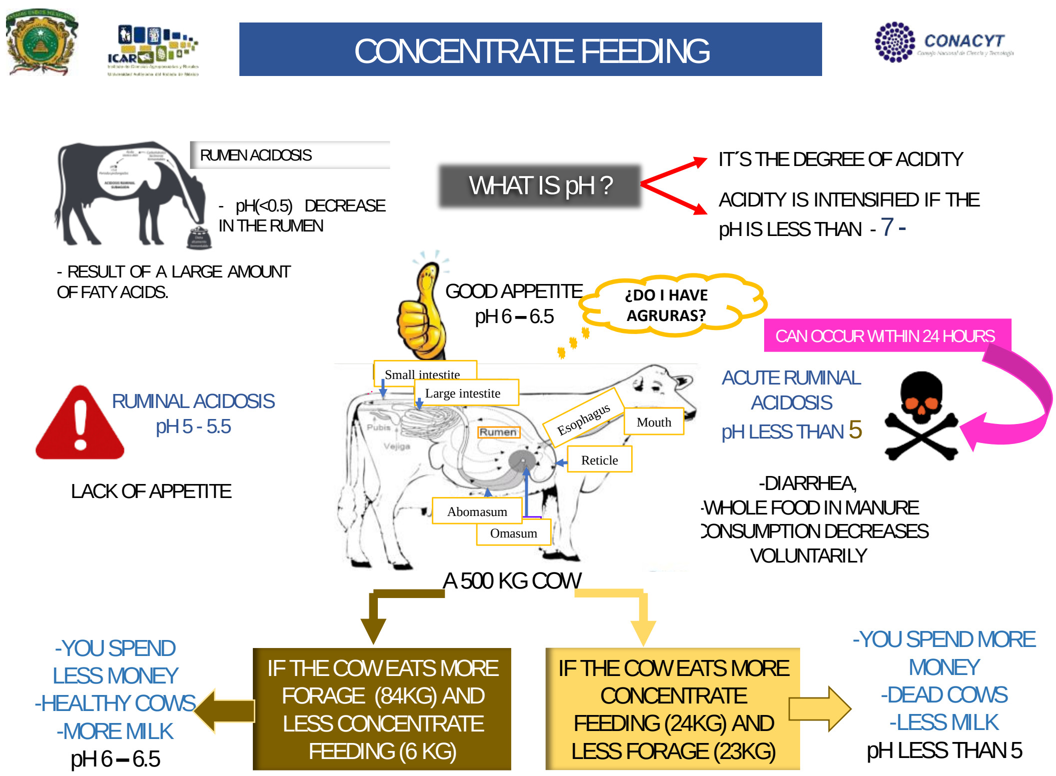

Figure 3. Digital infographic of concentrate feeding.

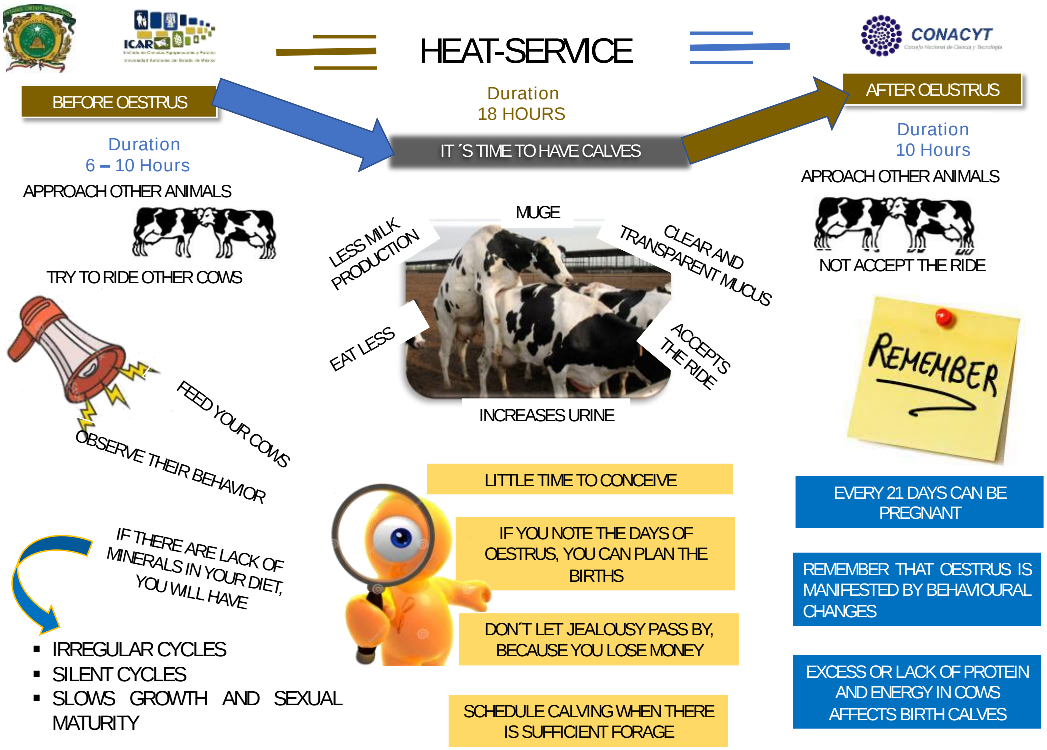

Figure 4. Digital infographic of heat-service.

Evaluation of the content of infographics

A five-point Likert type scale was used to evaluate the content of the infographics (Vogt and Burke, 2016). The way of **sharing** the infographics was measured by asking “How do you feel about sharing information regarding to ...” through an infographic and a WhatsApp™ message? The participants’ responses were recorded with a scale ranging from 1=very bad to 4=very good (Table 6). The scale used to measure the farmers' perception of the **difficulty** in understanding the content ranged from 1 (very difficult) to 4 (very easy). The **usefulness** and **interesting** of the infographic information was measured by asking how ... do you consider the information in the infographic ... in your farm? The participants' responses were recorded using a scale ranging from 1 (not at all useful) to 4 (very useful) for usefulness and from 1 (not at all interesting) to 4 (very interesting) for interest.

Farmers interest and motivation to use the infographics information

The perception of farmers regarding to their interest and motivation to use the information presented in the infographic (Table 7) was measured by asking, 'Are you interested in using the information in the infographic on your farm?' The responses were recorded on a five-point Likert scale, ranging from 1 (not at all interested) to 4 (very interested) and from 1 (not at all motivated) to 4 (very motivated), respectively. The scale also considered a neutral point. The farmers' perceptions were compared among groups using the non-parametric Kruskal-Wallis test. Pairwise comparison tests were used to identify differences among groups (Field, 2013).

RESULTS

General characteristics of participating farmers

The average age of the farmers was 48 years, with primary (31%), secondary (46%) and high school education (29%), although some farmers (2%) were illiterate. The average family size was four persons, of whom two were engaged in farming. The average farming experience of the farmers was 27 years. The average farm size was three hectares, of which more than half (67%) was used for maize cultivation, and the average herd size was 15 cows, of which seven were in production. The average milk yield was 18 litres per cow per day. The main source of income for most of the farmers (84%) was the sale of milk; but more than half (58%) had income from non-agricultural activities, with one or two family members working in enterprises close to home.

Grouping small-scale dairy farms

The factor analysis identified four factors explaining 73.3% of the cumulative variance, with a Kaiser-Meyer-Olkin coefficient of 0.753 and a significant Bartlett's test (P<0.001), confirming the reliability of the analysis (Table 1). In Factor 1, a positive association was observed among the variables describing the characteristics of the farm; i.e., the larger the herd, the higher the number of cows in production and the higher the milk sales per day, and the more available hectares. Factor 2 indicated that the older the farmer, the less education, but the more experience in milk production. Factor 3 indicated that the higher the technological level of the farm, the more technical assistance farmers had. Factor 4 captured a positive relationship between family members and family labour. That is, the higher the number of family members, the greater the availability of labour in the farm.

The dendrogram (left) shows the grouping of the farms, and the plot of the linkage distances (right) shows with the solid line the cut-off point (between the Euclidean distance14 and 22), to define the four groups considered in the study (Figure 5).

Characteristics of the four groups identified

Table 2 shows the characteristics of the four groups identified by hierarchical cluster analysis. All 11 variables analysed showed significant statistical differences (*P*<0.05) among groups. Group 1 consisted of 23 farmers with secondary education (similar to group 3), age of 55 years (similar to farmers in groups 2 and 4) and more experience as dairy farmers (similar to groups 2 and 4). Farmers in group 1 had the largest herd size, cows in production, milk yield per day and land availability (hectares). They also had the highest availability of technology, similar to group 4.

Group 2 consisted of 29 farmers with primary education (similar to group 4). The farm characteristics were similar to those of groups 3 and 4; and the technological level was similar to that of group 3. Group 2 was mainly characterised by the highest number of family members and the highest availability of family labour. Group 3 consisted of 33 farmers with secondary education, the youngest, but with the least experience in milk production, the least technical assistance and the lowest milk production. Group 4 consisted of 23 farmers with primary education, but the highest technological level and the highest level of technical assistance on the farm.

Importance of the groups of technologies

Table 3 shows the degree of importance of each group of technologies as perceived by the farmers. The feeding technology groups showed significant differences (*P*<0.022) among groups of farmers. Farmers in groups 1 and 4 considered feeding technologies to be quite important. The management, health and reproduction and agricultural technology groups did not show statistical differences (*P*>0.05) among groups in terms of their importance. In most of the groups of farmers, the groups of feeding technologies and health and reproductive were considered quite important, while the groups of management and agricultural technologies were considered to be important on the farm.

Importance of each technology per group of farmers

Table 4 shows the degree of importance of each technology. Most of the management technologies did not show significant differences (*P*>0.05) among groups; but ear tagging with SINIIGA identification, dehorning and mechanical milking were considered as important by the farmers of the four groups, while the milking parlour, cooling tank and milk yield record per cow were considered less important by the four groups. On the other hand, heat-service, calving recording and health recording (vaccination and deworming) showed significant differences (*P*<0.001) among groups of farmers. Heat-service

Table 1. Relationship among variables that describe the small-scale dairy farmer from Aculco using factor analysis.

Analysed variables	Factor 1	Factor 2	Factor 3	Factor 4	Communality
Farm characteristics					
Milking cows (heads)	**0.934**	0.143	0.086	0.047	0.902
Herd size (heads)	**0.908**	0.017	0.147	0.086	0.853
Milk sold per day (litres)	**0.907**	0.079	0.210	-0.084	0.880
Land area (hectares)	**0.549**	0.388	0.143	-0.112	0.515
Farmer characteristics					
Age of the farmers (years)	0.081	**0.876**	-0.019	0.054	0.777
Farmer’s education (years)	-0.039	**-0.803**	-0.009	0.174	0.677
Farmer’s experience (years)	0.235	**0.739**	0.249	0.171	0.692
Technological level					
Technological level (n)	0.252	0.047	**0.797**	0.006	0.701
Technical assistance	0.115	0.095	**0.851**	-0.021	0.748
Family labour					
Family members (n)	0.033	0.082	0.160	**0.797**	0.669
Family labour (n)	-0.046	-0.094	-0.180	**0.792**	0.671
Explained variance	**26.94**	**19.66**	**14.32**	**12.32**	

Extraction method: principal component analysis; Rotation method: Varimax with Kaiser normalisation.

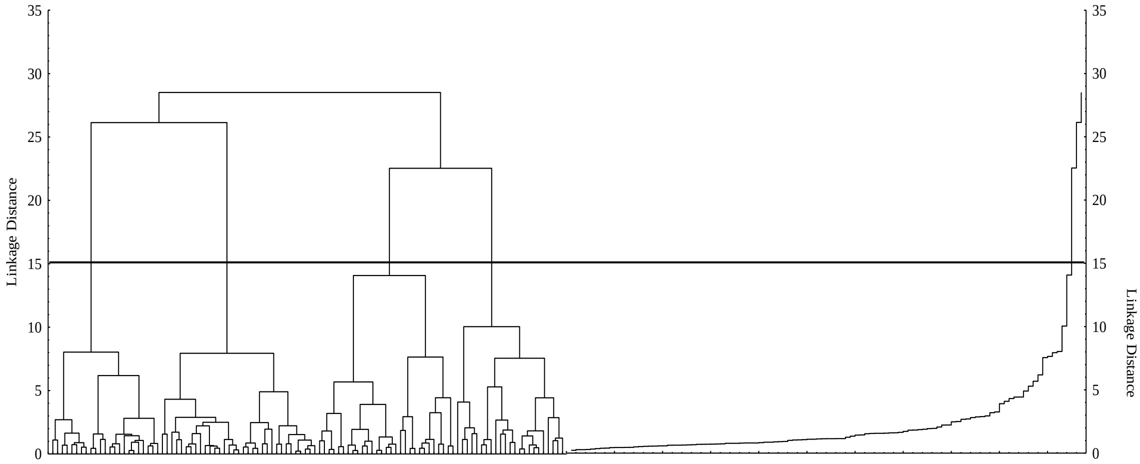

Figure 5. Groups of farms identified with dendrogram (left) and plot of linkage distances (right).

Table 2. Characteristics of the four clusters resulting from hierarchical cluster analysis.

	Group 1 (n=23)		Group 2 (n=29)		Group 3 (n=33)		Group 4 (n=23)		
Analysed variables	Median	IQR[1]	Median	IQR[1]	Median	IQR[1]	Median	IQR[1]	P^2
Farm characteristics									
Milking cows (heads)	14.0[a]	6.0	5.0[b]	3.0	4.0[b]	3.0	5.0[b]	4.0	< 0.001
Herd size (heads)	28.0[a]	14.0	9.0[b]	10.0	8.0[b]	5.0	13.0[b]	6.0	< 0.001
Milk sold per day (litres)	175.0[a]	160.0	60.0[b]	68.0	45.0[c]	40.0	80.0[b]	50.0	< 0.001
Land area (hectares)	5.0[a]	6.0	2.0[b]	4.0	1.5[b]	2.0	3.0[b]	3.0	< 0.001
Farmer characteristics									
Age of the farmers (years)	55.0[a]	22.0	54.0[a]	14.0	37.0[b]	17.0	50.0[a]	17.0	< 0.001
Farmer´s education (years)	9.0[a]	6.0	6.0[b]	3.0	9.0[a]	2.0	6.0[b]	3.0	< 0.002
Farmer’s experience (years)	35.0[a]	25.0	30.0[a]	20.0	10.0[b]	14.0	35.0[a]	20.0	< 0.001
Technological level									
Technological level (n)	25.0[a]	13.0	20.0[b]	32.0	18.0[b]	10.0	26.0[a]	8.0	< 0.001
Technical assistance (%)	35.0		14.0		3.0		87.0		------
Family labour									
Family members (n)	4.0[b]	2.0	6.0[a]	2.0	4.0[b]	1.0	4.0[b]	1.0	< 0.001
Family labour (n)	1.0[b]	2.0	2.0[a]	1.0	1.0[b]	1.0	1.0[b]	1.0	< 0.001

[1]IQR= Interquartile range. [2]P value of Kruskal-Wallis test. Medians within a row not sharing a common uppercase Roman letter (a, b, c) differ, pairwise comparison test (*P*<0.05).

Table 3. Farmers’ perception of the importance per technology group.

	Group 1 (n=23)		Group 2 (n=29)		Group 3 (n=33)		Group 4 (n=23)		
Technology groups	Median	IQR[1]	Median	IQR[1]	Median	IQR[1]	Median	IQR[1]	P^2
Management technologies	3	1	3	1	3	1	3	1	0.061
Feeding technologies	4[a]	1	3[b]	1	3[b]	1	4[a]	0	<0.022
Health and reproductive technologies	4	1	3	1	4	1	4	1	0.592
Agricultural technologies	3	2	3	2	3	2	4	1	0.076

[1]IQR=Interquartile range. [2] *P* value of the Kruskal-Wallis test. Degree of importance= 1=not important, 2=little important, 3= important, 4=quite important and 5=very important. Medians within a row not sharing a common uppercase Roman letter (a, b) differ, pairwise comparison test (*P*<0.05).

was considered very important by groups 1 and 4; and quite important by groups 2 and 3. Calving recording was considered little important by groups 2 and 3; whereas farmers in groups 1 and 4 considered it quite to very important. The majority of groups of farmers (1, 2 and 3), considered health recording as little important for the farm.

In the feeding technologies, maize silage showed significant differences ($P<0.011$) among the four farmers groups (Table 4). Farmers in groups 1 and 4 considered it as very important, while for groups 2 and 3, it was considered as little important. On the other hand, the rest of the feeding technologies did not show significant differences ($P>0.05$) among groups. Hay and grazing pasture were considered as little important, while cut and cut and carry pasture and concentrate feeding were considered as quite important by the farmers of the four groups.

Most of the health and reproduction technologies did not show significant differences ($P<0.05$) among groups of farmers (Table 4); however, vaccination, deworming and brucellosis and tuberculosis campaign were considered to be very important by farmers of the four groups; while udder cleaning was considered as important for farmers of groups 3 and 4. In the case of artificial insemination, it showed significant statistical differences ($P<0.049$) among groups, and it was considered to be very important by most groups (1, 2 and 4) of farmers.

Table 4. Importance of the groups of technologies per group of farmers.

	Group 1 (n=23)		Group 2 (n=29)		Group 3 (n=33)		Group 4 (n=23)		
Technologies	Median	IQR[1]	Median	IQR[1]	Median	IQR[1]	Median	IQR[1]	*P*[2]
Management technologies									
Dehorning	3	2	4	2	3	1	4	2	0.086
Mechanical milking	3	2	3	1	3	1	3	2	0.171
Milking parlour	2	0	2	0	2	0	2	0	0.840
Cooling tank	2	0	2	0	2	0	2	1	0.296
Milk yield record per cow	2	0	2	0	2	0	2	1	0.353
Heat-service	5^{a}	1	4^{b}	2	4^{b}	2	5^{a}	1	<0.001
Calving record	5^{a}	3	2^{b}	2	2^{b}	2	4^{a}	3	<0.011
Health record	2^{b}	2	2^{b}	1	2^{b}	1	4^{a}	3	<0.008
Feeding technologies									
Hay	2	0	2	0	2	0	2	0	0.782
Maize silage	5^{a}	3	2^{b}	2	2^{b}	2	5^{a}	3	<0.010
Cut and carry pasture	5	1	4	1	5	1	5	1	0.422
Grassing pasture	2	3	2	3	2	3	2	3	0.847
Concentrate feeding	5	1	5	1	5	1	5	1	0.958
Health and reproduction technologies									
Vaccination	5	3	4	3	4	3	5	3	0.966
De-worming	5	1	5	1	5	2	5	0	0.130
Brucellosis-tuberculosis campaign	4	2	4	2	3	2	4	2	0.350
Udder cleaning	2	1	2	2	3	2	3	2	0.173
Udder sealing	2	1	2	1	2	1	2	1	0.740
Diagnosis of mastitis	2	1	2	1	2	1	2	2	0.877
Artificial insemination	5^{a}	1	5^{a}	1	4^{b}	1	5^{a}	0	<0.049
Agricultural technologies									
Tractor	5	4	5	4	4	4	5	0	<0.024
Plough	1	0	1	0	1	0	1	0	1.000
Harrow	5	4	5	4	4	4	5	1	<0.023
Seeder	4	2	5	2	3	2	5	1	<0.047
Cultivator	4	4	1	4	1	4	5	1	<0.034
Chopper	4	3	2	3	2	2	5	3	0.052
Baler	2	3	2	3	2	2	3	4	0.990
Hammers mill	4	2	3	2	3	2	5	1	0.108
Improved seeds	4	2	3	2	3	0	5	2	0.007
Chemical fertilisers	5	1	5	2	4	2	5	1	0.012

[1]IQR=Interquartile range. [2]*P* value of the Kruskal-Wallis test. Medians within a row not sharing a common uppercase Roman letter (a, b) differ, pairwise comparison test ($P<0.05$). Degree of importance= 1=not important, 2=little important, 3= important, 4=quite important and 5=very important.

In the agricultural technologies; tractor, harrow, seeder and cultivator, there were significant differences (*P*<0.048) among the four groups of farmers (Table 4). On the other hand, the rest of the agricultural technologies did not show significant differences (*P*>0.05) among groups. Tractor, harrow and chemical fertiliser were considered very important by groups 1, 2 and 4; and quite important by group 3. Cultivator, chopper, hammer mill and improved seed were considered as very important by group 4; quite important by group 1; while farmers in groups 2 and 3 considered them as not important or not important at all. The plough and the baler were considered of little or no importance by groups 1, 2 and 3; while group 4 considered the baler to be important.

Distribution of the infographics of the most important technologies

A total of 83% of the farmers received the infographics without any problems, 6% received it, but due to visual problems a relative had to read it to them, and the remaining 11% had internet problems due to lack of connection or lack of charge on their mobile phone, so the infographics were delivered to the farmers in printed form. Finally, more than half of the farmers (60%) requested a printed version of the infographics due to its ease of readability. Additionally, 60% of farmers expressed that they are not accustomed to using WhatsApp™ for receiving information related to farm management.

Farmers' perception of receiving and sending infographics via WhatsApp™

Table 5 shows the results of the farmers' perception of receiving and sending infographics via WhatsApp™. Similar percentages of farmers in groups 1 and 2 found the infographics on maize silage and artificial insemination to be informative and well-understood. In contrast, 88% of farmers in group 3 found the concentrate feeding infographic to be informative, but 73% reported difficulty understanding certain technical terms such as pH and ruminal acidity. Meanwhile, 87% of farmers in group 4 found the heat-service infographic to be unimportant, but easy to comprehend. Farmers from groups 3 and 4 find it easy to share the infographic through WhatsApp™. The majority of farmers in all four groups expressed their interest in receiving information through infographics via WhatsApp™.

Evaluation of the content of infographics

Table 6 presents the results of the evaluation of the infographics' content. The farmers' perception of the way the infographics were shared did not show any significant differences (P>0.05) among the groups. They considered it a good way to share information through infographics and WhatsApp™. However, there were significant differences (P<0.05) among the groups regarding the variables of difficulty, usefulness, and interest in the information presented in the infographics. All four groups of farmers found the infographics to be easy to understand, useful and interesting; however, farmers in group 4 found the heat-service infographic to be very easy to understand; while farmers in group 3 indicated that the concentrate feeding to be very useful and very interesting.

Farmers interest and motivation to use the infographics information

Table 7 displays the results of farmers' interest and motivation to use infographic information. In contrast, farmers in group 3 indicated a high level of interest and motivation to use the infographic information on concentrate feeding. The variables of interest and motivation exhibited significant differences (P<0.05) among groups. Farmers in groups 1, 2, and 4 expressed interest and motivation to use the infographic information on the farm. Farmers also stated that they would consult the information as needed.

Table 5. Farmers' perception of receiving and sending infographics via WhatsApp™.

	Group 1 (n=23) Maize silage % Farmers	Group 2 (n=29) Artificial insemination % Farmers	Group 3 (n=33) Concentrate feeding % Farmers	Group 4 (n=23) Heat-service % Farmers	*P*[1]
The infographic had important information.	44.0^{b}	55.0^{b}	88.0^{a}	13.0^{c}	<0.001
The infographic had information that was not understood.	0.0^{b}	3.0^{b}	73.0^{a}	0.0^{b}	<0.001[2]
The infographic was difficult to share on WhatsApp™.	44.0^{a}	45.0^{a}	21.0^{b}	13.0^{b}	<0.029
You agree to continue receiving information through infographics via WhatsApp™.	83.0	76.0	85.0	91.0	0.522

[1]*P* value of the Chi-squared test (*P*<0.05). Different superscripts (a, b, c) indicate significant differences among groups according to the z-test with Bonferroni adjustment (*P*<0.05). [2]*P* value of the Chi-squared test (*P*<0.05). Different superscripts (a, b, c) indicate significant differences among groups according to Fisher test.

Table 6. Evaluation of the content of infographics.

	Group 1 (n=23) Maize silage		Group 2 (n=29) Artificial insemination		Group 3 (n=33) Concentrate feeding		Group 4 (n=23) Heat-service		
	Median	IQR[1]	Median	IQR[1]	Median	IQR[1]	Median	IQR[1]	P^2
Sharing information through infographic.	3.0	1.0	3.0	0.0	3.0	1.0	3.0	1.0	0.641
The information of the infographic was **difficult** to understand.	3.0^b	1.0	3.0^b	0.0	3.0^b	1.0	4.0^a	1.0	<0.001
The information of the infographic was **useful**.	3.0^b	0.0	3.0^b	0.0	4.0^a	1.0	3.0^b	1.0	<0.018
The information of the infographic was **interesting**.	3.0^b	0.0	3.0^b	0.0	4.0^a	1.0	3.0^b	1.0	<0.001

[1]IQR=Interquartile range. [2]*P* value of the Kruskal-Wallis test. Medians within a row not sharing a common uppercase Roman letter (a, b) differ, pairwise comparison test (P<0.05).
Degree of sharing*:* 1=Very bad, 2=Bad, 0=Do not know, 3=Good, 4=Very good.
Degree of difficulty*:* 1=Very difficult, 2=Difficult, 0=Do not know, 3=Easy, 4=Very easy.
Degree of usefulness: 1=Not at all useful, 2= not very useful, 0=Do not know, 3=Useful, 4=Very useful.
Degree of interesting*:* 1=Not at all interesting, 2= not very interesting, 0=Do not know, 3=Interesting, 4=Very interesting.

Table 7. Farmers interest and motivation to use the infographic information in the farm.

	Group 1 (n=23)		Group 2 (n=29)		Group 3 (n=33)		Group 4 (n=23)		
	Median	IQR[1]	Median	IQR[1]	Median	IQR[1]	Median	IQR[1]	P^2
There is **interest** in using the information.	3.0^b	1.0	3.0^b	1.0	4.0^a	0.0	3.0^b	1.0	<0.006
There is **motivation** in using the information.	3.0^b	1.0	3.0^b	1.0	4.0^a	0.0	3.0^b	1.0	<0.001

[1]IQR=Interquartile range. [2]*P* value of the Kruskal-Wallis test. Medians within a row not sharing a common uppercase Roman letter (a, b) differ, pairwise comparison test (P<0.05).
Degree of interest: 1=Not at all interested, 2=Not very interested, 0=Do not know, 3=Interested, 4=Very interested.
Degree of motivation: 1=Not at all motivated, 2=Not very motivated, 0=Do not know, 3=Motivated, 4=Very motivated.

DISCUSSION

General characteristics of participating farmers

According to Martínez-García *et al.* (2021), small-scale dairy farmers are typically under 50 years old, have primary and secondary education, and possess 26 years of experience. Only a small proportion of farmers have high school (3%) and university (3%) education, as identified by Martínez-García et al. (2016) and García Villegas *et al.* (2021). The study observed a 29% increase in the proportion of farmers with a high school education. This change in education is due to the generational changeover taking place in the area, which is also affecting their source of income. Studies carried out in the same area have shown that 17% of farmers have other income from non-agricultural activities (Martínez-García *et al*., 2012), in this study it has risen to 58%, this is because they do not want to continue relying solely on the sale of milk due to the problems they face with the high feed costs, the reduction they have perceived in their income and the effects of climate change (atypical rains) that affect the production of fodder and grains.

Grouping of small-scale dairy farms

Multivariate analysis has been used to study technology adoption (Martínez-Garcia *et al*., 2012), structural characteristics (Blanco-Penedo *et al*., 2019) and to identify the importance of the information and communication technologies (ICT) by farmers (García-Villegas *et al*., 2020). In this research was used to identify groups with similar characteristics for promoting innovation. Thus, characterisation has been also used as a tool to deal with the heterogeneity of farms (Kuivanen *et al*., 2016). The four identified groups had distinct characteristics. For example, group 1 had the largest farm size, group 2 had the most available family labour, group 3 had the youngest farmers with better schooling, and group 4 had the highest level of technical assistance. Martínez-García *et al*. (2012) pointed out that differences among groups can help to generate hypotheses and design strategies for the extension services. In groups 1, 2 and 3, it was observed that the absence of technical support impeded the adoption of innovations. However, studies have shown that technical assistance can aid in the development of skills and strengthen the adoption of innovations (Martínez-García *et al*., 2016; Juárez-Morales *et al*., 2017; Blanco-Penedo *et al*., 2019).

Importance of technologies group and each technology per group of farmers

The technologies required by dairy farmers are determined by their significance, productivity, and benefits for the farm (Martínez-García *et al*., 2016; Juárez-Morales *et al*., 2017). Farmers in groups 1 and 4 considered feeding technologies to be of great importance in feeding their herd. This could be attributed to the high feeding costs, which represent 50 to 70% of total costs (Martínez-García *et al*., 2015). In recent years, the economic difficulties faced by farmers have worsened (Martínez-García *et al*., 2021). These situations have led to the abandonment of farming or the search for alternative sources of income outside of agriculture.

Farmers in groups 1, 3, and 4 considered health and reproductive technologies to be important. For example, both adopters and non-adopters perceived artificial insemination as highly significant (Martínez-García *et al*., 2016). In this study, farmers had a similar perception, rating the technology as highly important. This is because the technology contributes to the profitability and sustainability of the farm by increasing milk production and reducing costs associated with feeding a bull (Martínez-García *et al*., 2015). Furthermore, the implementation of popular technologies can have financial benefits and improve productivity and economic outcomes, as demonstrated by the success of the heat-service in breeding management (Barnes *et al*., 2019). Additionally, the low cost of these technologies is a significant factor to consider. Thus, farmers are more willing to adopt innovations that require a low level of investment (Martínez-García *et al*., 2016), which increases their confidence in using the technology (Barnes *et al*., 2019).

Design and distribution of the infographics of the most important technologies

The use of infographics has increased in the last decade, due to wider and easier access to technology (Joshi and Gupta, 2021), such as the dissemination of information through WhatsApp™ messages (Garcia-Villegas *et al*., 2021). It is a simple and attractive application to farmers (Rose *et al*., 2016); this research found that farmers do not have the habit of using WhatsApp™. The limited use of WhatsApp™ among farmers in groups 2 and 4 could be attributed to the absence of internet access, as well as the advanced age (over 50 years) and low level of education (primary) of the farmers. To address this issue, extension services should be conducted to enhance the ability of older farmers to use WhatsApp™. Additionally, face-to-face extension approaches can be employed to disseminate information. According to Barnes *et al*. (2019), extension services can increase the probability of farmers adopting new technologies.

La infografía fue diseñada por los autores de este estudio considerando las aportaciones de diseño y presentación de contenido de anteriores estudios ( ), siendo de las primeras infografías dirigidas a pequeños productores de leche con información de tecnologías de su interés y enviadas de manera personalizada a través de WhatsApp™. Observando la percepción de los productores del diseño y contenido de la inforgrafía.

Hughes et al. (2021) pointed out that infographics keep the attention to the readers, when they have visual elements and images in an attractive way. In addition, the visual presentation and easy to read can increase comprehension of the infographic (Rose *et al*., 2016; Evans *et al*., 2017); However, 60% of farmers requested a printed version of the infographics due to visual problems caused by the small size of smartphone screens, making it difficult to read. According to Mangen *et al*. (2013), reading electronic formats can decrease concentration, generate greater stress and fatigue for readers, and limit their understanding of the text.

Farmers' perception of receiving and sending infographics via WhatsApp™

The infographics on maize silage and artificial insemination provided important information to farmers in groups 1 and 2. They also indicated that the information was well understood. This suggest that the infographics had an effective design and presented information in an engaging manner. Overall, the use of infographics can be a useful tool for communicating important information to farmers. Evans *et al*. (2017) noted that an easy-to-read infographic with visual aids can increase awareness and interest. However, the digital infographic on concentrate feeding shared with farmers in group 3 contained unfamiliar words such as 'pH' and 'ruminal acidity'. Despite this, the farmers found it important to learn new, interesting, and useful information for their farms. This may be attributed to their young age and high level of education. Therefore, it is recommended to develop extension programmes that promote technologies deemed important by farmers. This is because farmers are more likely to participate in training and adopt such technologies (Garcia-Villegas *et al*., 2020).

It was observed that 87% of farmers in group 4 stated that the heat-service information in the infographic was not important. This may be attributed to their knowledge, experience, and familiarity with the information described in the infographic. However, farmers expressed interest in reading the information of the infographic. Additionally, farmers mentioned that the combination of images and concise text in the infographic helped them to understand the information easily. Evans *et al*. (2017) noted that infographics with minimal text and familiar images can enhance farmers' comprehension. Therefore, infographics must be used as a spearhead for awakening curiosity of farmers and search further information; this should be useful for developing farmer's skills.

Over 50% of farmers from groups 3 and 4 found it easy to share the infographic via WhatsApp™. This opinion is attributed to group 3, who are the youngest farmers with better education. This group of farmers is more receptive to adopting information and communication technologies (Michels *et al*., 2019; García-Villegas *et al*., 2021). However, it was observed that farmers in group 4 have a primary education and are 50 years old, but are interested in using and managing WhatsApp™. Therefore, they can be considered innovative farmers. Extension services should be created to encourage both young and older farmers to develop the ability to use WhatsApp™ for sharing infographics among farmers. Michels *et al*. (2019) suggested that promoting and training the use of smartphone applications could be an alternative for improving herd management. Thus, WhatsApp™ could be a suitable alternative since the majority of farmers in all four groups expressed their interest in receiving information through infographics via WhatsApp™. This platform provides an easy and quick way to disseminate information to thousands of people (Rose *et al*., 2016; Joshi and Gupta, 2021). However, it is important to ensure that the application and information are presented in a simple and accessible manner, in order to appeal to farmers of all educational backgrounds and levels of prior knowledge (Michels *et al*., 2019).

Evaluation of the content of infographics

Farmers in all four groups believe that sharing information through infographics and WhatsApp™ was effective. This demonstrates that the smartphone application, WhatsApp™, can be adapted to the working routines of farmers due to its mobility, as mentioned by García-Villegas *et al*. (2020). Additionally, all four groups of farmers found the information presented in the infographics to be clear, useful, and interesting. The content and visual presentation of the information play an important role to increase understanding (Rose *et al*., 2016; Joshi and Gupta, 2021). For instance, farmers in group 4 found the heat-service infographic to be very easy to understand; while farmers in group 3 indicated that the concentrate feeding infographic was very useful and very interesting. This suggests that farmers are more likely to adopt innovation when the information is both useful and interesting for application on the farm (Bonke *et al*., 2018).

Farmers interest and motivation to use the infographics information

Farmers from groups 1, 2, and 4 expressed interest and motivation in using the information presented in the infographic on their farms. They identified new activities that they can incorporate without additional costs. In contrast, farmers from group 3 indicated a high level of interest and motivation in using the concentrate feeding infographic. Farmers were very interested and very motivated because they have discovered unknown information that they consider important for their farms. The innovation does not require additional activities or costs, and farmers can access the information as often as needed. Martínez-García *et al*. (2016) indicated that the innovations with low level of investment are more likely to be implemented in the farm; and when farmers trust the innovation, the likelihood of adoption is higher (Barnes *et al*., 2019).

CONCLUSIONS

It is concluded that the four groups of farmers showed varying degrees of importance towards the four groups of technologies considered in the study. Therefore, different approaches should be implemented, taking into consideration the most important technologies that are appropriate to the characteristics of the farm. For instance, the group of health and reproduction technologies was deemed significant by farmers in groups 1, 3, and 4, whereas the group of feeding technologies was considered important by farmers in groups 1 and 4. The characterisation of the farmers enabled the identification of technological preferences for each group. For example, group 1 farmers considered maize silage to be the most important, while group 2 prioritised artificial insemination. Group 3 farmers preferred concentrate feeding, and group 4 farmers prioritised heat-service. Thus, these technologies were used to create infographics and disseminate information among farmers via WhatsApp™. Therefore, infographics have proven to be a useful tool for sharing information on important technologies with dairy farmers. They present information through attractive images without technical jargon, making it easy to understand regardless of the farmer's age or level of education. However, infographics that contain technical elements should be accompanied by additional technical assistance services. Infographics, used in conjunction with WhatsApp™, are tools that could improve extension services for small-scale dairy farmers in rural areas.

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