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Dairy Manure Management Perceptions and Needs in South American Countries

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Milk production is important in South American countries being based mainly on grazing systems. Dairy slurry management has become an important issue in these production systems because of the large volumes produced and the environmental effects. Thus, manure management regulations are emerging in the region. This research aims to identify priorities for management strategies and technology transfer by assessing perceptions, needs and barriers toward dairy manure management by stakeholders in South American countries. A questionnaire was prepared and distributed in Spanish and Portuguese in different formats: on paper and online (PDF format and SurveyMonkey™ platform) between March 2015- November 2017. It was divided into two sections, the first addressed issues related to water quality and pollution, odor generation, fertilizer value, pathogens impact and biogas production. Responses were measured across a standard 5-point Likert type scales. Section two addressed needs and hindrances concerning about manure application. A total of 593 surveys were completed: Argentina (n = 308, 52%), Brazil (n = 217, 37%) and Chile (n = 68, 11%). The majority of respondents were dairy farmers (31%), professional advisors and consultants (29%) and representatives of public institutions and researchers (31%). Some differences appear according the country. Overall, a large majority perceive that manure is a good fertilizer (91%), also they believe that it contributes to pathogen's transmission and groundwater and shallow aquifers 'contamination. Stakeholders (60%) perceived biogas production as a good option for manure treatment. Most of respondents (79%) would use manure to replace mineral fertilizers, with little differences between countries (Argentina 79%, Brazil 80% and Chile 68%). The most selected needs were: a management handbook, increased investment in equipment and technologies and better access to laboratory analysis. The most chosen barriers were: cumbersome management, lack of knowledge and of specific laws, with differences between countries and respondents. The survey showed interest in dairy manure management as a source of nutrients for grassland and crops, especially among farmers and advisors whom requested

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guidelines for responsible management. Policymakers and stakeholders should focus on promoting manure reuse on dairy farms through incentives, technologies and/or appropriate strategies, in order to improve nutrient use and reduce pollution to the wider environment.

Keywords: environmental regulations, organic fertilizer, dairy slurry, dairy stakeholders, technology adoption, waste technologies, dairy grazing systems

INTRODUCTION

The dairy industry is an important sector in South American countries, where Argentina, Brazil, and Chile possess 70% of the South American dairy herds and produce 73% (43 million liters) of the milk of this region (FAOSTATS, 2016). Dairy farming is mainly pasture-based, in non-irrigated areas with a low proportion of herds in confinement, but with part-time confinement for feeding with silage and concentrates. Cows are milked one to three times per day; after each milking, the parlor is cleaned. Cleaning is generally performed with or without scraping and washing with or without pressure. The average effluent volumes used are 27.7 and 36.6 L day^{-1} cow^{-1}, respectively, for Argentina and Chile (Salazar et al., 2010). Previous studies indicate that the slurry produced has high contents of rain and cleaning water. As a result, dry matter and nutrient contents are low, and the costs of transporting the slurry to arable farms are relatively high (Salazar et al., 2007; Charlón et al., 2013). The rapid development of the dairy industry has resulted in the increase of the total wastewater discharge. As a result, developing a reasonable and effective water resource management to deal with water pollution challenges associated with the dairy industry has become an urgent issue in different countries such as China (Bai et al., 2017).

The use of livestock manure for fertilization is a valid practice and should be part of the waste management of animal production systems, mainly because of the high nutrient and water contents of manure (Watson and Atkinson, 1999), reducing the need to purchase chemical fertilizers and to irrigate the crops. However, in case of inadequate manure management, there is the risk of point source or diffuse pollution, compromising soil, air, and water quality (e.g., Isermann, 1990; Erisman et al., 2008). In South American countries, dairy slurry is used mainly without treatment, although in some cases, mechanical separation is carried out. The effluent is stored in earth banks and lined lagoons or concrete tanks and applied to the field by surface application (e.g., via slurry tanks or irrigation pumps) throughout the year (Salazar et al., 2010). Higher concentrations of nutrients in the environment are often associated with an over-use of fertilizers and manures, intensive livestock breeding, climatological and edaphic conditions, and inadequate agricultural practices and management (Herrero and Gil, 2008; Oenema, 2015). The generation of high amounts of manure in concentrated areas from livestock production systems requires adequate on-farm and off-farm management. In several countries, an equilibrium between the amount of manure produced and the availability of an agricultural area to recycle this manure is difficult to achieve (Bernal, 2017). However, in most South American countries, dairy intensification is a rather recent process, and the relationship between the amount of manure and crop area is more suitable. In addition, dairy production systems in South America are mainly based on grazing, where most of the feces and urine enter the soil directly, reducing the amount of manure production (Salazar et al., 2010).

In Argentina, Brazil, and Chile, the lack of knowledge and the low adoption rate of waste management technologies are the most conflicting issues concerning environmental conservation (Palhares, 2009; Salazar et al., 2010; Charlón et al., 2017a). In these countries, new regulations for manure management are emerging, and farmers and other professionals show an increasing interest in the agronomic use of animal manure; however, special guidelines for the implementation of good management practices are crucial.

To analyze the possibilities of adopting certain technological innovations in terms of manure management in the South American agricultural sector, it is important to know the needs and constraints of producers, consultants, researchers, students, and governmental agents regarding such implementations. Stakeholder perceptions are important aspects to be evaluated, as stakeholders are mainly responsible for the implementation, evaluation, and adaptation of manure management practices. Agri-environmental programs are basically designed to promote changes in the behavior of farmers, either via amplifying behavior which leads to positive externalities or by restricting behavior which leads to negative externalities (Ahnström, 2009; Blackstock et al., 2010; Wissman et al., 2013).

The adoption of adequate manure management practices also depends on the regulatory context and the local market, for example environmental policies and the agricultural industry structure of the country under consideration, or on other, more complex issues, especially when they relate to environmental aspects (Sunding and Zilberman, 2001; Prokopy et al., 2008). The production system, farm size, and management practices are also aspects to be considered to evaluate. Thoma et al. (2013), investigating management practices at US dairy farms, showed how a large diversity of management practices and technologies used in production units translates into significant differences in environmental impacts. There is thus a high potential to improve the environmental performance of the dairy sector.

In Denmark, incentives and legislative requirements for the processing of organic waste were introduced recently to meet environmental objectives. This situation was an incentive for the evaluation of the perception of producers toward

the use of organic waste (Case et al., 2017). It is important to carry out studies to understand the decisions of farmers, professional consultants, and policy makers regarding the adoption of alternative organic crop fertilizers, especially against the background of no regulatory incentives or no history of using these techniques. Generally, surveys to assess perceptions, attitudes, and needs focus on different aspects (Petit and van der Werf, 2003; Herrero et al., 2010; Barnes and Toma, 2012; Wolf et al., 2016; Hou et al., 2018). Also, they are generally used at the regional scale to compare stakeholder perceptions between regions and countries (Hou et al., 2018).

On a global level, only few studies have specifically considered manure and the use of organic fertilizers by farmers and professional consultants (Gebrezgabher et al., 2015). Although South America accounts for 54% of the livestock and 5% of the dairy cows in the world (FAOSTATS, 2016), there are no published studies on these issues.

In this context, we identified, for the first time, the requirements for management strategies and technology transfer by assessing the perceptions, needs, and barriers in terms of dairy manure management by stakeholders in South American countries. The results of our study will contribute to the discussion of upcoming policies and regulations on dairy manure use.

MATERIALS AND METHODS

We used a descriptive methodology to obtain information about the perceptions, needs, and barriers in terms of dairy manure management, explaining the stakeholders' understanding. Descriptive survey types were used to obtain information concerning the current status of the subject and to demonstrate relationships between different issues (Jackson, 2009; Saunders et al., 2012), obtaining qualitative data. The issues in dairy manure management were defined by expert judgment, facilitating the delimitation of the research theme and the discussion about policies and regulations.

Country Selection and Context

Argentina, Brazil, and Chile have similar livestock production systems, which are based on pasture grazing with daily confinement for feeding with silage and concentrates. These countries have an increased consumption of animal products, and the milk supply chain has important social relevance in terms of employment and income; currently, the milk sector is undergoing verticalization. There are no or few specific environmental regulations for manure management, and the social pressure to adequately manage dairy manure is increasing, with regional regulations being implemented (e.g., in Córdoba Province, Argentina).

Survey Questionnaire and Data Collection

Data were collected between March 2015 and November 2017. A questionnaire survey was constructed to determine the perceptions, needs, and barriers in terms of dairy manure management by the participants. We surveyed dairy farmers (DF), professional advisors and consultants (PAC), dairy farm employees (DFE), service and inputs providers in dairy technologies, students and representatives of public institutions working in agro-environmental policies and from dairy companies, and researchers from academic institutions; the latter category was classified as "OTHERS" (Herrero et al., 2010; González-Pereyra et al., 2015; Hou et al., 2018). Prior to the survey, the researcher explained to each respondent that it was a survey to assess their perception of manure management and that the results would be used exclusively for research purposes. No respondents were identified by name in the questionnaires, so the authors cannot relate the participant to the answers; in this way, the ethical and more principles of each respondent were not violated.

The survey was prepared in Spanish and Portuguese in three different formats: on paper, which was handed at conferences, workshops, symposiums, and field days (Argentina); online in a PDF format and sent by e-mail (Argentina and Brazil); and via an online survey using the SurveyMonkeyTM platform (Chile). All formats used the same questions and structure. Survey dissemination strategies differed between countries according to working styles, connectivity, and the possibility of contacting the stakeholders, always meeting the usual ways of collecting information. Such an approach generally facilitates high cooperation rates at a low economic cost (Rojas Tejada et al., 1998).

The survey was divided into two sections. The first section addressed seven issues related to:

- Groundwater contamination: (1) Do you agree that groundwater can be contaminated by effluent lagoons?
- Odor as a pollutant: (2) Do you agree that effluent lagoon odors are environmental pollutants?
- Manure as a fertilizer: (3) Do you agree that manure is a good fertilizer?
- Transmission of pathogens: (4) Do you agree that effluents can be vehicles for the transmission of pathogens?
- Biogas manure treatment: (5) Do you agree that manure treatment through biogas is the best option?
- Contamination of shallow aquifers: (6) Do you agree that shallow aquifers can be contaminated by disposing effluents and slurry in the lower areas of the farm?
- Water quality impact: (7) Do you agree that the quality of the water used in the dairy parlor influences manure management and its use as a fertilizer?

Responses were measured across a standard 5-point Likert type scale, ranging from strongly agree (5 points), agree (4 points), neutral (3 points), disagree (2 points) to strongly disagree (1 point) (Likert, 1932; Barnes and Toma, 2012; Sullivan and Artino, 2013).

The second section addressed an option that allowed the respondents to choose whether manure or slurry should be reused as fertilizer. There were also five options in terms of "needs" and five in terms of "barriers," and the respondents could choose one or multiple answers (Bernal, 2017; Case et al., 2017; Hou et al., 2018). The response options were selected based upon previous studies and tested by experts in the field of manure management (Salazar et al., 2007, 2010; Asai et al., 2014; Palhares,

2014; Vankeirsbilck et al., 2016; Charlón et al., 2017b; Palhares et al., 2017).

The preliminary version of the questionnaire was based on the definition of a basic structure that was built by the personal experience of the authors in the different local contexts. The questions in the first section were selected from previous studies (Herrero et al., 2010, 2011). The lists of needs and barriers were based on interviews with key actors and experts in the dairy sector and on previous surveys (Herrero et al., 2011). We then performed a pilot test with a small sample of postgraduate students, rural area consultants, and researchers. Once the answers were evaluated, the final version was designed.

Statistical Analyses

All data from the different versions were downloaded and compiled in one Microsoft Excel 2010 file. The responses were cleaned and checked for inconsistencies. A descriptive analysis of the results of both sections of the survey was carried out (median, ranges, and frequencies and percentages) for individual countries, type of respondents, and for all results.

For analysis of the first section of the questionnaire (seven Likert questions), both univariate and bivariate analyses were conducted to obtain the frequency of response. These data were then used to construct the typology based on the responses to the statements. Multiple correspondence factorial analysis (MCA), hierarchical classification of Ward based on seven factorial axes, and cluster analysis were performed to obtain significant modalities at $p < 0.05$. All seven Likert questions related to the environmental issues described below were defined as active variables, while country and the profession were considered as supplementary variables (Lebart et al., 1995, 1998). On the other hand, mean comparisons between the three countries were performed for these seven variables via the Kruskal-Wallis rank sum test ($p < 0.05$), and Dunn's multiple comparison procedure was applied to detect differences between countries ($p < 0.05$).

Since in the second section, there were several multiple-response questions for the selection of needs and barriers, the absolute number of respondents referring to each option was converted to the percentage of the total number of respondents who answered the question in order to allow a comparison between countries (Barnes and Toma, 2012; Hou et al., 2018). To compare countries in terms of different needs and barriers, a Chi^2 homogeneity test was used at $p < 0.05$. To evaluate the association of needs and barriers with the respondent's profiles, a Chi^2 independence test was used at $p < 0.05$ (SAS Institute, 2011).

RESULTS

Respondent Profiles

A total of 593 surveys were completed, with 308 (52%) from Argentina, 217 (37%) from Brazil, and 68 (11%) from Chile. **Figure 1** shows an overview of all respondents in terms of profile and country. Of all respondents, 77% were dairy farmers ($n = 182$), professional advisors, and consultants ($n = 170$), as well as representatives of public institutions involved in agro-environmental policies, dairy companies, and researchers of academic institutions ($n = 106$).

In Argentina, the highest percentage of respondents (77%) corresponded to dairy farmers ($n = 108$, 36%), professional advisors and consultants ($n = 79$, 26%), service and inputs providers, representatives of public authorities, and researchers at academic institutions ($n = 73$, 24%). In Brazil, the highest percentage of respondents (90%) corresponded to professional advisors and consultants ($n = 76$, 35%), students ($n = 63$, 29%), and dairy farmers ($n = 56$, 26%). In Chile, 81% of the respondents were representatives of public authorities, people working in dairy companies, researchers at academic institutions ($n = 22$, 32%), dairy farmers ($n = 18$, 26%), and professional advisors and consultants ($n = 15$, 22%).

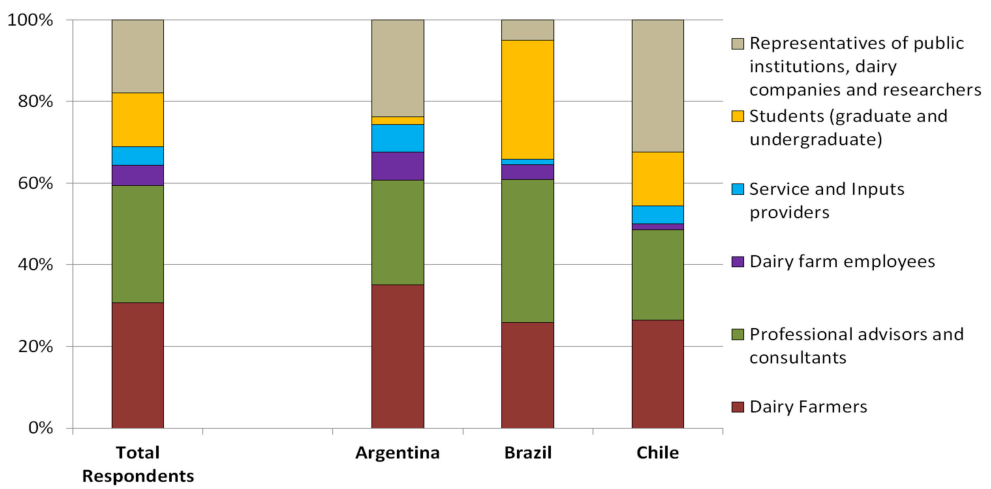

FIGURE 1 | Overview of survey respondents' profiles of the three South American countries.

Manure Management and Environmental Perceptions

The general perceptions of the 593 respondents, expressed as percentage according the 5-point Likert scale, are shown in **Figure 2**. Overall, the large majority of respondents in all regions believed (strongly agree and agree) that manure is a good fertilizer; however, at the same time, there was an agreement that manure can cause problems to the wider environment. More than 40% strongly considered odor as a pollutant, and more than 50% related manure to the transmission of pathogens. It is interesting that most of the respondents believed that manure can cause groundwater contamination, but at the same time, there was a low agreement in that it can affect water quality (**Figure 2**).

Five clusters were defined by a dendrogram. Correspondence analysis for perceptions on manure management and environmental impacts, including countries and respondent's profiles, showed that five groups were statistically significantly different ($p < 0.05$). Group 1 contained 240 respondents, mostly from Argentina, who strongly agreed or agreed (5 and 4) on six of the seven questions (except biogas as an alternative to treatment). Group 2 contained 41 respondents who were indifferent to all the questions, except for the importance of biogas treatment. This group was not made up of respondents from one particular country. Group 3 contained 239 respondents, mostly from Brazil, who the issues in an intermediate way (opinions 4-3 and 2), except for the function of the effluent as a fertilizer, to which they fully agreed. In group 4, there were 46 people who disagreed with all questions. Group 5 contained 57 individuals who did not respond to five of the seven questions, with the exception of the effluent as a producer of odors that are contaminants and the effluent as a water pollutant.

To evaluate the different perceptions for each environmental aspect considered in the questionnaire by countries and by type of respondents, we calculated mean values and standard deviations (**Tables 1**, **2**). To assess these values, we considered for all the Likert scale responses that: strongly agree = 5 points, agree = 4 points, unsure = 3 points, disagree = 3 points, strongly disagree = 1 point, and no response = 0 point. Significant differences between Argentina and Brazil and between Chile and Brazil were observed for the aspects in questions 1–5 ($p < 0.05$), according to the Kruskal Wallis test and Dunn's multiple comparison procedure (**Table 1**).

In Argentina (**Figure 3A**) the largest group of respondents (63, 44, and 63%, respectively) considered the consequences of the effluent lagoons for groundwater contamination and for shallow groundwater in lowland areas and agreed that pathogen transmission could be a consequence of manure management. At the same time, an impressive group of respondents perceived the importance of the use of manure as a fertilizer (50%).

Almost all Brazilian respondents agreed with the use of manure as fertilizer, and about 80% believed that biodigestion

TABLE 1 | Perceptions of manure management and its environmental impact in Argentina, Brazil, and Chile expressed as means values ± standard deviation according the survey response.

Issues surveyed	Argentina	Brazil	Chile
(1) Groundwater contamination	$4.34^{a} \pm 1.12$	$3.62^{b} \pm 1.43$	$4.07^{a} \pm 1.27$
(2) Odor as a pollutant	$4.03^{a} \pm 1.34$	$3.42^{b} \pm 1.46$	$4.26^{a} \pm 1.15$
(3) Manure is a good fertilizer	$4.21^{a} \pm 1.10$	$3.73^{b} \pm 0.64$	$4.19^{a} \pm 1.11$
(4) Transmission of pathogens	$4.28^{a} \pm 1.22$	$3.61^{b} \pm 1.42$	$4.23^{a} \pm 1.02$
(5) Biogas manure treatment	$3.23^{a} \pm 1.28$	$4.73^{b} \pm 1.20$	$3.26^{a} \pm 1.29$
(6) Contamination of shallows aquifers	$3.78^{a} \pm 1.48$	$3.83^{a} \pm 1.40$	$4.07^{a} \pm 1.27$
(7) Water quality impact	$2.75^{a} \pm 1.57$	$2.94^{a} \pm 1.53$	$2.99^{a} \pm 1.61$

[a]Different letters in rows shows significant differences between countries, Dunn test ($p < 0.05$). Perception Likert 5-point scale from strongly agree = 5 points to strongly disagree = 0 point.

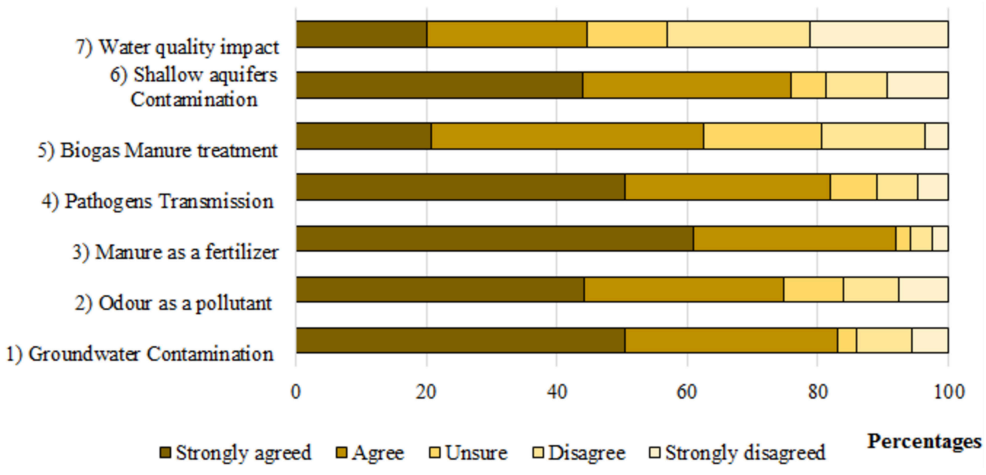

FIGURE 2 | Regional perceptions distribution of 593 respondents (%) according a 5-point Likert scale about seven issues related to manure management.

TABLE 2 | Perceptions of manure management according different respondents expressed as median ± standard deviation according the survey response.

Issues surveyed	DF	PAC	DFE	SIP	ST	OTHERS
(1) Groundwater contamination	$4.07^{a} \pm 1.36$	$4.04^{a} \pm 1.28$	$4.33^{a} \pm 0.92$	$4.07^{a} \pm 1.27$	$3.92^{a} \pm 1.24$	$4.03^{a} \pm 1.39$
(2) Odor as a pollutant	$3.71^{a} \pm 1.45$	$3.89^{a} \pm 1.39$	$3.47^{a} \pm 1.55$	$4.11^{a} \pm 1.45$	$3.76^{a} \pm 1.33$	$4.03^{a} \pm 1.33$
(3) Manure is a good fertilizer	$4.41^{a} \pm 1.05$	$4.53^{a} \pm 0.84$	$4.70^{a} \pm 0.53$	$3.70^{a} \pm 1.66$	$4.45^{a} \pm 0.77$	$4.22^{a} \pm 1.06$
(4) Transmission of pathogens	$3,76^{a} \pm 1.45$	$4.22^{bc} \pm 1.17$	$4.13^{ac} \pm 1.07$	$3.96^{ac} \pm 1.74$	$3.97^{ac} \pm 1.15$	$4.24^{bc} \pm 1.28$
(5) Biogas manure treatment	$3.36^{ac} \pm 1.32$	$3.36^{ac} \pm 1.31$	$3.93^{bc} \pm 1.01$	$3.48^{ac} \pm 1.55$	$4.18^{b} \pm 0.90$	$3.11^{a} \pm 1.20$
(6) Contamination of shallows aquifers	$3.63^{a} \pm 1.54$	$4.04^{a} \pm 1.28$	$4.10^{a} \pm 1.06$	$3.96^{a} \pm 1.34$	$3.69^{a} \pm 1.41$	$3.76^{a} \pm 1.54$
(7) Water quality impact	$2.91^{ab} \pm 1.62$	$2.96^{ab} \pm 1.54$	$3.60^{b} \pm 1.54$	$2.78^{ab} \pm 1.60$	$2.62^{a} \pm 1.37$	$2.55^{a} \pm 1.57$

[a]Different letters in rows shows significant differences between respondents, Dunn test ($p < 0.05$). Perception Likert 5-point scale from strongly agree = 5 points to strongly disagree = 0 point. Different Groups of respondents. DF; Dairy Farmers; PAC, Professionals advisors and consultants; DFE, Dairy Farm Employees; SIP, Service and Inputs Providers; ST, Students; OTHERS, representatives of public institutions working in agro-environmental policies and from dairy companies and researchers from academic institutions.

is a good option for manure management (**Figure 3B**). The use of manure as fertilizer and biodigesting are coincident, since the effluent from the biodigester can be used as a fertilizer. The statements 4 and 6 obtained similar percentages of agreement and were directly related, since groundwater contamination with manure can represent a pathway of pathogen transmission. The statement that odors are pollutants obtained the second lowest level of agreement, with slightly more than 60% of the respondents, although a high percentage of the respondents believed that there is no adequate regulation in Brazil.

In Chile, most of the stakeholders strongly agreed or agreed with the use of manure as a source of fertilizer; however, at the same time, the respondents were aware of the fact that inappropriate manure management can cause environmental problems (**Figure 3C**). On the other hand, the same respondents placed less importance on water quality related to manure reuse; for them, manure treatment via anaerobic digestion was not a technology prioritized by farmers.

For the three countries, the impact of the water quality used in the milking parlor on the quality and management of manure as fertilizer had the lowest importance (**Figure 2**). This could be explained by the low salt concentrations in the groundwater of Brazil and Chile (**Figures 3B,C**), esp. in the vicinity of dairy farms. However, this was not the case for Argentina (**Figure 3A**), where groundwater quality is an important aspect, with relatively high salt concentrations in the groundwater under dairy farms.

We found significant differences between Argentina and Brazil and between Chile and Brazil in terms of the aspects in questions 1–5 ($p < 0.05$), according to the Kruskal Wallis test and Dunn's multiple comparison procedure (**Table 1**).

The mean values for the different groups of respondents did not differ significantly for statements 1, 2, 3, and 6 (**Table 2**), but were significantly different in terms of pathogen transmission (4), biogas treatment (5), and water quality impact (7) ($p < 0.05$). Statements 1 and 6 are related because they consider groundwater and contamination due to incorrect effluent disposal; regardless of the degree of education of the respondent, this relationship was identified by all profiles. All respondent profiles, esp. the dairy farm employees, also understood that the use of manure as fertilizer is a good practice. In terms of effluent as a transmission vehicle for pathogens, there was a significant difference between DF and PAC and between DF and OTHERS. In the case of statement 5, the most significant difference was observed between ST and OTHERS, being the highest average verified for ST. This group, which attended university, was more exposed to such specific knowledge and therefore more open to new practices and technologies.

Needs and Barriers

Most of the respondents said that they would use manure to replace mineral fertilizers (79%), with slight differences between countries (Argentina 79%, Brazil 80%, and Chile 68%). One group (15%) would not consider the use of dairy manure on farms, also with differences between countries (Argentina 16%, Brazil 9%, and Chile 32%). The higher value for Chile was probably related to the increasing use of dairy manure on farms. In Argentina and Brazil, 5 and 11% of the respondents, respectively, did not answer these questions.

Regardless of the group of respondents, between 68 and 84% would use manure as fertilizer (**Figure 4**). However, the largest group that would not use manure was composed of dairy farmers (22%), with considerable differences between countries (68% Argentina, 15% Brazil, and 18% Chile). In this group, the lack of knowledge (29% Argentina and 47% Brazil) and the specific costs and regulations for Chile (33%) were identified as barriers. Within the group of hesitant respondents regarding the use of manure, most were also dairy farmers (68%), following the same trend between countries (60% Argentina, 15% Brazil, and 18% Chile) and the same barriers.

The participants were asked to select one or more different options from a list of five needs and barriers in terms of the use of dairy manure and slurry to replace mineral fertilizers (**Table 3**). Across all respondents ($n = 593$), 571 participants selected one or more needs (Argentina, $n = 310$; Brazil, $n = 214$, and Chile, $n = 47$), and 458 participants selected one or more barriers (Argentina, $n = 224$; Brazil, $n = 188$, and Chile, $n = 49$).

Of all respondents, 21% selected all needs (five options), with similar percentages for the three countries (Argentina 22%, Brazil 20%, and Chile 19%). Only 4% of the respondents did not select any option, corresponding to the 80% to the group that would not reuse manure. The mean total value representing the number of choices selected was 2.83 options for each respondent. For four

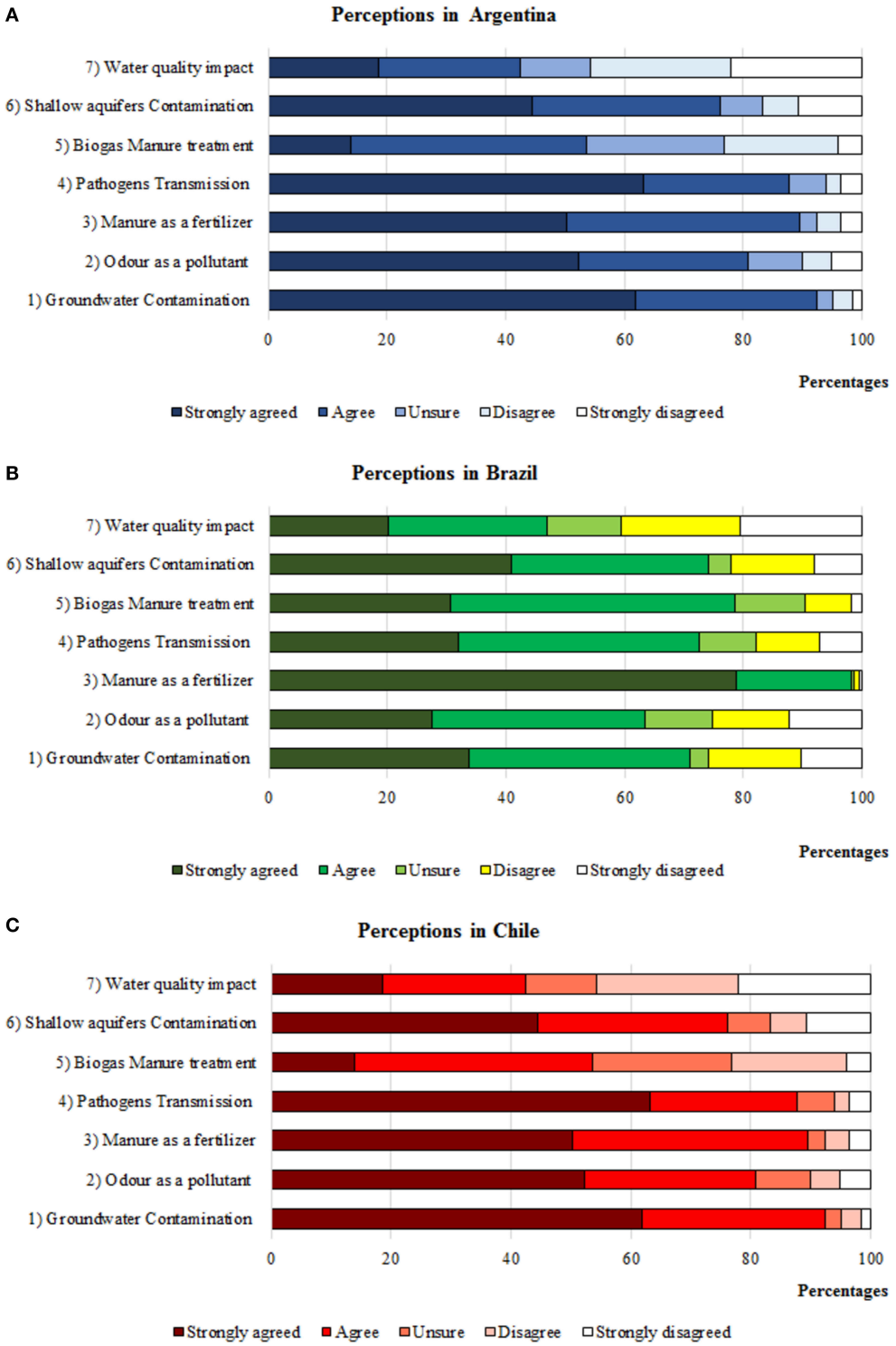

FIGURE 3 | Perceptions distribution of respondents from **(A)** Argentina (308), **(B)** Brazil (217), and **(C)** Chile (68) expressed in (%) according 5-point Likert scale respondents about seven issues related to manure management.

options, similarities were observed between the needs selected among the three countries. The most important needs were more equipment for the application and manuals or guides for manure management. Significant differences ($p < 0.05$; test Chi^2) were observed only for the option "Requirement of trained personnel," with higher values for Brazil.

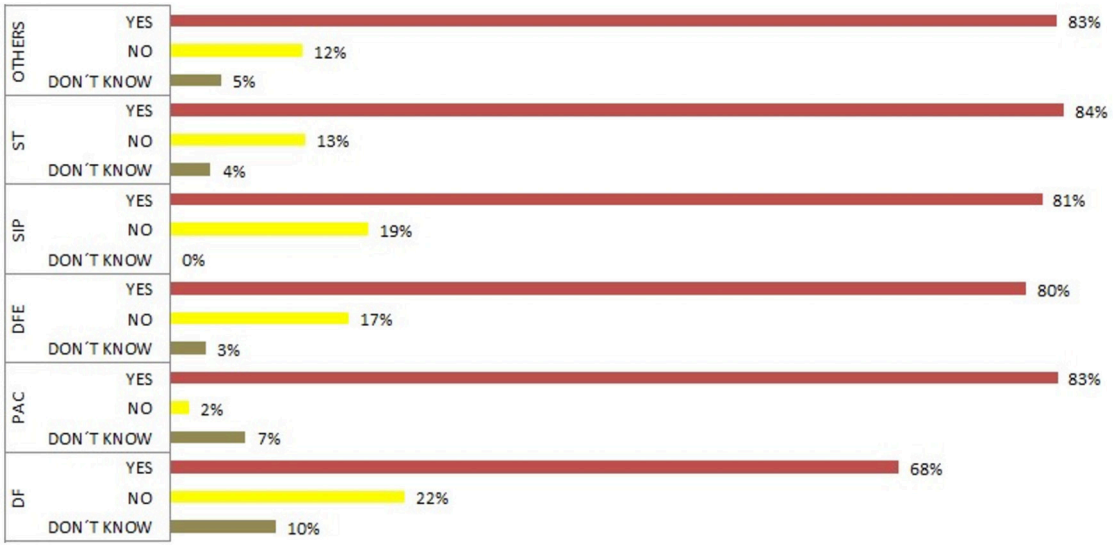

FIGURE 4 | Intentions to reuse effluents or slurries as fertilizers according different groups of respondents in Argentina, Brazil and Chile expressed as number. DF, Dairy Farmers; PAC, Professionals advisors and consultants; DFE, Dairy Farm Employees; SIP, Service and Inputs Providers; ST, Students; OTHERS, representatives of public institutions working in agro-environmental policies and from dairy companies and researchers from academic institutions.

TABLE 3 | Needs and barriers selected for dairy manure management in the three South American Countries.

		Argentina (%)	Brazil (%)	Chile (%)	Total respondents (%)
Needs	Manual or guide for manure application	58	61	60	60
	Laboratory analysis	53	57	57	55
	Trained Personnel	45	59	32	49
	Manure application equipment	68	70	68	69
	Legislation regarding manure management	55	46	52	51
Barriers	Lack of interest	6	4	12	6
	Lack of knowledge	33	60	2	40
	Very expensive	26	19	29	24
	Cumbersome management	28	35	24	30
	Lack of legislation	24	12	37	21

On average, the respondents selected one or two barriers; none selected all five options and only five individuals from different countries selected four options. Of all respondents, 23% did not select any barrier, with differences between countries (Argentina 28%, Brazil 13%, and Chile 28%). The options "non-existence of laws that impose them" and "the reuse of these wastes ends up being a complicated management" were most frequently selected, with differences between countries. Significant differences were observed for the barriers "lack of interest," "lack of knowledge," and "lack of legislation" ($p < 0.05$; test Chi^2). For all three countries, "high costs" and "cumbersome management" were barriers selected, with similar values between countries. Brazilians presented the lowest percentage of "lack of interest in using manure as fertilizer" and the highest percentage of "lack of knowledge." Although for Argentina, "lack of knowledge" was the first barrier identified, dairy producers mentioned the cost (27%), while professionals, advisors, and consultants mentioned cumbersome management (27%). Also, the lack of rules was recognized as an issue. It should be highlighted that all respondents showed an interest in slurry management (greater than 90%). For Chile, most of the needs were ranked similarly, apart from "trained personnel," which was ranked lower. In relation to barriers, "lack of knowledge" and "interest" were ranked lowest.

Needs and barriers, according to the categories of respondents, are shown in **Figures 5**, **6**. When considering respondents in the three countries in terms of advocating the use of manure as fertilizer (78%), the needs were identified as follows: 79% agreed that is important to have more equipment for the application on land, 60% required a manual or guide for application, 55% requested laboratories for analysis of manure and slurry, 52% believed it to be important to have legislations

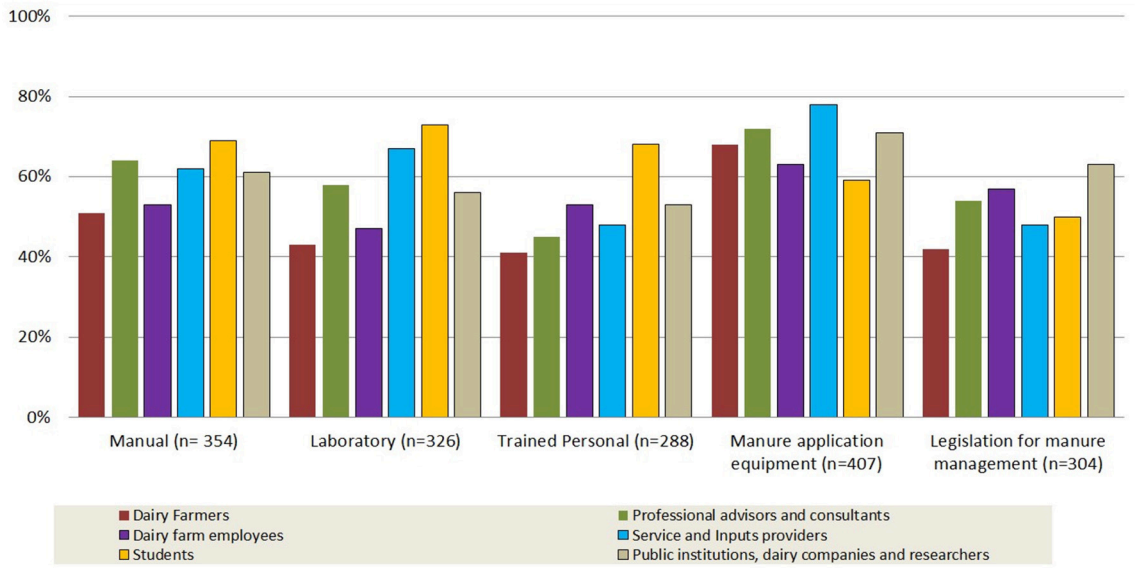

FIGURE 5 | Needs chosen according to type of respondents in Argentina, Brazil, and Chile.

and rules to regulate applications, and 49% considered it to be important to have trained personnel on the farms. In the other side the 15% that answered did no show that there is a lack of interest (94%), that they will not use because there are not any rule or law that oblige them to reuse waste (79%), a very expensive technical option (76%), a cumbersome and difficult management (70%), and a lack of knowledge for the application (60%).

Significant differences ($p < 0.05$; test Chi^2) in terms of three (more laboratories, more trained personnel, and specific legislation) of the five needs were observed between the types of respondents for all countries (**Figure 5**). The need for more laboratories was selected by professional advisors and consultants and by service and inputs suppliers. The need for more trained personnel was mainly selected by advisors and consultants. The importance of specific legislations for manure management was recognized by representatives of public institutions, dairy companies, and researchers.

On the other hand, significant differences ($p < 0.05$; test Chi^2) in terms of two ("lack of knowledge" and "lack of legislation") of the five barriers were observed between the different types of respondents for all countries (**Figure 5**). Notable, "lack of knowledge" was selected more frequently by dairy farm employees, while "lack of legislation" was selected more frequently by professionals, advisors, consultants, representatives of public institutions, dairy companies, and researchers.

DISCUSSION

This is the first study analyzing stakeholders' perceptions on dairy manure management in Latin America, considering three different countries in which the dairy sector is an important industry. Our results contribute to the establishment of adequate programs to improve manure management, to the development of appropriate policies, and to the research and education programs. Similar studies have been carried out by Blok et al. (2015), who stated that this methodology allows a better understanding of the needs and perceptions of stakeholders, facilitating successful innovations for sustainable production and consumption. In a study in Denmark, Case et al. (2017) assessed the impacts of new legislative requirements for the processing of organic waste through the evaluation of the perception of producers toward the use of organic waste, while Hou et al. (2018) focused on how manure management is likely to be affected by a wide range of diverse socio-political and environmental factors.

The types of stakeholders participating in the present study were similar to those interviewed by Hou et al. (2018) across different European countries. All respondents had some experience regarding manure management, in contrast to the stakeholders interviewed in our study. The different percentages of respondents in our study between the three countries are due to the type of audience in the conferences, workshops, symposiums, and field days where the questionnaires were applied. These events had a technical and/or scientific profile, and more than 50% of the total of the respondents represented dairy farmers, professionals, and consultants involved in decisions related to manure management on dairy farms.

Despite the productive similarities between the three countries, we observed some differences in the perception of some issues. In particular, there were differences in terms of the levels of adoption and application of regulations and policies. This indicates that the same program, technology, or policy could achieve similar results in Chile and Argentina, but different ones in Brazil.

In the case of Chile (Salazar et al., 2007) and Argentina (Charlón et al., 2017a), the discussion about manure dairy

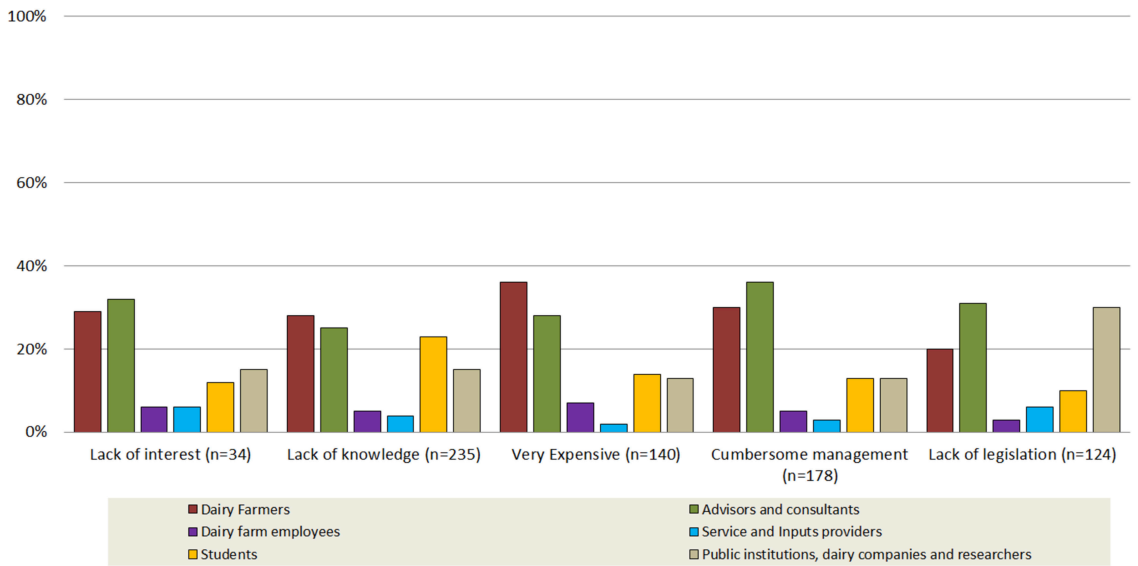

FIGURE 6 | Barriers chosen according to type of respondents in Argentina, Brazil, and Chile.

management and, consequently, the internalization of the theme by stakeholders is more advanced than in Brazil (Palhares, 2014), probably because in Chile and Argentina, the dairy industry has been more intense over a longer period of time, and the pressure from society is higher. In addition, previous studies (e.g., Hou et al., 2018) have mentioned that the use of manure is related to the availability of land, with higher pressure on countries with small farming areas. As mentioned before, the dairy production in Brazil has only been intensified recently (Palhares, 2014), and the pressure from environmental agencies and the society is therefore lower, facilitating the use of manure as fertilizer.

In Argentina, the strong perception of the importance of using manure as fertilizer could be explained because of the implementation of recent environmental initiatives, focusing on the agronomic use of the slurry. Currently, guidelines for adequate management practices are being developed by the sector industries.

In some countries, there are specific regional regulations related to manure and dairy effluent management (Argentina and Brazil), promoted mostly due to the pressure of society and as a result of pollution incidents. On the other hand, there are also agreements between the government and farmer federations, such as "Cleaner Production Agreements" (Chile), which promote a better use and management of dairy effluent. In addition, dairy companies implemented a bonus for their own producers that meet environmental standards, where effluent management is considered (Argentina and Chile; Charlón et al., 2017a).

In Argentinian dairy areas, water contamination with high concentrations of nitrate is an important environmental issue, and the high salinity in these areas could further affect dairy production and impede the reuse of manure (Carbó et al., 2009; Charlón and Herrero, 2012; Charlón et al., 2017b). In this sense, stakeholders might be more conscious in relation to water contamination, water quality issues, and pathogen transmission compared to stakeholders in Brazil and Chile. Besides, this situation could be related to the diffusion of these issues in the mass media and in local workshops and seminars. Most of the stakeholders know that excess salinity of groundwater may be an important restriction for using cattle manure because of the potential soil salinization in soils in dairy land area in Argentina (Charlón and Herrero, 2012). In Argentina, the local community perceptions about the pollution of surface and groundwater were studied by Peluso and Usunoff (1997). These authors found that in general, the community considers those environmental problems as important, such as the pollution of surface water caused by sewage. Similar results regarding such awareness were reported by Sudarmadi et al. (2001) in terms of the perception of environmental and health problems, both in an educated group and a community group in Indonesia. The authors observed a better understanding of such problems when broad information was supplied by newspapers, television, movies, and the radio.

When comparing the three countries, all Brazilian averages to statements 1 to 4 were lower than those for Argentina and Chile; therefore, the experience of these countries could help to enhance the knowledge and propose policies to dairy manure management in Brazil, thereby improving the stakeholder's perceptions of the environmental impacts. The highest Brazilian valuation in relation to biogas use, which was also the highest average among all means, may be the result of the influence of two current governmental programs. One of them is the National Plan on Climate Change and the National Program for a Low Carbon Agriculture. This plan encourages the adoption of sustainable production systems to ensure GHG emission reductions while raising the incomes of framers, particularly with the adoption of technologies such as the biodigestion

of animal wastes. Another program is the Brazilian Electrical Energy Agency regulation, which permits farmers to generate electricity credits through biogas production (ANEEL, 2012). Wissman et al. (2013) mentioned that programs that work with economic incentives can modify decision prioritization by farmers. Anaerobic digestion is widely used where financial incentives are linked to renewable energy policies, making it a profitable activity even at a modest scale (Loyon et al., 2016). Also, the growth of anaerobic digestion in Denmark is largely due to an incentive policy such as investment support for construction of biogas plants and government support strategies to increase interactions between various social groups (Raven and Gregersen, 2007). Another important aspect is the history of biodigesters in Brazil. The first system has been installed in a dairy farm in 1979 and has been part of the sector ever since. In the case of Argentina, the temperate climate, the farm scale, and the lack of appropriate financial support to implement this technology have been factors that make difficult the adoption of this technology (Charlón et al., 2017a). In Chile, anaerobic digesters on dairy farms are extremely rare (c. < 1%) (INIA, 2016). However, recently, a program has been developed to incentive the use of biodigesters on dairy farms. Important restrictions will mainly be the low potential for methane production of dairy slurry, the high cost of anaerobic digestion plants, and the low dry matter content (and organic matter content) of dairy slurries based on grassland systems (Salazar et al., 2007).

We observed a contradiction in terms of the perceptions in Brazil about issues 1 and 6. On the one hand, the three countries strongly agree that "groundwater may be contaminated by effluent lagoons," similar to respondents of Argentina and Chile. However, issue 6, which is linked to the same problem and says "the shallow aquifer may become contaminated by disposing effluents in the lowlands," has not received the same perception in Brazil. Although both issues are linked, they are two forms of water contamination associated with the disposal of manure. This situation could be explained because there is an obligation by Brazilian state environmental legislations that all effluent storage ponds should be waterproofed (Palhares, 2008). This is probably the reason why Brazilians do not consider storage lagoons as a source of groundwater contamination. The impact of unsealed effluent storage lagoons was verified by Drommerhausen et al. (1995), who developed an extensive study. They evaluated the impact of effluent lagoons on different soil types in eight dairy farms in the United States and demonstrated that effluent lagoons receive a continuous load of water with excreta daily; when they are not well constructed and sealed, they may become permanent source of groundwater contamination.

The statement "manure is a good fertilizer" obtained the highest agreement. Hou et al. (2018) showed that the use of treatment manure technologies is low in regions that have sufficient land for manure applications, as is the case in Argentina, Brazil, and Chile, where dairy slurries are mainly applied directly to the soil without treatment (Salazar et al., 2010).

Foged et al. (2011) found that less than 10% of the total animal manure were treated in the EU-27 in 2010. We do not have this type of statistical information for any of the countries in our study, but according to the authors' expertise and observation, the use of treatment technologies is low and will remain low due to technical and/or economic limitations. Regardless of the productive and environmental realities of each country, it can be said that the respondents understand this practice as a way to dispose of manure, reuse water, and recycle nutrients. It is also possible to achieve a livestock sector with low carbon emissions by better nutrient recycling.

The question remains whether manure as fertilizer is being used correctly, as there are several studies that show that misuse results in environmental impacts on water, soil, and air. Knowlton and Ray (2013) mentioned that animal manure can be a valuable resource for farmers, providing nutrients, improving the soil structure, and increasing the vegetative cover to reduce the erosion potential. At the same time, the application of manure nutrients in excess of crop requirements can result in environmental contamination. To mitigate environmental risks, governments in Western Europe (Sutton et al., 2010), North America (Compton et al., 2011; US Environmental Protection Agency Science Advisory Board-USEPA, 2011), and Oceania (Ministry of the Environment, 2012) have enacted legislations to control livestock expansion, manure land-spreading, and other farm practices.

Excessive nutrient accumulation and plant uptake may impact animal health and production (Djekic et al., 2014). The use of manures, wastes, composts, and sludges as fertilizers and soil physical and chemical conditioners is advisable, but only when performed considering the concept of nutrient balance and the four Rs (right product, right rate, right time, right location) (Oenema et al., 2003). Waldrip et al. (2015) showed how imbalances between nutrient imports and managed exports can result in nutrient losses to the environment and additions to soil storage, limiting the sustainability of livestock production systems.

Another aspect is the low pressure from governmental legislations. In this context, only recently, a specific legislation for manure management has been launched in Cordoba, Argentina (Charlón et al., 2017a), and most of the manure management is regulated in these countries according to general environmental legislations and regulations in order to avoid water, soil, and air pollution.

The need considered most important by respondents across all countries was "greater variety of equipment." This situation is understandable, because in these three countries, technologies for manure application are relatively new, and new technologies and equipment are only developed relatively slowly. According to Salazar et al. (2010), dairy slurry is applied using mainly surface equipment (e.g., irrigation pumps and tank spreaders). In the study carried out by Hou et al. (2018), it was observed that in European countries, where manure has been applied to the soil over a large number of continuous years, the dominant needs were "reduction of excessive costs," "pathogen control prior to application," and "adaptation of treatment and management systems to changes in legislation."

The second most important need, "manual or guide for manure application," is directly related to the first barrier

"lack of knowledge." This indicates that countries should edit technical materials such as manuals, factsheets, etc., taking into account local conditions to help producers, dairy employees, and consultants to adequately use manure as fertilizer. It is important that these materials are recognized as referential by all stakeholders, otherwise they will not be effective in improving the practice. Due to the particularities of each country, these materials should be produced in particular, but it is interesting that there are minimum contents and performance indicators agreed upon between countries, such as the use of the concept of nutrient balance, the best forms of manure disposal, the potential environmental risks, etc. In this way, countries will be able to generate common indicators that will assist in the evaluation of their own policies and programs as well as in the design of common actions. This common information is also important for proposing research projects and strengthening research networks among countries.

In European countries, a key step in improving the efficiency of agriculture and reducing negative impacts on the environment has been the publication of Codes of Good Agricultural Practice (GAP), which provides guidelines for farmers, taking into account manure management on farms. In addition, a set of more "friendly-reading" publications have been published by the MAFF in the United Kingdom, covering aspects of manure characterization and management for use on crops and grassland (Dampney et al., 2000). Complementary strategies have been implemented for different countries. Another approach has been the development of decision support systems, using electronic calculation worksheets and models to predict the value of manure and potential N losses (e.g., Nicholson et al., 2013). A similar approach could be implemented in South American countries, using current research information and generating guidelines, recommendations, and electronic tools to improve manure management on dairy farms. As a stage prior to specific manure management regulations, the dissemination of GAP could be beneficial for the sector.

In Denmark, the barriers selected by farmers in terms of manure use as organic fertilizer were evaluated by Case et al. (2017). The most important problems were odor nuisance, unreliable nutrient content, difficult planning, expensive machinery, and the absence of a quality certification. In our study, we also encountered some of these barriers (e.g., cumbersome management), although some were rather identified as needs (manure equipment, lab analysis).

In other countries, such as in the EU, where regulations have been in place for years, different stakeholders feel pushed by the new legislation to treat dairy wastes. The use of high amounts of mineral fertilizers per unit area, with increased costs of these alternatives, makes manure a more attractive alternative. On the other hand, in these countries, farmers are generally pressed to export manure from farms with higher animal density to areas of agricultural production (Hou et al., 2018). This situation is different in South American countries, were dairy production systems generally have low stocking rates that do not exceed one cow per hectare and where lands are available for manure spreading. Also, in these countries, crop production for feed is important, and such production is generally located near the dairy production area, enabling the combination of dairy and crop production.

According to these results, transferring knowledge by different technology activities will be important in these three countries. It is necessary to develop educational/training strategies (written and oral) so that farmers, employers, and consultants have technical guidelines on how to manage and transfer knowledge related to dairy manure. It is also important to internalize this issue in the University curricula and in technical discussions of stakeholders. In addition, an important technology transfer target will be farmer federations, milk companies, and the public sector, where scientific base information should be transferred to complete such knowledge. The agricultural economic literature shows that innovations do not occur randomly, but rather that incentives and government policies affect the nature and the rate of innovation and adoption. Both the generation of new technologies and their adoption are affected by intentional public policies (e.g., funding of research and extension activities), unintended policies (e.g., manipulation of commodity prices), and activities of the private sector (Sunding and Zilberman, 2001).

Policy makers and stakeholders should focus on appropriate technologies and "win-win" strategies to effectively generate enthusiasm to reuse manure and slurry on the farms. It is necessary to continue the research and transfer in subjects such as the efficient use of nutrients from manure and effluents, mitigating the possible negative impacts. In this context, information and advice based on research have been important aspects of dealing with the environmental problems associated with agriculture in most of the countries in Europe (Thevenet et al., 1993). As farmers are being subject to increasing pressure from the public to reduce environmental impacts, there is a considerable need to provide extended information. There is also an overriding need for farmers and their advisers to understand and accept the impacts of agriculture on the environment and to have the confidence to use technical solutions developed to reduce nutrient losses. Evidently, research institutes and extension services have to provide farmers with appropriate information and tools (Magette, 2000). Such measures should be implemented through a combination of the different actors to eliminate technological barriers for the convenience of the product (Case et al., 2017).

In Argentina, Brazil, and Chile, farmers already have some experience in the regulation of dairy wastes, but because of the current trend toward intensified production, increasing farm scales, and social issues, these regulations need to be improved considering the productive, social, economic, and environmental characteristics of each country. The results from this survey can support actions and programs to disseminate manure management practices in the dairy sector. In this sense, research plays a fundamental role, since environmental and productive standards should be proposed to guarantee environmental conservation and economic viability.

Finally, there are many opportunities and options for improving the manure management of a dairy farm; however, there is no single model applicable for all farms. In addition, the stakeholder's perceptions could change according to different

drivers such as public perception, environmental legislations, or own interests. Efforts should therefore focus on the different dairy production systems and the particular soil and climatic conditions where the farms are located. It is also important that the technology and management practices proposed to the farmers include an economic assessment, especially against the background of the current economic pressures (Magette, 2000).

AUTHOR'S NOTE

This paper is an international research that was carried out in three countries. The researchers MH and VC (Argentina), JP (Brazil), FS (Chile) are part of the Manure research network in South America and have a broad expertise in the different manure management systems. They are all involved in a collaborative research in manure management. MT is a Ph.D. candidate in nutrient and manure management and its environmental impact.

AUTHOR CONTRIBUTIONS

In this paper, MH, VC, JP and FS have been involved in the survey development and data collection in each country, in its analysis and in the discussion of the results comparing the different countries and stakeholders. In particular FS was involved in Chilean results, VC in Argentinean results and JP in Brazilian results. MT worked in the acquisition of data in Argentina and in drafting the manuscript. AP was responsible for all the statistics analysis and also she interacted with the all the group of authors in drafting the manuscript. MH was the responsible of the conception and design of the study and worked in the Argentinean interpretation of data and in drafting the whole manuscript.

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