FACTORS DRIVING THE ADOPTION OF MAIZE SILAGE AND INSIGHTS TO IMPROVE EXTENSION ACTIVITIES TOWARDS SMALL-SCALE DAIRY FARMERS IN CENTRAL MEXICO †

[FACTORES QUE INFLUYEN EN LA ADOPCIÓN DE ENSILADO DE MAÍZ Y ASPECTOS PARA MEJORAR EN ACTIVIDADES DE EXTENSIÓN HACIA PRODUCTORES DE LECHE EN PEQUEÑA ESCALA DEL CENTRO DE MEXICO]

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SUMMARY

Background. Small-scale dairy farms play an important role in supporting livelihoods in both developing and developed countries. **Objective.** The aim of the research was to identify the determinants of adoption of maize silage and insights to improve extension activities towards smallholders in central Mexico. **Methodology.** A detailed study was conducted with 48 farmers who were already engaged with the use of the innovation. First, a hierarchical regression analysis was conducted and subsequently, farmers were divided into three groups. To identify differences among groups, parametric and non-parametric analyses were conducted. **Results.** Farmers' intention was influenced by experience, milk yield and land sown to maize. Findings suggested that farmers' decision to use the innovation was based on usefulness in Group 3, importance in both groups 1 and 2, increases both in profitability and milk yield in Groups 2 and 3. However, high initial investment and rent of machinery during the harvest season were observed as major constrains. **Implications.** The study identified determinants to use and adopt maize silage by smallholders and provided insights to improve extension activities towards non-users. Thus, this paper added to the growing body of evidence on information towards a better understanding of factors driving farmers' decisions to adopt an innovation and highlighted some extension approaches to be tested on the field. **Conclusions.** It was concluded that the hitherto unnoticed maize silage can be a suitable innovation to farmers without studies, with small farm size and low availability of land.

Key words: Smallholders; Farmers' intention; Farmers' decision; Adoption of innovation.

RESUMEN

Antecedentes. La lechería a pequeña escala tiene un papel importante en el mantenimiento de los medios de vida tanto en países en desarrollo como en los desarrollados. **Objetivo.** El objetivo del trabajo fue identificar factores que influyen en la adopción de ensilaje de maíz, con el propósito de mejorar las actividades de extensión hacia los pequeños productores de leche del centro de México. **Metodología.** Se realizó un estudio detallado con 48 productores que hacen uso del ensilado de maíz. Primero, se realizó un análisis de regresión jerárquica y, posteriormente, los productores se dividieron en tres grupos. Para identificar las diferencias entre los grupos, se realizaron análisis paramétricos y no paramétricos. **Resultados.** La intención de los productores para usar ensilado de maíz estuvo influenciada por la experiencia, la producción de leche y la tierra sembrada con maíz. Los resultados indican que la decisión de los productores para utilizar la innovación fue basada en la utilidad (Grupo 3), la importancia (Grupos 1 y 2) y en el aumento de la rentabilidad y la producción de leche (Grupos 2 y 3); sin embargo, la alta inversión inicial y el alquiler de maquinaria durante la temporada de cosecha, fueron consideradas como las mayores limitantes. **Implicaciones.** El estudio identificó factores que influyen en el uso y adopción del ensilaje de maíz por los productores de leche en pequeña escala; así mismo, los resultados proporcionaron información para mejorar las actividades de extensión que pueden ser dirigidas a los productores

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que no hacen uso de la innovación. Por lo tanto, el trabajo contribuye a una mejor comprensión de los factores que influyen en las decisiones de los productores para adoptar ensilado de maíz y destaca algunos enfoques de extensión que pudieran ser probados en el campo. **Conclusiones**. Se concluyó que el ensilaje de maíz puede ser una innovación adecuada para los analfabetos, con un tamaño de granja pequeño y poca disponibilidad de tierra.
Palabras clave: Pequeños productores; Intención de productores; Decisión de productores; Adopción de innovación.

INTRODUCTION

Small-scale dairy farms play an important role in supporting livelihoods in both developing and developed countries. They contribute to employment generation, food security and family income (Bernués and Herrero, 2008). In Mexico, small-scale cattle systems represent 89% of the total farms that rear cattle in the country (INEGI, 2014). Most small-scale dairy farmers (90%) rate milk sales as the main source of their family income (Martínez-García *et al*., 2012).

In 2015, it was estimated that Mexico produced about 25 million tonnes of maize grain (*Zea mays*), and the State of Mexico was the third highest producer at national level. It contributed 8% of the maize yield (FIRA, 2016). In central Mexico, there is a strong integration of the maize crop and milk production. Small-scale dairy farmers use the maize crop in forms of ground maize grain, baled long maize stover, ground maize stover and maize silage to feed their cattle throughout the year. Silage is a fermentation process for conserving forage, the most common silo types used by small-scale dairy farmers were heap, bunker and earth silo, which had earth walls and was usually below grown level (Reiber *et al.,* 2010). Maize silage is an innovation that can reduce milk production costs (Celis-Alvarez *et al.,* 2016, Martínez-García *et al.,* 2015a). It can, also, improve the economic sustainability of small-scale dairy farms (Prospero-Bernal *et al.,* 2017). Martínez-García (2011, unpublished) pointed out that "innovation can be defined as an interactive process of co-learning and negotiation amongst participants, which involves a set of new tools or knowledge that can be used by farmers in order to produce changes in agriculture practices, with a social and/or economic impact".

Maize silage has, however, showed a low rate of adoption at 32%, among small-scale dairy farmers (Martínez-García *et al*., 2015b). Farmers' adoption rate has depended on availability of money, machinery and knowledge on how to manage the innovation (Martínez-García *et al*., 2015b). The innovation seems to suit large farms and having many cattle (Prospero-Bernal *et al.,* 2017). Nonetheless, exceptional small-scale dairy farmers use the innovation. However, there is a wide gap on adoption rate among farmers with different sizes of land and number of cattle. Hence, a better understanding of the factors that influence the farmers' adoption process depending on farm size and number of dairy cattle is essential. The study required to involve farmers who were already engaged with the adoption of the innovation on maize silage technology. The study outcomes will provide insights to improve extension activities towards increased adoption rate in the maize silage innovation.

Studies have reported that the farmers' perception about the usefulness, importance and difficulty of the innovation influenced the adoption rate of an innovation (Juarez-Morales *et al*., 2017, Martínez-García *et al*., 2018, Schaak and Mubhoff, 2018). The objectives of the current study were to identify the determinants of adoption of maize silage by small-scale dairy farmers with small farm sizes and low availability of land from central Mexico and provides insights to improve extension activities towards non-user of the innovation. This involved studying the effect of farmers and farm characteristics, farming knowledge, farm inputs and innovation characteristics on the adoption rate of maize silage among small-scale dairy farmers in Central Mexico.

MATERIALS AND METHODS

Description of the study area

The study was conducted in the Municipality of Aculco, which is located in the northwest of the State of Mexico (Crespo *et al*., 2014); between coordinates 20° 06' and 20° 17' N; 99° 40' and 100° 00' W. The mean altitude was 2440 m with a sub-humid temperate climate and the rainy season from May to October (Celis-Alvarez *et al.,* 2016). Aculco has developed into a milk production area since 1960. The development has been through investments from the Mexican government involving infrastructure such as irrigation channels, construction of dams and the promotion of cut-and-carry pastures that supported dairy production. These developments have induced cheese production growth in Aculco, which has developed a strong interaction and relationship among small-scale dairy farmers, milk collectors and cheese producers (Crespo *et al*., 2014). Hence dairy farming and cheese production are a major activity in the study area.

Sampling and data collection procedures

A questionnaire was designed according to Martínez-García *et al*. (2015b), divided into three sections. The first section focused on characteristics of the farmer including farmer's age, years of education, years of farming experience, years of experience using maize silage (Tables 1 and 2),

access to extension services, advice to make maize silage and main source of income (Table 3). The second section focused on farms-related characteristics including number of family members, family labour availability, herd size, milking cows, milk yield per cow per day, milk sold per day, milk price per litre (USD), total hectares, and hectares sown to maize (Tables 1 and 2). The variables collected in the second part of the survey were selected based on previous studies on factors influencing technology adoption (Martínez-García *et al*., 2018, Schaak and Mubhoff, 2018). The variables collected were farmers' intention to use maize silage and farmers' perception about usefulness, importance and difficulty to use the innovation on the farm during the next year (Tables 2, 3 and 4). To measure these variables, a five-points Likert type scale was used (Bryman and Cramer, 2011). Where 1=very weak to 5=very strong for intention, and 1=not useful to 5=very useful for usefulness, and the other two five-point scales ranging from 1=not important to 5=very important and 1=very difficult to 5=very easy for importance and difficulty respectively. The second part of the survey, also, captured the farmers' perception about some factors influencing the use of maize silage on the farm such as maize seed cost, land availability, money availability, machinery availability and knowledge for making silage (Martínez-García *et al*., 2015b) (Table 5). These variables were measured through four-points Likert type scale, where 1=do not know, 2=no influence, 3=low influence and 4=high influence. Additionally, factors that favoured and those that constrained the use of maize silage on the farm were collected such as availability of land to produce maize, maize silage increase milk yield and profitability of the farm and initial investment for making silage.

The forty-eight participating farmers were identified using a purposive sampling method (Vogt and Burke, 2016). The farmers were selected from nine communities of the municipality of Aculco, such as: La Cocepción, Tixiñu, San Jerónimo, San Lucas, El Tepozán, San Pedro Denxhi, Gunyo, Santa Ana Matlavat and Arroyo Zarco. The sample size represented 5% of the total small-scale dairy producers in the study area. Casián and Castillo (1987) recommended that studies conducted within rural communities should consist of 5 to 10% of the total population. The participants were selected considering two desirable characteristics: a) farmers who had already adopted maize silage, b) farmers with cattle herd size of 3 to 35 cows. This cattle herd size has been used to define the small-scale dairy farms in Mexico (Juárez-Morales *et al*., 2017). The data were collected from February to April 2014 and the interviews were either conducted in the farmers' house during their free time or in the shed during milking. A database was organized and fixed as recommended by Broman and Woo (2018).

Statistical analysis

The data was analysed using SPSS ver. 24. First, the data was explored to identify missing values, outliers and irregularities and corrected as necessary. Secondly, descriptive statistics of the whole sample were calculated, including farmer and farm characteristics, and farmers' perception on usefulness, utility and difficulty of the use of maize silage on the farm. Thirdly, to identify variables that influenced the farmers' intention to use maize silage on the farm in the next year, a hierarchical regression analysis was conducted (Table 2). The farmers' intention was considered as an dependent variable. The farmer's characteristics were included in the first step, farm characteristics in the second, and farmer's perception of maize silage on usefulness, importance and difficulty were considered in the third step. The regression analysis was done using simple ordinary least squares (OLS) and assumptions were checked according to Lalani *et al*. (2016).

Fourth, the forty-eight farmers were classified into three groups according to their land availability sizes and a Quartile Analysis (QA) was conducted according to Bernués and Herrero (2008). The first quartile (Q1=25%) grouped farmers with the lowest land availability; the second (Q2=50%) grouped farmers with medium land availability and the third (Q3=75%) grouped farmers with the highest land availability (Tables 1, 3, 4 and 5). From this classification, 14 farmers with 1.0-2.9 ha formed Group 1, Group 2 comprised 21 farmers with 3.0-6.9 ha, and Group 3 considered 13 farmers with 7.0-24.0 ha. Fifth, to compare the three groups regarding the four variables that described farmer's characteristics and the nine that corresponded to farm characteristics, a one-way analysis of variance (ANOVA) was conducted (Table 1). Since each sample size was less than 50 observations the data was tested for normal distribution using Shapiro-Wilk test (Field, 2013). The Games-Howell test was applied to identify differences (P<0.05) between groups. This post hoc test is recommended when sample sizes are unequal (Field, 2013). Sixth, a non-parametric Spearman correlation was conducted to correlate farmers' intention with the variables that describe farmer and farm characteristics, usefulness, importance and difficulty (Table 3) (Field, 2013).

Seventh, the non-parametric Kruskall-Wallis test was used to compare groups, and Mann Witney U tests was used to identify differences (P<0.05) among the three groups regarding farmers' intention and farmer's perception on usefulness, importance and difficulty of the use of maize silage on the farm (Table 4). The same non-parametric tests were used to determine differences between groups for factors that influenced farmer's decision to use maize silage such as price of maize seed, availability of land, availability of money,

availability of machinery and knowledge for making maize silage (Table 5). For the non-parametric tests, the median and interquartile range (IQR) were used as measures of central tendency and dispersion, since the variables were measured in an ordinal scale (Juárez-Morales *et al*., 2017).

RESULTS

Farmer characteristics

Classifying farmers according to their average land sizes produced three groups: Groups 1, 2 and 3 respectively (Tables 1, 3, 4 and 5). The average farmers' age was 49 years and most farmers (65%) had elementary education (seven years on average) although 14% of the farmers had attained high school or university education. The average farming experience was 26 years in which five years the farmer used maize silage on the farm. Seventy-five percent of the farmers reported no contact with extension services (Table 3). Among the three farmer groups, only farmer's experience in using maize silage significantly ($P<0.05$) differentiated the groups (Table 1). However, farmers in Group 1 tended to have the lowest values and those farmers in Group 3 had the highest values of the parameters studied. Farmers in Group 1 were younger, had the lowest level of education, had the lowest experience using maize silage and owned the smallest farms. Group 3 recorded the highest scores for these parameters although these differences did not reach significance ($P>0.05$).

Farm characteristics

The average family size were four and two of these members on average carried out the farm activities (Table 1). Most farmers (90%) rated milk to be the main source of their family income (Table 3). The overall average total herd size was 15 cattle of which nine were in production and yielded 16.5 litres milk, per cow daily. The average farm size was seven hectares of which four were destined for sowing maize. The amount of milk sold daily was 135 l per farm at an average price of 0.38 USD/l. The family size and number of farm workers; the milk yield and price were not different ($P>0.5$) among farmers in the three groups. The herd size, number of milking cows, amount of milk sold, farm size and total area under maize differed ($P<0.05$) among the three farm groups. However, the herd size, number of milking cows and amount of milk sold were similar between groups 2 and 3 ($P>0.5$).

Factors that influenced the farmers' intention to use maize silage on the farm

Hierarchical regression analysis (n=48)

The results of hierarchical regression analysis are presented in Table 2. It shows that years of farmers' experience in using maize silage had a positive influence on farmers' intention to use maize silage in the next 12 months. However, the variables milk yield per cow per day and total hectares sown to maize showed a negative influence on farmers' intention. Surprisingly, the variables such as usefulness, importance and difficulty did not significant ($P>0.05$) influence the farmers' intention. The model R^2 in the step three was 0.419 indicating that all variables combined in the model explain 42% of the variation in intention to use maize silage. The Durbin-Watson test was 2.179, indicating no violation of the homoscedasticity assumption.

Table 1. Descriptive statistics of farmer and farm characteristics.

Variables	Group 1 (n=14)	Group 2 (n=21)	Group 3 (n=13)		
Farmer characteristics	Average	Average	Average	[1]**SEM**	[2]***P***
Farmer's age (years)	47.4	47.6	48.8	5.0	0.960^{ns}
Farmer's education (years)	5.4	7.6	7.5	1.2	0.220^{ns}
Farmer's experience (years)	21.4	28.2	28.6	5.2	0.340^{ns}
Farmer's experience using maize silage (years)	2.9^{c}	4.4^{b}	7.0^{a}	0.4	<0.001
Farm characteristics					
Number of family members	3.8	4.5	4.3	0.4	0.280^{ns}
Family labour (persons)	2.0	2.0	2.1	0.5	0.990^{ns}
Herd size (heads)	9.0^{b}	16.0^{a}	21.0^{a}	2.6	<0.002
Milking cows (heads)	6.5^{b}	9.2^{a}	12.7^{a}	2.1	<0.034
Milk yield per cow per day (L)	15.8	15.6	19.0	2.3	0.220^{ns}
Milk sold per day (L)	68.7^{b}	140.0^{a}	196.0^{a}	24.6	<0.002
[3]Milk price (USD/L)	0.37	0.39	0.39	0.1	0.190^{ns}
Total hectares	1.3^{c}	4.6^{b}	13.0^{a}	0.2	<0.001
Total hectares sown to maize	1.3^{c}	3.5^{b}	9.2^{a}	0.3	<0.001

[1]SEM = standard error mean, [2]P = one-way ANOVA ($P<0.05$), ^{abc} = different superscripts indicate significant differences among Groups ($P<0.05$), ^{ns} = Not significant ($P>0.05$) when the Games-Howell test was applied. [3]Price on USD, 13.13 MXN (year 2014).

Table 2. Factors that influenced the farmers' intention to use maize silage on the farm.

Variable	*b*	[1]*SE*	*β*	*P*
Step 1				
Farmer's characteristics				
Constant	-2.662	3.548		
Farmer's age (years)	0.031	0.019	0.401	0.108
Farmer's education (years)	0.040	.054	0.139	0.465
Farmer's experience (years)	-0.008	0.016	-0.099	0.634
Farmer's experience using maize silage (years)	0.293	0.119	0.553	**<0.020**
Step 2				
Farm's characteristics				
Number of family members	-0.046	0.149	-0.056	0.757
Family labour (persons)	0.022	0.155	0.027	0.887
Herd size (heads)	0.005	0.044	0.041	0.911
Milking cows (heads)	0.046	0.074	0.281	0.536
Milk yield per cow per day (L)	-0.070	0.031	-0.369	**<0.034**
Milk sold per day (L)	-0.005	0.004	-0.401	0.314
[3]Milk price	0.363	0.469	0.144	0.445
Total hectares	0.102	0.053	0.767	0.064
Total hectares sown to maize	-0.273	0.114	-1.055	**<0.023**
Step 3				
Farmer's perception of maize silage on…				
Usefulness	0.641	0.489	0.276	0.199
Importance	-0.033	0.552	-0.014	0.953
Difficulty	0.334	0.232	0.291	0.159

Note: R^2=0.115 for Step 1; R^2=0.324 for Step 2, R^2=0.419 for Steps 3; [1]SE=Standard Error. Dependent variable: Intention to use maize silage. Durbin-Watson: 2.179.

Table 3. Correlation between farmers' intention and farmer and farm characteristics.

Variables	Group 1 (n=14) (*r*)	Group 2 (n=21) (*r*)	Group 3 (n=13) (*r*)
Farmer characteristics			
Farmer's age (years)	-0.477[ns]	0.392[ns]	0.183[ns]
Farmer's education (years)	0.368[ns]	0.029[ns]	-0.251[ns]
Farmer's experience (years)	-0.217[ns]	0.127[ns]	0.246[ns]
Farmer's experience using maize silage (years)	0.732**	0.380[ns]	-0.293
Farmers' access to extension services	0.193[ns]	0.157[ns]	-0.361[ns]
Farmers' advise to make maize silage	-0.121[ns]	-0.273[ns]	-0.416
Main source of family income	-0.395[ns]	-0.081[ns]	-0.190
Farm characteristics			
Number of family members	-0.175[ns]	-0.147[ns]	-0.272[ns]
Family labour (persons)	0.133[ns]	0.105[ns]	-0.174[ns]
Herd size (heads)	0.194[ns]	0.369[ns]	-0.275[ns]
Milking cows (heads)	-0.062[ns]	0.221[ns]	-0.271[ns]
Milk yield per cow per day (L)	0.046[ns]	-0.127[ns]	-0.344[ns]
Milk sold per day (L)	-0.175[ns]	0.244[ns]	-0.177[ns]
[1]Milk price	0.276[ns]	0.290[ns]	0.062[ns]
Total hectares	-0.208[ns]	-0.321[ns]	-0.129[ns]
Total hectares sown to maize	-0.098[ns]	-0.124[ns]	0.208[ns]
Farmer's perception of maize silage on…			
Usefulness	0.351	-0.133	0.702**
Importance	0.526*	0.442*	0.380
Difficulty	0.243	0.173	-0.043

[ns]= Not significant (P>0.05), * Significant correlation P<0.05 (2-tales), ** Significant correlation P<0.01 (2-tales).
[1]Price on USD, 13.13 MXN (year 2014).

Table 4. Usefulness, importance and difficulty of using maize silage.

Variable	Group 1 (n=14) Median	[1] IQR	Group 2 (n=21) Median	[1] IQR	Group 3 (n=13) Median	[1]IQR	[2]*P*
Usefulness	5.0	1.0	5.0	0.0	5.0	0.0	0.432
Importance	5.0	1.0	5.0	0.5	5.0	0.0	0.381
Difficulty	4.0	0.0	4.0	1.0	4.0	1.5	0.195

[1]IQR=Interquartile Range; [2]*P* = Kruskall-Wallis test (*P*<0.05), Level of usefulness: 1=Not useful, 2=Little useful, 0=Do not know, 4=Useful, 5=Very useful, Level of importance: 1=Not important, 2=Little important, 0=Do not know, 4=Important, 5=Very important, Level of difficulty: 1=Very difficult, 2=Difficult, 0= Do not know, 4=Easy, 5=Very easy.

Correlation between farmers' intention and farmers and farm characteristics

The farmers' intention was not (*P*>0.05) correlated with the variables that described the farmer and farm characteristics (Table 3) except in Group 1 where years of farmer's experience using maize silage was significantly positively correlated (*P*<0.05) to farmers' intention. The farmers' intention of Group 3 was significantly positively correlated (*P*<0.05) with the usefulness of maize silage. In Group 1 and 2, there was a significant positive correlation (*P*<0.05) between farmers' intention and farmers' perception about the importance of maize silage on the farm. However, famers' intention of the three groups was not correlated (*P*>0.05) with the difficulty perceived in the use maize silage (Table 3).

Overall the farmers in Group 1 showed the lowest percentage of extension services received (21%) and advice for making maize silage (30%) (Table 3). Most of the farmers (79%) reported milk sales as their main source of family income. The remaining 21% of the farmers indicated that they had off-farm incomes.

Farmers' intention and perception on usefulness, importance and difficulty of using maize silage on the farm

The farmer's perception on usefulness, importance and difficulty of using maize silage on the farm is showed in Table 4. The farmers from all the three groups (*P*<0.05) perceived that maize silage was very useful and very important as cattle feed, particularly during the dry season. They also expressed that it was easy to use on the farm (Table 4). The farmers rating was strong (median=4.5, Group 1) to very strong (median=5, Groups 2 and 3).

The effect of seed price, land, money, machinery and knowledge on farmer's decision to use maize silage

The factors that influenced farmers' decisions to use maize silage on the farm are presented in Table 5. Four out of the five factors evaluated were not statistically different (*P*>0.05) among the three groups. However, farmers from Groups 1 and 2 expressed that land availability had high influence (*P*<0.05) to their use of maize silage. Farmers from all the three groups agreed that the availability of money, machinery and knowledge had high influence on their decisions to use the innovation on the farm (*P*<0.05).

More than half of farmers (57%) from Group 1 expressed that the high initial investment (900 USD per ha) for making silage was considered the major constrain. On the other hand, thirty-six percent of farmers in Group 1 pointed out that an ample availability of land to produce maize was a factor that favours the use of maize silage. The farmers from Groups 2 and 3 revealed that using maize silage had economical and productive benefits on the farm, since most felt silage increases milk yield and profitability of the farm.

DISCUSSION

Farmer and farm characteristics and factors that influenced the farmers' intention to use maize silage on the farm

Grouping farmers has been used to evaluate sustainability (Prospero-Bernal *et al.,* 2017) and to study technology adoption in small-scale dairy farms (Martínez-García *et al.,* 2015b). Martínez-García *et al.* (2015b) and Prospero-Bernal *el al.* (2017) reported that the level of education, herd size and availability of land, played an important role in the adoption of maize silage. However, this conflicted with the findings in the current study that farmers without studies, with few milking cow and low availability of land were users of the innovation as observed in Group 1.. Thus, the findings in the current study suggested that maize silage was a suitable innovation for small-scale dairy farmers who had little education and small farms.

The farmers' experience was a key determinant that favoured the use of maize silage by the small-scale dairy farmers (Table 2). The longer the farmers' experience, the stronger was the farmers' intention to use maize silage over the next 12 months. This is in accord with Martínez-García *et al.* (2016) who

reported that the farmers' experience played an important role in adoption of improved varieties of grass. The negative relation of milk yield per cow per day with the farmers' intention to use maize silage is because as the milk yield increases the nutrients from silage will not be sufficient. The farmer will need to feed the cattle will more nutritious feed such as legumes and compounded dairy meals hence his intention to expand the silage crop area will diminish. The bigger the area already sown with maize silage crop, the weaker was the intention to expand it because the land for expansion became limiting on the small scale dairy farm. This will reduce the farmers' intention to expand the application of the innovation.

Correlation between farmers' intention and farmer and farm characteristics

The current study recorded that farmers' decision to use maize silage was not based on the farmer and farm characteristics as these variables were not correlated with farmers' intention. Some studies have reported that farmers' intention to adopt new innovations was based on the farmers' beliefs and their perception of the innovation (Juárez-Morales *et al.,* 2017, Martínez-García *et al.,* 2018, Schaak and Mubhoff, 2018). The current study recorded that farmer's perception about the importance (Groups 1 and 2) and usefulness (Group 3) of the innovation played an important role on farmers' decision to use maize silage. Hence, farmers' intention to use maize silage was because of the immediate benefits perceived by farmers, as reported in the adoption of improved pastures and grazing practices (Martínez-García *et al.,* 2018, Schaak and Mubhoff, 2018). Therefore, people involved in the process of technology transfers must take into account the perception of potential adopters.

The farmers in the three groups found it easy to make maize silage on the farm This could be associated with farmers' experience and knowledge to manage the innovation. Thus, farmers' perception about usefulness, importance, and easiness of the innovation were key determinants for driving the use and adoption of maize silage on the farm. This agrees with a report on the adoption of agricultural and animal husbandry technoloiges in small-scale dairy farms by Martínez-García *et al.* (2016). Rogers (2003) reported that innovations were adopted faster if they were easy to understand and use. Moreover, exposure to information about utility in terms of productivity and cost effectiveness of innovations reduce uncertainty and complexity. In order to improve adoption rates among non-users, extension programmes should be conducted to increase farmers' experience, develops skills and knowledge for making maize silage. The implementation of a systems approach is recommended. It emphasises an interactive learning among farmers, researchers, extension, technology suppliers and policymakers, which allows a continuous learning among actors and produces a favourable change in adoption of innovations (Schut *et al.,* 2015).

The effect farmers' intention and perception, innovation characteristics and farm inputs and knowledge on farmer's decision to use maize silage

Farmers in Groups 1 and 2 manifested that land availability had high influence on the use of maize silage on the far. However, since the innovation could be used successfully in smallest-scale dairy farms that hard both small and large farm areas, then critical limiting size of the farm for using the innovation has not been reached. This fin dings contradict the study reported by Prospero-Bernal *et al.* (2017), since farmers considered that the availability of land favoured the use of maize silage.

The positive farmers' beliefs of the innovation (Groups 2 and 3) such as increased profitability of the farm and improved milk yield could be drivers that favoured and encouraged farmers to use and adopt the innovation. This agrees with the findings of Juárez-Morales *et al.* (2017) and Martínez-García *et al.* (2018) who reported that farmer's beliefs were important factors to the use and adoption of improved pastures. Therefore,

Table 5. The effect of farm inputs and knowledge on farmer's decision to use maize silage.

	Group 1 (n=14)		Group 2 (n=21)		Group 3 (n=13)		^2P
How much does it influence… in the use of maize silage	Median	IQR	Median	IQR	Median	IQR	
Price of maize seed	3.0	2.0	3.0	1.0	3.0	1.0	0.227
Availability of land (ha)	4.0[a]	0.3	4.0[a]	1.0	3.0[b]	2.0	<0.049
Availability of money	4.0	0.0	4.0	0.0	4.0	0.5	0.190
Availability of machinery	4.0	0.0	4.0	0.0	4.0	1.0	0.284
Knowledge for making silage	4.0	1.3	4.0	2.0	4.0	2.0	0.481

IQR=Interquartile Range; Level of influence: 1=Do not know, 2=No influence, 3=Little influence, 4= High influence, ^2P = Kruskall-Wallis test (P<0.05), [abc]=Different superscripts indicate significant differences among groups (P<0.05), Mann- Whitney test.

appropriate extension programmes could consider encouraging and reinforcing the positive beliefs of the use of maize silage, especially among farmers who had not already been engaging in the use of the innovation. Martínez-García *et al.* (2015b) documented that farmers had a strong preference for programmes and activities that take place on farm. Therefore, policy makers must develop extension programmes that are conducted on dairy farms.

The farmers pointed out that maize silage was an innovation that required a high initial investment, the rent of machinery was expensive, and knowledge was important to make a proper maize silage. The farmers in all the three groups shoed that the availability of money, machinery and knowledge to make maize silage had a high influence and were key factors for decision making. However, the current findings showed that these factors were not a constraint to use the innovation by farmers with the smallest scale dairy farms. The farmers reported a positive intention to use maize silage in the next year. Thus, the smallest scale-dairy farmers who had adopted the innovation should be used as demonstration to disseminate and inform on the innovation among non-users, through a farmer-to-farmer approach. Therefore, there is a need and an opportunity to understand small-scale dairy farmers' networks to support dynamic interactions that may foster the implementation of maize silage among non-users.

CONCLUSIONS

This study provided an important insight about factors that drive the use and adoption of maize silage from three groups of farmers with different farm size. The study has highlighted that maize silage is not just an innovation to farmers who had large farms but it is, also, suitable for small farms. Maize silage innovation can be implemented by both farmers with high or little academic education. The key determinants to use maize silage were farmers' experience, positive beliefs, usefulness, importance and benefits of the innovations on the farm. In order to improve the adoption rates of the innovation among non-users, extension programmes need to be conducted using different extension approaches including system approach, farmer-to-farmer and social networks approaches. However, effectiveness and usefulness studies need to be done on the field to rank the approaches.

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Data availability. Data are available with the corresponding author at: (cgmartinezg@uaemex.mx) upon reasonable request.

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