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Learnings from an exploratory implementation of an innovative training-program to reduce antibiotic use in the dairy sector

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Abstract: *Regarding antibiotic resistance issue, antibiotic use has to be reduced. In the dairy sector, antibiotics are mostly used for the control and treatment of mastitis. We designed an exposed/non-exposed epidemiological study in Western France to evaluate effectiveness, strengths and weaknesses of an innovative training program: one classroom-training day, virtual classrooms, and an individual support with the farmer. Two groups of farmers addressed two different themes, depending on their herds' udder health: (i) improvement of mastitis prevention during lactation for herds experiencing frequent clinical mastitis, and (ii) implementation of selective dry cow therapy for herds with good udder health, instead of implementing blanket dry cow therapy. We collected different sets of data to evaluate evolution of knowledge, practices of farmers, animal health and antibiotic use as well as their appreciation of the program. Some farmers appreciated the virtual classroom training method because it was flexible (frequency, timetable, etc.) and little time consuming. However, connection or computing logistic problems made the participation in the virtual classrooms difficult. For the "prevention" group, results also showed limited improvement of knowledge, perception and practices of farmers. Improvement of knowledge and perception was significant. Both exposed and non-exposed farmers did improve their practices of antibiotic use at dry-off, which could show a trend in the general population for the improvement of practices at dry-off, animal health and antibiotic use. The duration of the program (one and a half year) was relatively short to observe a change in practices, longer program could provide better results. Further insight should be provided with the results of "dry-cow" group.*

Keywords: *virtual classroom; sharing of practices; multi partner method; exposed/non exposed survey; udder health.*

Introduction

Mastitis is a production disease widespread in dairy cattle farms. It could be responsible for one third of the economic impact related to dairy cattle health disorders in Western France (Fourichon et al. 2001). In 2016, a dairy cow received on average the equivalent of 1.43 intramammary treatments in France (Méheust et al. 2017). Antibiotics used for mastitis amount to 70% of all the antibiotics administered to dairy cows (Gay et al. 2012). However, worldwide, antibiotic-resistant bacteria decrease antibiotic effectiveness for both livestock and humans (Gonggrijp et al. 2016). Reducing antibiotic use could limit the spread of antibiotic-resistant bacteria. Improving mastitis prevention as well as avoiding unnecessary antibiotic use are thus of paramount importance for public health and economic reasons.

In theory, scientific and technical knowledge gained about mastitis allow to implement the best preventive measures, and to limit antibiotic use to a minimum (De Vliegher et al. 2012; Sant'Anna & Paranhos da Costa 2011). However, the health indicator of good udder health did not improve over the last 18 years[1]. In addition, dairy farmers are still regularly using antibiotics in an inappropriate manner during lactating period (Oliveira & Ruegg 2014), and about two third of French dairy farmers could be implementing systematic dry cow therapy[2].

Theoretical frameworks, such as the Theory of Planned Behaviour, stipulate that the intention of an actor is necessary to trigger a change in practice (e.g. Panter-brick et al. 2006). Behavioural beliefs (attitudes), normative beliefs (social norms) and belief in self efficacy constitute intrinsic circumstances that are expected to influence the intention to a change of practices. Extrinsic circumstances such as community, culture and society, general knowledge, skills and ability influence taking action as well (Ellis-Iversen et al. 2010). Van Den Borne et al. (2014) showed that farmers' knowledge could influence their practices and dairy herds performances (van Den Borne et al. 2014). However, public concerns about antibiotic resistance and the importance of a reduction in antibiotic use are quite recent. Research shows that farmers could have a limited knowledge on antibiotic use and limited motivation to reduce antibiotic use (Friedman et al. 2007; Moreno 2014; Visschers et al. 2015). This could limit the change towards a reduction in antibiotic use (Scherpenzeel et al. 2016; Valeeva et al. 2007). In addition, literature showed the paramount importance of veterinary and non-veterinary advice, as well as exchange of knowledge between farmers for the implementation of preventive actions, and better antibiotic use (Mcdougall et al. 2017; Russell & Bewley 2013; Pardon et al. 2012; Poizat et al. 2017; Friedman et al. 2007; Vaarst et al. 2006). We thus hypothesise that improving knowledge and perception of farmers on mastitis prevention and management could improve their practices and their dairy herd health status.

Our objective was to evaluate the impact of an innovative training and advisory program focused on improvement of udder health prevention and antibiotic use on farmers' knowledge, perceptions, and practices, as well as its impact on herd health.

Material and methods

General approach and study design

The project named RedAB started in 2015. It aims at testing innovative tools for technical training and support to promote practices to reduce antibiotic use in the dairy cattle sector. This project had three target audiences: farmers, students and teachers from agricultural education. We focus here on the farmers' audience, who participated in an intervention study. Epidemiologist researchers participated in the development of the program design itself and proposed the evaluation strategy.

The intervention study is an exposed and non-exposed epidemiological study. It was performed on 87 conventional farms in western France; with 43 farms exposed and 44 unexposed to the educative program. Two thematic groups were distinguished. The first one had the objective to improve udder health, in the so called "prevention"-group. The second one worked on the implementation of selective dry cow therapy, in the so-called "dry-cow"-group. In the unexposed control farms, a basic advice program was implemented. Western France was chosen because this area is the most important dairy cattle region in France with 35.8% of the French production volumes (Martin-Houssart et al. 2016).

The impact of the training program was assessed using an adapted form of the process evaluation framework used for complex interventions (Moore et al. 2015) (Figure 1). The

[1] Somatic Cell Count (SCC) did not improved between 2005 and 2015 (Source : Résultats de contrôle laitier des espèces bovine, caprine et ovine – France 2015 – Institut de l'Elevage & France Conseil Elevage, available the 11/29/2017 at: http://idele.fr/recherche/publication/idelesolr/recommends/resultats-de-controle-laitier-france-2015.html).

[2] Source: French expert.

framework allows taking into account different elements that could influence the impact of the training program on farmers' knowledge, practices, herd health and antibiotic use: (i) compliance of farmers to the training sessions (instructor-led learning and virtual classrooms), (ii) compliance of farmers and advisors to farm advisory visits, (iii) ability of the training program to influence farmers' knowledge, practices, herd health and antibiotic use. The effectiveness of the program in terms of improving farmers' knowledge, preventive practices, udder health and antibiotic use was compared with unexposed farmers and with the initial situation of exposed farmers before the beginning of the training program (t0).

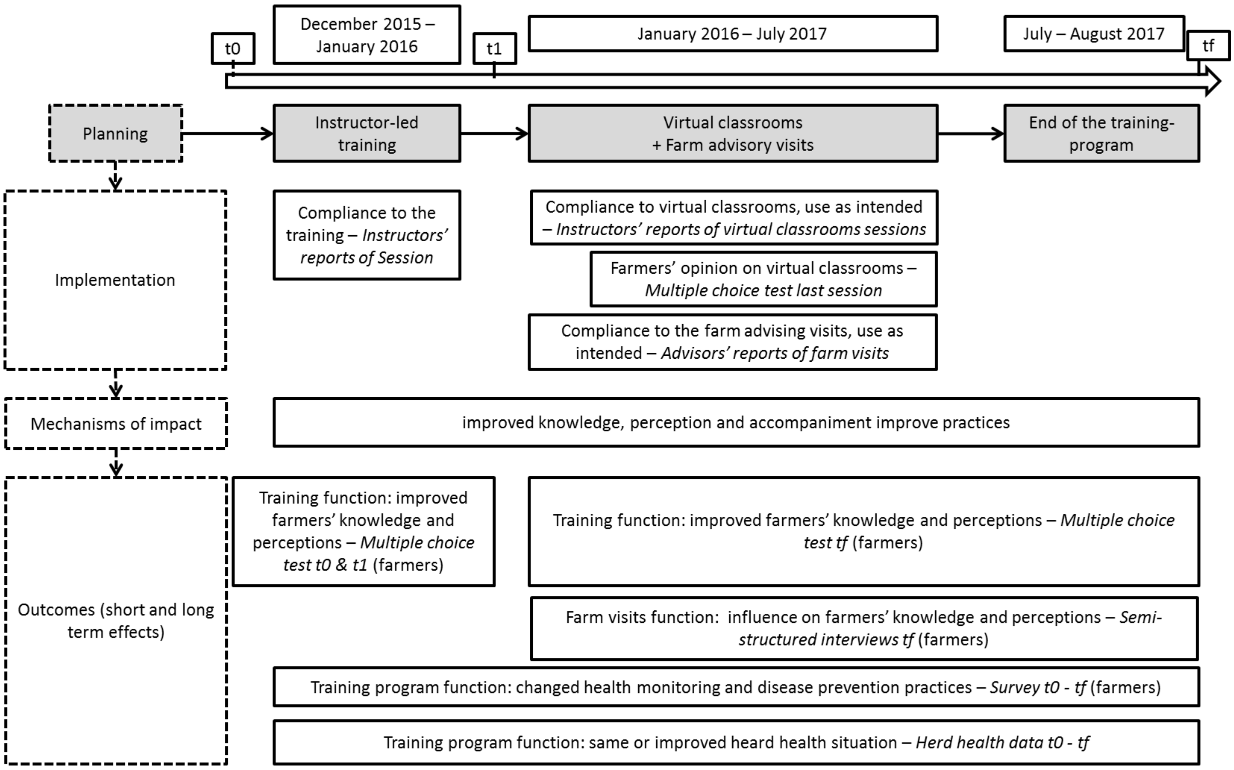

Figure 1. The designed and tested training program and process evaluation framework. The training program consisted of several consecutive activities (grey boxes). An evaluation framework was designed to measure different elements (farmers' compliance, improved knowledge, a change in practices, herd health and antibiotic use). The origin of the data is described in italics.

The designed and tested training and advisory program

We developed the training program in two ways: (i) training tools designed by the training department of "Chambre d'Agriculture" (local or regional public establishment of administrative character supporting farmers' development, applied research and extension services), and (ii) technical content designed with large consultation of veterinarians, animal health association (Groupements de Défense Sanitaire, GDS), French Livestock Institute, French National Milk Record, veterinary school od Nantes (Oniris) and Terrena (a French cooperative). Veterinarians and dairy technical advisors of GDS and French National Milk Record were involved in the different steps of the design and implementation of the program. They were invited to all training sessions to improve harmonisation of advice transmitted to farmers.

Before the initial meeting (t0), by signing a document that explained the different steps of the program, farmers committed formally to it. To promote group dynamics, the geographic distance between participating farmers and the number of farmers per area in the groups were limited. Two sub-groups were thus formed, each one corresponding to half of the number of participants in each group ("prevention" or "dry cow"). One sub-group was located in Brittany; the other was located in Normandy.

Instructor-led training was used to give information on following topics: antimicrobial resistance, mastitis prevention strategies at dry off (selective versus systematic treatment), selective dry cow therapy methodology explained step by step. Only wider issues on antibiotic use and impact of antimicrobial resistance and mastitis were addressed during the training. Instructor-led training was designed as such to stimulate group cohesion and exchange of knowledge, perception and practices between farmers. Indeed, exchange of knowledge between farmers could be more important than scientific proofs for them changing their practices (Friedman et al. 2007; Vaarst et al. 2006). To facilitate appropriation by farmers of mastitis risks factors at dry off for their farm and to trigger discussions between farmers and farm advisors, farmers filled in a self-diagnosis survey about their practices to prevent and treat mastitis. This document was used to support the first discussions and advice between the farmer and farm advisor.

After that first step, advisory visits and virtual classroom were implemented from December 2015 or March 2016 during 18 or 12 months.

Individual advisory programs were based on the self-diagnosis document filled in by farmers and aimed at (i) improving dairy udder health for “prevention” group, and (ii) support farmers in the implementation of selective dry cow therapy for “dry-cow” group. Advisors and farmers autonomously organised the visits. The self-diagnosis survey was used during the first farm visit.

A technical test was performed before the first virtual classroom to prevent technical issues linked to the use of the software, internet connection or computer equipment. Virtual classrooms were planned in consultation with farmers. They always had a reminder, by text message or by e-mail less than seven days before the virtual classroom date. The D day, they received a text message and a phone-call if they were late or did not notify their absence. Veterinarians and farm advisors were invited to participate in the sessions in order to harmonise the content of advice provided to farmers. A computer technician attended to all virtual classrooms to help farmers and instructors to deal with technical issues and mishaps. The main aim of virtual classrooms was to deal with themes relative to mastitis closer to the farmers’ daily challenges (milking, milking machine, etc.). They focused on (i) specific issues for the “prevention” group (milking machine and housing; mastitis treatment during lactating period; dry-off; presentation of two farmers’ audit results) and (ii) exchanges of experience and major restrains about the implementation of selective dry cow therapy for the “dry cow” group. Instructors promoted questions and discussions. Moreover, they commented on and rectified wrong practices, perception or knowledge described by farmers. The number of virtual classrooms was decided depending on the importance of different themes to address. The target was to have limited theoretical content during each classroom to favour discussions between farmers.

Exposed and non-exposed farmer selection

Farmers from GDS and National Milk Record subscribers’ list, as well as lists of clients from private veterinary practitioners and from Terrena suscribers’ list were selected. There was a succession of different steps (Fig. 2): first selection of “prevention” and “dry cow”-groups according to udder health criteria[3]. Then a random selection of farmers was assigned to the exposed group. With the help of the technical advisors of GDS and National Milk Record, farmers’ behavioural profile regarding advice was determined:

- 1: Farmers of habits; reliant on advice they are prone to follow. However, they are more risk adverse.
- 2: Willing farmers; prone to follow technical advice, often working in bigger structures and able to spent time on training.
- 3: Innovative and of independent character; used to several sources of information and prone to criticise technical health advice.

[3] “Prevention” group: cows having more than 50 clinical mastitis per 100 cows per year; “Dry cow” group: more than 70 % of cows at dry-off having less than 300 cells per mL of milk, or more than 75 % of lactating cows having less than 300 cells per mL of milk.

Then the remaining farmers were randomly assigned to the unexposed group and matched with the behavioural profiles of farmers in the exposed group. Farmers with a behavioural profile which were not corresponding to the ones of the exposed farmers were eliminated from the study.

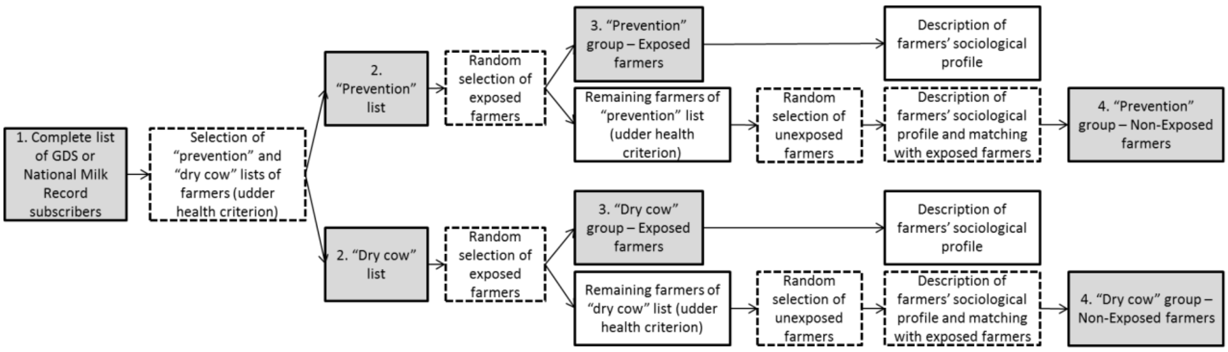

Figure 2. Exposed and non-exposed farmers’ selection.

In total, in the “prevention”-group, 20 exposed farms and 20 non-exposed farms were selected. In the “dry-cow”-group, 24 exposed farms and 24 non-exposed farms were selected.

The process evaluation framework and data collection

Compliance of farmers to the training sessions (instructor-led learning and virtual classrooms)

Instructors reported participation of farmers after each training session (Fig. 1). In addition, for the virtual classrooms, instructors also reported technical problems encountered.

Compliance of farmers and advisors to the advisory visits

Farm advisors reported after each advisory visit to the research team using a report sheet given to the farmer (Fig. 1). This sheet reported on the main observations and recommendations made by the advisor to the farmer.

Evaluation of users’ opinion on the training sessions and on the program in general

Users’ opinion took into account instructors’ and farmers’ opinions on the training sessions and on the program in general. We collected qualitative data. Qualitative data is relevant in the evaluation of complex interventions to provide a detailed understanding of satisfaction of participants and feasibility to further improve and develop the intervention (Moore et al. 2015).

Instructors of instructor-led learning sessions and virtual classrooms gave their opinion and feelings about the program and exchanges made during the sessions. They reported interactions between themselves, farmers, and veterinarians. Instructors could also evoke what they had found easy or difficult to implement (Fig. 1).

At the end of the last virtual classroom, farmers gave their opinion on the virtual classroom sessions using a short online multiple-choice test.

To explore farmers’ opinions on the program, qualitative semi-structured interviews were conducted. Interviews were conducted using an interview guide structured into four main themes: (i) the farm, the farmer and its herd health, (ii) changes in mastitis prevention and management linked to the program, (iii) personal view on the program, (iv) conclusion. The interview guide was a non-rigid support designed to provide open follow-up questions and reminders. Data were collected by a veterinary student in its last year of curriculum. With the informed consent of interviewees, interviews were recorded.

Evaluation of the program on farmers’ knowledge

Farmers' knowledge was evaluated at three different steps of the program (Fig. 1): (i) first, to evaluate the initial level of knowledge farmers, the test was submitted to exposed and non-exposed farmers before the instructor-led training (t0), (ii) second, to evaluate the impact of the instructor-led training, the test was submitted to exposed farmers on average three months later, (iii) finally, to evaluate the general evolution of farmers' knowledge and the impact of the program on their knowledge, the test was submitted to exposed and non-exposed farmers.

The content of the test differed between the "prevention" and the "dry cow" group to meet their specific training objectives. 18 items were identical; 19 differed for the "prevention group" and 29 for the "dry cow" group. The test consisted in an affirmation and the farmer should answer using a four point Likert scale: "I strongly disagree", "I rather disagree", "I rather agree", "I fully agree". The Likert scale measured the gap between the answer of the farmer and the correct answer. (Content of questions of the multiple-choice test can be requested from author.)

A Chi-squared test was implemented using R to compare the results of farmers to the test.

Evaluation of the program on farmers' practices

To report farmers' practices, a form that went over most important preventing and dry cow practices was used. Farmers' practices were recorded during farm visits at t1 and at tf (Fig. 1). A quotation was given to the described practices and a four point Likert scale was used to measure the gap between the farmers' practice and the recommended practice.

Evaluation of the program on udder herd health and antibiotic use

The collection of data regarding dairy herd health included (i) for t0 data of the year prior to the beginning of the program, (ii) for tf data of the year prior to the las visit to collect data.

Data from the French National Milk Record was collected to calculate major indicators of udder health: somatic cell count (SCC) in the herd milk; somatic cell count in the bulk; frequency of clinical mastitis (number of antibiotic treatment decisions).

During the on-farms visits, information on antibiotic use on farms was collected (inspection book and veterinarian bills). To complete the collection of data when information collected on farms was not exhaustive, attending veterinarian of farmers were contacted to provide more details on antibiotic use on farms.

Antibiotic use was evaluating using the following indicators: Animal Daily Dose[4] (ADD) to treat mastitis during lactating period; ADD for antibiotics used at dry-off; ADD total for all antibiotics used for udder health issues.

To compare antibiotic consumption of farmers between the exposed and non-exposed group, we used a Chi-square test or a Fisher exact test; in a same group between t0 and tf, we used a Bhapkar test.

Same statistical methods as for antibiotic use were implemented.

Results

Data analysis was completed for "prevention" group, but was still in process for "dry-cow" group. Results from the first group are thus more emphasised.

Farmers' selection and farmers' psychological profile

Different difficulties in data collection and availability of farmers led to the exclusion from the intervention study of 2 exposed farmers and five non-exposed farmers from the "prevention" group. The 24 exposed and 24 non-exposed farmers from the "dry-cow" group remained in

[4] ADD is the dose of antibiotic needed to treat an animal during one day.

the analysis of results presented below. There was only partial matching of behavioural profiles of exposed and non-exposed farmers in the “prevention” group (Fig. 3).

In the “dry cow” group all exposed farmers could be matched with non-exposed farmers based on the behavioural profile (Fig. 3).

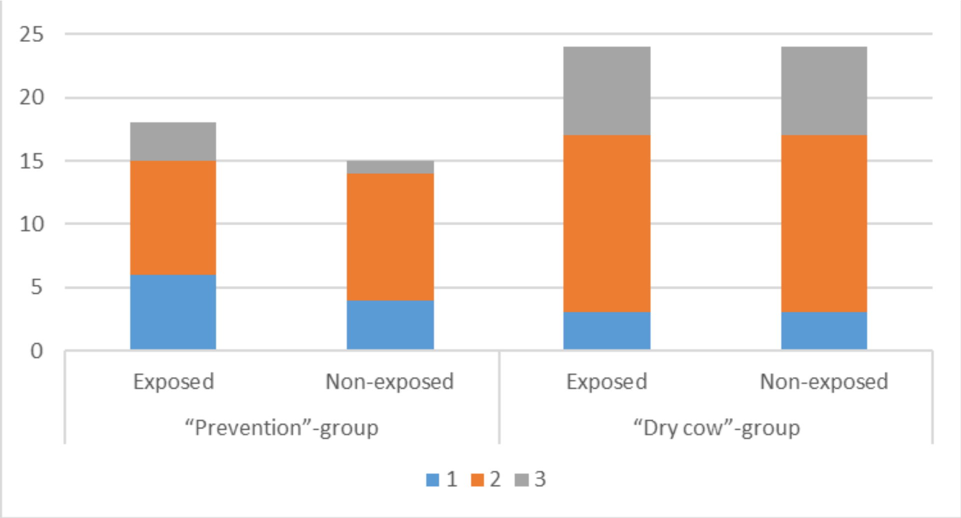

Figure 3. Behavioural profile of exposed and non-exposed groups.

Compliance of farmers to the training sessions

The instructor-led trainings were followed by all exposed farmers. Farmers’ compliance to the virtual classrooms sessions varied (Table 1). Compliance rates varied between 20 to 80 percent depending on training sessions. Most virtual classrooms had a participation rate of approximately 60 percent. There were four virtual classrooms for the “prevention”- group, but the last one was cancelled in Normandy because only two farmers attended the training session. There were only two virtual classrooms for “dry cow” group.

The number of farmers attending the virtual classrooms reduced over time. This was obvious in the “dry cow”- group where the second virtual session had to be cancelled because of lack of involvement of farmers. Sending an SMS or calling farmers at the beginning of the virtual classrooms increased by one or two the number of farmers attending the training sessions.

Virtual classrooms lasted from one to one and a half hour. Due to technical problems (at the instructors’ workplace), two virtual classrooms’ appointments were moved. There were between one to five technical problems at the beginning or during each virtual classroom (most often two technical problems). Technical problems were linked to poor accessibility of the internet and computer equipment (microphone). The computer technician’s work was thus of paramount importance to tackle technical problems without interrupting the training sessions. Technical problems however limited the participation to the session for two farmers.

Table 1. Number of farmers or advisors participating in the training program: instructor-led training, virtual classrooms, and farm advisory visits.

“Prevention”-group			*“Dry cow”-group*	
	Exposed	Non-exposed	Exposed	Non-exposed
Farmers’ participation in instructor-led training				
	18	-	24	-
Farmers’ participation in virtual classrooms				
First	16	-	14	-

Second	14	-	6	-
Third	15	-	-	-
Forth	6	-	-	-
Advisors’ and farmers’ participation in farm advisory visits				
First	15	15	24	24
Second	12	-	20	-
Third	5	-	18	-

Compliance of farmers and advisors to the advisory visits

Due to its reliance on advisors on field, some unexpected events disturbed the schedule of farm visits. The number of farmers and advisors implementing farm visits reduced over time (Table 1).

Depending on the advisors involved, some of them wrote clear reports, others did not give any piece of information about their visits and the advice provided to farmers.

In general, farmers appreciated advisory visits: “*interesting*”, “*constructive*”, “*relevant*”, “*individually adapted*”, “*answered well to my questions*” (Exposed farmers’ declarations). They also liked the succession of different visits: “*during the second visit, [it was] good to review the elements we talked about during the first visit*” (Exposed farmers’ declarations). However, other farmers disliked the repetition of visits and the rather concomitance of timings with virtual classrooms.

Evaluation of users’ opinion on the training sessions

Instructors reported that depending on the group, interactions and discussions between farmers and between farmers and veterinarians or themselves met uneven success. Some groups were dynamic, others lacked of dynamism.

Discussions and sharing of practices seemed to be easier for the “prevention”-group. This group worked largely on prevention measures to prevent mastitis. This covers a large area of possible virtuous practices and farmers were interesting in sharing and learning about that.

In the “dry cow”-group, discussion and sharing of practices was more difficult. Some discussions were based on the presentation of trials made by participating farmers in the groups. Presenting failures or mistakes was delicate, both for the farmer involved and for the instructor. Discussions also needed the analysis of results and data collected on farms to assess success or failures, and this required more time than the delay imposed by the training program.

Farmers appreciated the most the duration of virtual classrooms (Table 2): “*Not have to book an entire day for a meeting that’s good. Here [with virtual classrooms], 1h30 is enough*”; “[I appreciate] having the theoretical part without moving and loosing time”. (Exposed farmers’ declarations).

Meetings were planned approximately at the end of the morning, before lunch time and were less than one hour and a half. However, efficiency, usefulness and interest of contents were diversely appreciated. For the “prevention”-group, usefulness and interest of contents were higher than for the “dry cow”-group. On the contrary, efficiency was better for the “dry cow” group. Length between two sessions was sometime too long: “*First virtual classes were too narrowed, then there was a big gap with many cancellations and technical problems, and people gave up*”.

Table 2. Evaluation of the virtual classrooms by farmers at the end of the last virtual classroom. Quotation is a note on twenty.

	"Prevention"-group (/20)	*"Dry cow"-group (/20)*
Efficiency	7.5	12.5
Usefulness	13.3	10.1
Should be expanded	10	9.4
Duration	20	19
Interest of contents	14.4	10

Evaluation of the program on farmers' knowledge

From this part, only results from the "prevention" group are presented. Differences between t0 and tf are considered in the analysis.

The poorest level of knowledge at the beginning of the program was related to antimicrobial resistance (Table 3). In their answers, farmers underestimated the impact of mastitis on farm income and on dairy industry. One of the poorest mark regarding the knowledge of farmers on mastitis showed that farmers were not yet able to implement rigorous mastitis control using tools that exist.

Table 3. Average marks related to farmers' knowledge (exposed and non-exposed from the "prevention" group) on main domains of the multiple-choice test (best mark: 3).

Explored domain of knowledge and perceptions	Exposed (n=18)		Non-exposed (n=15)		p-values*			
	t0	tf	t0	tf	E/NE (t0)[1]	E/NE (tf)[1]	E (t0/ tf)[2]	NE (t0/ tf)[3]
All questions	**1.83**	**2.18**	1.95	1.97	NS	**++**	**++**	NS
Mastitis	**1.92**	**2.29**	2.16	2.20	+	NS	**++**	NS
Impacts of antibiotic resistance and mastitis	1.72	2.02	1.57	1.71	NS	+	+	NS
Antibiotics and antibiotic resistance	**1.87**	**2.23**	2.04	1.95	NS	**++**	**++**	NS

*NS = Non-significant; "+" = 0.05<p-value<0.10; "++" = p-value<0.05.
[1]E/NE = Comparison of exposed and non-exposed farmers at the beginning (t0) or at the end (tf) of the program.
[2]E (t0/tf) = Comparison of exposed farmers at the beginning and at the end of the program.
[3]NE (t0/tf) = Comparison of non-exposed farmers at the beginning and at the end of the program.

At the beginning of the program, exposed farmers tended to have lower marks than non-exposed farmers in general and on questions related to mastitis in particular. However, at the end of the program, exposed farmers significantly increased their knowledge and perception whereas the non-exposed farmers did not change their marks between t0 and tf.

Farmers having behavioural profile 2 ("willing farmers", n=9) did better improve their knowledge compared to farmers having profile 1 ("farmers of habits, n=6), who better improved their knowledge compared to farmers having profile 3 ("innovative and independent farmers", n=3). The difference was statistically significant considering all questions of the multiple-choice test (p-value<0.10); and considering questions on antibiotic and antibiotic resistance (p-value<0.05).

Evaluation of the program on farmers' practices

Farmers' practices implemented to prevent mastitis during milking did not significantly improved during the program (Table 4).

Farmers' practices regarding the use of a sealant did significantly improve for exposed farmers during the duration of the program (p-value<0.05): more farmers did use sealant at dry-off, with or without antibiotics (Table 4). At the end of the program, exposed farmers significantly acknowledged more the existence or usefulness of health protocol provided by veterinarians to improve their practices for mastitis treatment.

Table 4. Comparison of farmers' preventive practices implemented during milking and to treat mastitis between t0 and tf (exposed and non-exposed from the "prevention" group).

		Exposed (%) (n=18)		Non-exposed (%) (n=15)		p-values*			
		t0	tf	t0	tf	E/NE (t0)[1]	E/NE (tf)[1]	E (t0/tf)[2]	NE (t0/tf)[3]
Prevention practices during milking									
Use of milking gloves	Never	59	59	60	60	NS	NS	NS	NS
	Sometimes	12	6	13	7				
	Always	29	35	27	33				
Teat pre-dipping	No : without soap	39	33	27	13	NS	NS	NS	NS
	Yes : disinfectant	61	67	73	87				
Foremilking	Never	23	18	13	7	NS	NS	NS	NS
	Yes on selected cows	12	18	13	14				
	Systematically	65	64	14	79				
Teat post-dipping	No	0	0	0	7	NS	NS	NS	NS
	Yes: disinfectant	28	22	13	7				
	Yes: teat dip	72	78	87	86				
Cows constrained after milking	No	56	55	20	21	NS	**++**	NS	NS
	With feed fence	22	28	33	21				
	No possible access	22	**17**	47	**58**				
Disinfection of liners during milking	Never	28	17	22	7	NS	NS	NS	NS
	Yes after selected cows	44	55	64	73				
	Yes after all cows	28	28	14	20				
Practices of mastitis treatment									
Mastitis treatment during lactation	1, always the same	33	28	20	13	NS	NS	NS	NS
	2, for 1st and 2nd line treatment	17	22	27	33				
	Individually adjusted	50	50	53	54				
Alternative treatment	Never	78	78	86	74	NS	NS	NS	NS
	Maybe (reflexion or training ongoing)	11	11	7	13				
	Yes, sometimes	11	11	7	13				
Dry-cow therapy	Uniform protocol	33	33	33	27	NS	NS	NS	+
	Protocol adapted to each cows	39	28	53	33				
	Sometimes without antibiotics	28	39	14	40				
Sealant	Never	**28**	**6**	27	20	NS	NS	**++**	+
	Yes	50	55	60	40				
	Yes, and sometimes without antibiotics	22	39	13	40				

Health protocol	Don't know / useless	33	6	38	36	NS	+	**++**	NS
	Know, useful	**67**	**94**	62	64				

*NS = Non-significant; "+" = 0.05<p-value<0.10; "++" = p-value<0.05.
[1]E/NE = Comparison of exposed and non-exposed farmers at the beginning (t0) or at the end (tf) of the program.
[2]E (t0/tf) = Comparison of exposed farmers at the beginning and at the end of the program.
[3]NE (t0/tf) = Comparison of non-exposed farmers at the beginning and at the end of the program

Evaluation of the program on udder herd health and antibiotic use

Few changes related to practices of mastitis treatment and antibiotic use were observed.

Exposed farmers tended to reduce their antibiotic use for treatments of clinical mastitis (p-value<0.10), and for treatments implemented at dry-off (p-value<0.05) (Table 5).

Non-exposed farmers did also significantly improve their antibiotic use over the period, mainly at dry-off. At tf, the difference of practices between exposed and non-exposed farmers was non-significant.

Table 5. Comparison of udder herd health and antibiotic use over a year between t0 and tf (exposed and non-exposed from the "prevention" group).

	Exposed (n=18)		Non-exposed (n=15)		p-values*			
	t0	tf	t0	tf	E/NE (t0)[1]	E/NE (tf)[1]	E (t0/ tf)[2]	NE (t0/ tf)[3]
Antibiotic use practices								
ADD mastitis per lactating period per cow (days)	3.1 (1.1-8.5)	2.6 (0.6-5.3)	3.6 (1.2-6.8)	3.6 (1.0-8.7)	NS	NS	+	NS
ADD dry-off per cow (days)	**0.9** (0.1-1.1)	**0.6** (0.1-1.2)	**1.0** (0.8-1.4)	**0.6** (0.4-1.1)	NS	NS	**++**	**++**
ADD total per cow (days)	**4.0** (2.0-9.6)	**3.1** (0.9-5.9)	4.6 (2.3-8.0)	4.33 (1.4-9.1)	NS	NS	**++**	NS
Udder herd health								
SCC (herd) (x 1000 cells/mL)	265 (161-373)	255 (121-381)	295 (156-473)	286 (120-423)	NS	NS	NS	NS
SCC (bulk milk) (x 1000 cells/mL)	**220** (147-324)	**210** (119-356)	**238** (140-279)	**228** (122-307)	NS	NS	NS	NS
Occurence of clinical mastitis (cases per 100 cows per year)	**95.6** (51.4-164.2)	**66.5** (18.9-109.4)	**98.4** (47.8-147.8)	**64.9** (26.0-104.0)	NS	NS	**++**	**++**

*NS = Non-significant; "+" = 0.05<p-value<0.10; "++" = p-value<0.05.
[1]E/NE = Comparison of exposed and non-exposed farmers at the beginning (t0) or at the end (tf) of the program.
[2]E (t0/tf) = Comparison of exposed farmers at the beginning and at the end of the program.
[3]NE (t0/tf) = Comparison of non-exposed farmers at the beginning and at the end of the program

Differences of improvement between exposed farmers of different behavioural groups were non-significant (p-value>0.10). However, a trend in the evolution of scores could be noticed, and were consistent with the improvement of knowledge marks: farmers of profile 2 did more reduce total ADD (-1.21) than farmers of profile 1 (-0.42) and 3 (-0.56).

The number of mastitis did significantly reduce between t0 and tf both for exposed and non-exposed farmers (p-value<0.05).

Discussion

Main impacts of the program on farmers' knowledge, perception, practices, and on dairy herd health

The results of data about knowledge and perception of farmers on mastitis and antimicrobial resistance confirmed the possibilities for improvement. First, farmers underestimated impact of mastitis on farm income and on dairy industry, while economic levers are important to trigger changes of practice (Russell and Bewley, 2013). In addition, farmers' knowledge on antimicrobial resistance was deficient. This is consistent with the only recent concern for antimicrobial resistance (Friedman *et al.*, 2007). However, the knowledge is also a lever to change practices (Ellis-iversen *et al.*, 2010). Finally, the results showed that farmers are still not able to precisely manage mastitis with existing tools. They also did not rely enough on the scientific expertise of advisors and veterinarians.

These elements confirmed the paramount importance of improving both perception and knowledge of farmers through training and advisory programs. A significant improvement of knowledge for exposed farmers was observed on mastitis, impacts of antibiotic resistance, and on antibiotic resistance itself. However, evolution of knowledge was better for farmers prone to follow technical advice than for other behavioural types of farmers.

A reduction of antibiotic consumption was observed, including treatment implemented at dry-off, but on a limited extent. However only marginal improvement of prevention practices during milking was recorded. This could be linked first to the duration of the program. Second, the organisation of data collection could explain the limited evolution of practices. Due to schedule constraints, data collection for tf included records registered during the implementation of the program, as advisory visits were still in progress. To stand back and better evaluate the impact of the program, the collection of data on practices and udder herd health should have started at the end of the program. A change in practices is a process that require new knowledge and time to be implemented (Panter-Brick *et al.*, 2006; Ellis-iversen *et al.*, 2010). Finally, farmers included in the intervention study were no voluntary applying for the program. Their motivation could thus have been limited.

Strengths and weaknesses of the evaluative method

The design of the evaluation framework measuring the impact of the training program took into account different elements: knowledge, perception, practices, herd health, antibiotic consumption. Methods used are of qualitative and quantitative nature, allowing evaluating the impact of the whole program with more precision (Moore *et al.*, 2015; Duval *et al.*, 2017).

The epidemiological design allowed for the control of important parameters influencing the results. First, the willingness of farmers to follow advice was evaluated, which showed an influence on the improvement of exposed farmers on knowledge, perception and practices. Second, the program showed similar effects on the two exposed groups of farmers, which demonstrates a certain reproducibility of the results. Third, the comparison of the results between exposed and non-exposed groups showed that exposed farmers' improvement of antibiotic use at dry off could also be linked to a more general trend, as non-exposed farmers also improved their practices. Veterinarians could be increasingly advising for selective dry-cow therapy.

Some limitations can also be addressed. The training program was complicated, time consuming and long for farmers involved in the process. Including non-exposed farmers was important. However, this increased constraints and complexity of the program and data collection. In addition, non-exposed farmers were not involved in the project. Five of them gave up during the program, only two exposed farmers gave up. At the end, only 33 farmers were included in the analysis of the results of the "prevention" group, which limited the power the of statistical analysis. More data with the analysis of the "dry-cow" group should help.

Evaluation of farmers' perception and practices is difficult. Perceptions are abstract concepts and linked to personal evaluations. Practices evolve on longer periods than the one considered for the program. And evaluation of practices is difficult as farmers can implement the same preventive practices in a correct or non-correct way. This would have an impact on farmers' ability to prevent mastitis, but would not change the results of the analysis.

Contributions and limitations of the innovative training program

The design of the training program took into account different important elements to trigger an improvement of farmers' practices. From a theoretical point of view, the program aimed at improving both perception and knowledge of farmers, which are two important levers. From a practical point of view, the program mobilised different tools, some of them of an innovative form: training, virtual classroom, advisory program and farmers sharing practices. This program thus used the three major farmers' channel of information (Vaarst *et al.*, 2006; Friedman *et al.*, 2007; Russell and Bewley, 2013; Mcdougall, Compton and Botha, 2017). Key messages to improve practices were thus communicated several times and through different communication channels. However, the initial design of the training program was complex and time consuming both for farmers, instructors and computer technicians. This could limit the extension to a larger scale of this kind of program.

Advisory visits were implemented by advisors who were not involved in the conception of the program. They were invited to all training sessions, but they were not all available to come. The form of accompaniment developed in the program was innovative for them too, and they complied to it showing uneven efforts. Advisory visits were thus different among exposed farmers.

The most innovative part of the training program consisted in virtual classrooms. They present advantages compared to instructor-led trainings and Massive Open Online Courses (MOOC).

First, the organisation of the virtual classrooms was flexible as meetings can be easily modified without logistical constraints. In addition, the duration of the meetings (maximum one hour and a half) are less time consuming for farmers than other traditional trainings which need at least half a day or a complete evening. Finally, the software can be programmed to automatically send reminders, which proved to be effective. All those elements combined, the attendance to the virtual classrooms (20% in the worst case, but most often between 60 to 89%) seemed to be better than the attendance to more traditional trainings, or other MOOC where attendance is close to 10% (Goldberg *et al.*, 2015). Social interactions during MOOC are important to involve participants (Goldberg *et al.*, 2015; Redondo-Duarte and Valencia, 2017). Shorter MOOC programs could be more successful in case of shorter periods of interactions (Goldberg *et al.*, 2015).

Second, the constraint of meeting date and the live exchange during virtual classrooms increased social involvement and gave an advantage compared to the organisation of more "traditional" MOOC sessions (Watson *et al.*, 2017). The diminishing of farmers' involvement is very strong in MOOC sessions and was limited for our virtual classrooms.

However, technical difficulties linked to the use of the software (complicated interface to use), internet connection or computer equipment were numerous and did not diminished over time. This discouraged some farmers and sometimes increased the delay between two virtual classrooms. Those limitations could be linked to the nature of the software, to the farmers' familiarity with computer use, or to the network coverage. Both points should be improved in the coming years.

Conclusion

Results showed uneven success of the training program. However, if farmers did commit to follow the training program, they were not actor in the process. Developing tools for trainings and advisory programs adapted to farmers' constraints require further evolution. To this effect, new forms of virtual trainings could be developed. However, the impact of such programs should be further confirmed with more data and future field research.

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