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Longitudinal study of respiratory health in dairy farmers: influence of artificial barn fodder drying

F. Mauny*, J.C. Polio*, E. Monnet**, D. Pernet*, J.J. Laplante+, A. Depierre*, J.C. Dalphin*

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ABSTRACT: Factors influencing respiratory consequences of dairy farming have not been extensively investigated to date. To evaluate the effects of barn fodder drying on respiratory symptoms and lung function, a 5 yr follow-up study was performed in the Doubs (France).

A cohort of male dairy farmers was analysed in 1990. The initial cross-sectional results suggested that barn-drying fodder may protect dairy farmers from lung function impairment. In 1995, 113 barn-drying farmers (92%) and 231 traditional-drying farmers (84%) were re-analysed. Barn and traditional fodder-drying farmers were compared for prevalence of symptoms and spirometric measures of lung function.

After controlling for age, smoking status, altitude and cumulative exposure, barn-drying farmers compared to traditional-drying farmers had a lower prevalence of chronic bronchitis (4 *versus* 10%; p<0.05) and slightly higher values of forced expiratory volume in one second (FEV_1) (p=0.06) and FEV_1/vital capacity (VC) (p<0.01). Nevertheless, decline of the respiratory function parameters was not significantly different between the two groups. Variables positively and significantly associated to longitudinal decline of lung function parameters were: age (FEV_1, FEV_1/VC); altitude (VC, FEV_1) and chronic bronchitis and dyspnoea at the initial survey (FEV_1/VC). Persistence and emergence of chronic bronchitis, dyspnoea and symptoms at exposure were also significantly associated to an acceleration in the annual decline of the respiratory function.

In conclusion, the mode of fodder drying does not seem to significantly influence the decline in lung function. Nevertheless, this study confirms the results of the initial cross-sectional analysis and supports the hypothesis that barn drying fodder may have a protective effect on respiratory health in dairy farming.
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Depts of *Chest Diseases and **Public Health, University of Besançon, and +Medical Dept of "Mutualité Sociale Agricole du Doubs", Besançon, France.

Correspondence: J.C. Dalphin
Dept of Chest Diseases
Hôpital Saint Jacques
2 place Saint Jacques
25000 Besançon
France

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Many epidemiological studies [1–3] have shown a close association between both acute and chronic respiratory diseases and agricultural occupational exposure. The risk of chronic impairment in lung function or chronic bronchitis has already been demonstrated or strongly suspected in grain workers [4, 5] and swine workers [6].

Dairy farmers have been less extensively studied. One study, in Finland, found that the annual incidence of chronic bronchitis appeared to be higher in farmers than in nonfarmer control subjects [7]. Controlled cross-sectional studies have suggested a moderate but significant impairment of expiratory flow rate in dairy farmers [8–10]. Occupational exposure, especially to organic dusts, has been incriminated [3, 4, 11].

In the Doubs, a damp and rainy semimountainous region of France, dairy farming is the principal agricultural activity. Because of the label of quality on milk and cheese, there is no use of silo feeds, cereals, chemical fertilizers and pesticides. Thus, besides cow allergens which specifically play a role in asthma in dairy farmers [12], hay and micro-organisms inside constitute the principal occupational exposure. In this region, the haymaking season is rainy. For this reason, artificial barn fodder drying has become more widely used over the last 20 yrs. An aerobiological study conducted in the Doubs had shown that exposure to fungal and bacterial micro-organisms (thermophilic actinomycetes) was lower in modern farms than in traditional farms and in particular, that barn fodder drying very significantly reduced air contamination by thermophilic actinomycetes [13].

The present cohort study began with a cross-sectional study conducted in 1990 which suggested a protective effect of barn fodder drying on farmers' respiratory function [14]. In this cross-sectional study, two groups of male farmers, one using barn drying and the other traditional drying, were compared; barn-drying farmers had slightly but significantly better respiratory function flow parameters. Both groups were re-examined in 1995 in order to analyse factors influencing the evolution of symptoms and the decline of respiratory function, with special attention to use of barn fodder drying.

Methods

The study was conducted in co-operation with the "Mutualité Sociale Agricole (MSA) du Doubs", the French national insurance health mutual for farmers, whose medical department organizes annual free check-ups for all their members. The protocol was approved by the "Comité Consultatif pour la Protection des Personnes dans la Recherche Biomédicale", the local review board for research involving human subjects. Informed written consent was obtained from each subject.

Population

A cohort was established in 1990, during MSA check-up sessions in five districts of the Doubs region in France. Two districts were located on plains at altitudes of 250–400 m; three were located on tablelands with altitudes of 700–1000 m. One thousand eight hundred and fifty seven farmers agreed to participate in the study and were examined in 1990 (response rate 81.2%). Subjects included were male farmers, working exclusively on dairy farms and involved daily in cattle foddering. The barn-drying group included all those farmers who had been using a barn drying system for at least 3 yrs (n=123). The traditional storage group included the first five farmers examined at each session who had been using a traditional storage system (n=274). Farmers using traditional storage resided in the same geographical area as the artificial drying farmers.

In 1994, each subject was contacted individually and invited to participate in an investigation identical to the one performed in 1990. An explanatory letter concerning the objectives of the study and its practical value was sent to each subject. Subjects refusing to participate were contacted by telephone in order to obtain information about the reasons for their refusal. Subjects agreeing to participate were convoked individually to a specific examination session. These subjects were asked to answer a medical and occupational questionnaire, and were given spirometrics tests. Both procedures were performed blind. All examinations were performed on a morning following a foddering shift, between January and May 1995.

Questionnaires

Questions on respiratory symptoms were adapted from the questionnaire of the American Thoracic Society [15]. The basis of the questionnaire and the wording of the symptoms were identical to those used in 1990. Chronic bronchitis was defined as cough and chronic expectoration for 3 months of the year or more for at least two consecutive years. Dyspnoea was defined as shortness of breath when hurrying on the level or walking up a slight hill. Semidelayed respiratory symptoms (SDRS) were defined as cough and dyspnoea with fever occurring 4–10 h after exposure to mouldy hay. Asthma was retained when previously diagnosed by a physician. Atopy was defined as a history of allergic symptoms (any nasal allergies including hay fever and/or eczema or any kind of skin allergy).

Nonsmokers (NS) were defined as those having smoked on average less than one cigarette, one cigar, or one pipe a day for a year. Current smokers (CS) smoked this amount or more, and exsmokers (ES) had stopped smoking at least 1 month before the time at which they filled out the questionnaire.

The main questions of the occupational questionnaire concerned the size of the farm, the size of the herd, the method of storing and drying fodder, and the type of tasks regularly performed (milking, foddering, *etc.*). Geographic distribution was dichotomized according to altitude (plain or tableland). Exposure to fodder was estimated by the number of bale-years, that is the number of average density bales of hay (or its equivalent when farmers used other sizes of bales or methods of hay storage) effectively fed by the subject to the cattle per day, multiplied by the number of years of foddering.

Respiratory function tests

The same portable pneumotachograph (Autospiro Minato AS 500; Medical Science Company Ltd, Osaka, Japan) as that used in 1990 was used to measure slow vital capacity (VC), forced expiratory volume in one second (FEV_1), and forced mid expiratory flow ($FEF_{25–75}$). The spirometer was calibrated daily for atmospheric pressure, hygrometry and temperature, and periodically with a 1.5 L syringe. A minimum of three adequate measurements was required for each subject [16]. The best value was selected after correction to body temperature and ambient pressure, and saturated with water vapour (BTPS). For cross-sectional comparisons, values were expressed as a percentage of the European Community for Coal and Steel reference values, calculated in relation to sex, age and height [17].

Data analysis

Farmers no longer exposed to fodder in 1995 were excluded from analysis. Spirometric data considered as inadequate according to the recommendations used [16] were also excluded. The analysis was performed considering the initial assignment to one of the two fodder-drying groups, even if the subject had changed his type of fodder-drying between the two surveys.

Firstly, a cross-sectional analysis of the 1995 data was performed. Prevalence of symptoms was analysed using Cox's proportional hazards model to estimate prevalence rate ratios for fodder-drying, adjusted for age (in four classes: <40, 40–50, 50–60, >60 yrs), smoking habits (CS, ES, NS), exposure (bale-years in three classes: <500, 500–1000, >1000) and location (plain = 0, tableland = 1) [18]. Multiple linear regression was used to estimate the effect of barn fodder drying on respiratory function parameters, adjusted for the covariates used in Cox's model. Age, smoking (pack-years) and exposure (bale-years) were used as continuous variables.

Secondly, a longitudinal analysis was performed. The annual decline of respiratory function parameters in the two groups (1995 value - 1990 value/number of years) was assessed by multiple linear regression, adjusting for age in 1990 (years), location (plain = 0, tableland = 1), smoking habits and exposure between the two surveys. Exposure was estimated by the number of bale-years over the 5 yr period. Smoking habits were categorized as follows: nonsmokers; exsmokers before 1990; exsmokers between 1990 and 1995, current smokers having smoked less than 5 pack-years between 1990 and 1995; and current smokers having more than 5 pack-years between the two surveys.

Finally, the association between changes in respiratory symptoms during the study period and the annual decline of spirometric parameters was analysed for chronic bronchitis, dyspnoea, symptoms at exposure (cough or shortness of breath with wheeze) and semidelayed respiratory symptoms. The following three categories were considered: absence of symptoms in 1995 (whether or not symptoms were present in 1990), emergence of symptoms between 1990 and 1995; and presence of symptoms in 1990 and 1995. The course of respiratory symptoms was considered as an independent ordinal variable, assuming a continuous effect of the three classes of symptoms on annual decline in lung function. The effect of each symptom was analysed separately, adjusted for fodder drying type and covariates previously used by multiple linear regression.

Data analysis was performed using the BMDP statistical software package (BMDP Statistical Software™, BMDP, Los Angeles, USA). Standard statistical methods used included Chi-squared, Fisher's exact and Student's t-tests for univariate analysis. Cox's proportional hazards and multiple linear regression were used for adjusted multivariate analysis [19, 20]; interactions between significant covariates were tested. Adjustment in models was performed including potential confounders, not only those found during the analysis but also those known to be strong determinants of respiratory function. A p-value equal to or less than 0.05 was regarded as significant. Assumption for residual normality was assessed by normal probability plot of the residuals.

Results

Characteristics of the study population

A total of 372 subjects (94%) from the original cohort were seen and re-examined at the second survey in 1995. The mean interval between the two examinations was 4.6 yrs. The reasons for nonresponse to follow-up were refusal (15 cases), death (five cases), lost to follow-up (three cases) and nonrespiratory severe illness (two cases). Twenty eight subjects were no longer exposed to fodder and were excluded from analysis; 24 subjects had effectively retired and four had changed jobs (two due to semidelayed respiratory symptoms). Fourteen farmers were excluded from spirometric parameter analysis. The reasons for exclusion were missing data in 1990 or in 1995 (nine cases), or measures considered as inadequate according to the adopted criteria (five cases). The distribution of farmers who had changed their type of fodder drying is as follows: 14 initially traditional-drying farmers (5%) changed to barn fodder drying (two were symptomatic at exposure in 1990) and five initially barn-drying farmers (4%) stopped barn fodder drying (one was symptomatic at exposure in 1990). Final analysis was performed on 330 subjects (83%) for spirometric parameters and on 344 subjects (87%) for the other variables (except for dyspnoea, for which seven subjects were not evaluable).

Comparison between the study group and farmers excluded or lost was performed for initial parameters. Subjects included in the study were younger and less frequently smokers. They lived at higher altitudes, more frequently used artificial drying methods, and had more cattle, but cumulative exposure to fodder was not different. The included group was less symptomatic (significant for chronic bronchitis, $p<0.01$, and nearly significant for SDRS, $p=0.06$). All respiratory function parameters (percentage of reference values) were significantly higher in the included group ($p<0.01$ for VC, $p<0.001$ for FEV_1 and $p=0.05$ for FEV_1/VC). Complementary analyses were realized with the group consisting of ex-farmers and farmers lost to follow-up: smoking and type of fodder-drying were not significantly associated with either symptoms or with respiratory function.

Cross-sectional analysis of the 1995 survey

The two fodder drying groups were comparable for almost all demographic characteristics (table 1). Smoking status changes were not different between the artificial and the traditional drying group. Nevertheless, artificial-drying farmers lived more frequently in tablelands, had more cattle and were exposed more to fodder.

Table 2 shows the adjusted prevalence rate ratios (PRRs) of symptoms according to fodder drying in 1995. Only chronic bronchitis was significantly lower in the barn drying group (PRR: 0.32; 95% confidence interval (CI): 0.11–0.95). Tested interactions, including altitude-fodder-drying, were not significant.

Table 1. – Demographic characteristics in 1995 for barn-drying and traditional-drying farmers

	Barn drying	Traditional drying	p-value
Subjects n	113	231	
Age yrs	48.6±10.2	47.9±12	0.62
Height cm	174.4±6.2	173.9±5.6	0.45
Smoking status			
Current smokers	26 (23)	39 (17)	
Exsmokers	25 (22)	53 (23)	0.38
Nonsmokers	62 (55)	139 (60)	
Pack-years*	14.6±11.0	15.3±12.2	0.68
Alcohol consumption			
<10 g·day^{-1}	40 (35)	97 (42)	
10–50 g·day^{-1}	57 (50)	98 (42)	0.36
>50 g·day^{-1}	16 (14)	36 (16)	
Geography			
Plain	9 (8)	47 (20)	
Tableland	104 (94)	184 (80)	<0.01
Exposure to fodder			
Cattle†	91.3±47.1	70.3±35.0	<0.0001
Bale-years	1180.0±604.4	939.1±562.0	<0.001

Values are given as mean±SD or as absolute number with percentage in parentheses. *: among current smokers and exsmokers; †: average number during the 1990–1995 period.

Table 2. – Prevalence of symptoms and spirometric values in 1995 for barn-drying and traditional drying farmers

	Barn drying	Traditional drying	PRR†	p-value
Prevalence of symptoms				
Subjects n	113	231		
Atopy n	11 (10)	25 (11)	0.96 (0.46–2.01)	0.92
Chronic symptoms				
Chronic bronchitis	4 (4)	22 (10)	0.32 (0.11–0.95)	0.04
Dyspnoea	13 (12)	23 (10)	1.41 (0.69–2.91)	0.35
Asthma	4 (4)	9 (4)	0.96 (0.28–3.28)	0.95
Symptoms at exposure				
Eye irritation	13 (12)	29 (13)	1.06 (0.53–2.11)	0.96
Nose irritation	52 (46)	107 (46)	1.07 (0.75–1.51)	0.72
Cough	18 (16)	64 (28)	0.64 (0.3–1.10)	0.11
Shortness of breath with wheeze	10 (9)	37 (16)	0.61 (0.09–1.93)	0.18
SDRS	2 (2)	11 (5)	0.40 (0.09–2.38)	0.26
Spirometric values				
Subjects n	111	219		
VC % pred*	101.1±11.8	101.2±13.0		0.87‡
FEV_1 % pred*	99.8±13.2	97.0±14.8		0.06‡
FEV_1/VC % pred*	98.9±8.1	96.0±10.2		<0.01‡
FEF_{25-75} % pred*	86.4±22.8	82.0±23.8		0.08‡

Values are absolute number with percentages in parentheses unless, otherwise stated. *: results are expressed as mean±SD percentage values (European Coal and Steel Community standards) calculated in relation to age, sex and height. †: prevalence rate ratio (confidence interval at 95 per cent) for barn drying *versus* traditional drying adjusted for age, smoking status, geography and cumulative exposure from Cox's model. ‡: Wald's statistic for fodder drying coefficient (traditional = 0, barn = 1) in multiple linear regression adjusted for age, smoking status, geography and cumulative exposure. SDRS: semidelayed respiratory symptoms (cough and dyspnoea with fever occurring 4–10 h after exposure to mouldy hay); VC: vital capacity; FEV_1: forced expiratory volume in one second; FEF_{25-75}: forced midexpiratory flow; % pred: percentage of predicted value.

The percentage predicted values for FEV_1, FEV_1/VC and FEF_{25-75}, but not for VC, were higher in barn drying farmers (table 2). The difference between the two groups was significant for FEV_1/VC and nearly significant for FEV_1 and FEF_{25-75} after controlling for confounders. Further multiple regression analyses including alcohol consumption, smoking status expressed as CS, ES and NS, and number of cattle as an indicator of exposure were performed and did not modify the results.

Longitudinal analysis

After adjustment, the annual decline of FEV_1/VC was nearly significantly lower in barn drying farmers. The annual declines of VC, FEV_1 and FEF_{25-75} were not different between the two groups (table 3). Tested interactions were not significant. Further analyses using alcohol consumption, smoking status expressed as CS, ES and NS, and number of cattle as an indicator of exposure were performed and gave the same results. Table 4 shows regression models relating spirometric changes to individual determinants. Age and geography were positively and significantly correlated to the annual decline of respiratory function parameters. Smoking and cumulated exposure were not correlated with the changes in respiratory function.

The 1990 values of chronic bronchitis, dyspnoea, semidelayed respiratory symptoms and symptoms at exposure (cough or shortness of breath with wheeze) were separately tested. The 1990 values of chronic bronchitis and dyspnoea were positively and significantly correlated to the annual decline of FEV_1/VC ($p<0.01$ and $p<0.05$, respectively).

The course of symptoms for chronic bronchitis, dyspnoea, symptoms at exposure and semidelayed respiratory symptoms did not differ statistically between the two groups. After adjustment for confounders, there was a positive correlation between the annual decline of respiratory function and the course of symptoms categorized in three classes (absence in 1995, emergence between 1990 and 1995, and presence both in 1990 and 1995) (table 5). Interaction terms between the course of symptoms and drying type on decline in lung function were tested and were found not to be significant, suggesting a similar association between symptoms and changes in lung function in the two groups.

Table 3. – Annual decline of respiratory function for barn-drying and traditional-drying farmers

	Barn drying	Traditional drying	p-value
Subjects n	111	219	
Time between the two surveys yrs	4.5±0.3	4.6±0.3	0.27
VC mL·yr⁻¹*	-25.5±97.6	-8.4±101.8	0.27†
FEV_1 mL·yr⁻¹*	-36.3±67.7	-35.5±80.0	0.50†
FEV_1/VC %·yr⁻¹*	-0.46±2.1	-0.68±1.8	0.07†
FEF_{25-75} mL·yr⁻¹*	-52.2±152.01	-44.2±164.2	0.85†

Values are mean±SD, or absolute number. *: annual decline of parameters. †: Wald's statistic for fodder drying coefficient (traditional = 0, barn = 1) in multiple linear regression, adjusted for age, smoking, geography and cumulative exposure. For definitions, see legend to table 2.

Table 4. – Annual decline in lung function (VC, FEV_1, FEV_1/VC) according to exposure-related variables

Independent variable	VC		FEV_1		FEV_1/VC	
	Coeff.	SE	Coeff.	SE	Coeff.	SE
Age yrs	-0.185	0.524	-1.003*	0.412	-0.028**	0.010
Tableland	-65.428**	16.231	-58.678**	12.917	-0.408	0.325
Smoking	-9.532	9.124	-0.006	0.014	0.053	0.182
Bale-years (1990–1995)	6.394	6.942	2.089	5.491	-0.043	0.138
Barn drying	-18.709	12.773	7.394	10.017	0.450§	0.251
Intercept	54.334		54.259		0.839	
r^2	0.08		0.10		0.05	

Regression coefficients (Coeff.) with positive values indicate a protective effect. All variables listed were included simultaneously in the multiple regression models. Each coefficient and p-value is controlled for all other variables. Age and bale-years are continuous variables; for tableland and barn drying, reference categories are plain and traditional drying, respectively. *: $p<0.05$; **: $p<0.01$; §: $p<0.10$. For definitions, see legend to table 2.

Table 5. – Annual decline in lung function (VC, FEV_1, FEV_1/VC) according to change in symptoms status between 1990 and 1995

	Patients n (%)	VC	FEV_1	FEV_1/VC
Chronic bronchitis				
Not	306 (93)			
New	8 (2)			
Both	16 (5)			
Regression coeff.		-48.369**	-26.423*	0.069
Regression SE		16.703	13.285	0.335
r^2		0.11	0.09	0.05
Dyspnoea				
Not	291 (90)			
New	19 (6)			
Both	13 (4)			
Regression coeff.		8.149	-17.995	-0.533*
Regression SE		12.623	10.008	0.249
r^2		0.08	0.09	0.05
Symptoms at exposure				
Not	238 (72)			
New	59 (18)			
Both	33 (10)			
Regression coeff.		17.114	-11.882	-0.515*
Regression SE		11.442	9.148	0.228
r^2		0.09	0.08	0.05
SDRS				
Not	318 (96)			
New	9 (3)			
Both	3 (1)			
Regression coeff.		28.577	13.631	-0.699
Regression SE		21.629	17.230	0.431
r^2		0.09	0.08	0.05

The effect of each symptom is analysed separately, adjusted for age, smoking, exposure, fodder drying type and geography by multiple linear regression. For each symptom, subjects were divided into three classes as follows: not symptomatic in 1995 or no longer symptomatic (not); became symptomatic between 1990 and 1995 (new); and symptomatic both in 1990 and in 1995 (both). The three classes are considered as an ordinal independent variable. *: $p<0.05$; **: $p<0.01$. For definitions, see legend to table 2.

Discussion

This longitudinal study shows that the principal factors associated with an accelerated decline in respiratory function parameters are age (*i.e.* duration of exposure in this cohort), altitude and the existence of respiratory symptoms, especially when symptoms persist over the long-term. Furthermore, in 1995 as in 1990, barn-drying farmers had less chronic bronchitis and a slightly better respiratory function, but the artificial barn drying of fodder does not significantly reduce the annual decline in respiratory function.

Cross-sectional analysis on 1995 data shows artificial-drying farmers to be less symptomatic for chronic bronchitis and have better FEV_1/VC ratio values, both significantly. These results are consistent with and comparable to those found in 1990 [14]. In the initial analysis, however, the difference was slightly greater for respiratory function and the longitudinal study fails to prove that artificial barn drying of fodder could be used as a preventive method against long-term deterioration of lung function in dairy farmers. Nevertheless, the consistency of the results suggests that this technique contributes to maintaining good respiratory health in dairy farmers. It is possible that the preventive effect of barn drying was present before the beginning of the study in 1990, in a period when farmers worked in worse conditions on less mechanized farms. The aerobiological study we published in 1991, which demonstrated that barn drying fodder significantly reduced aerocontamination by micro-organisms, was carried out in 1987 [13]. These findings may no longer hold true. Moreover, a "healthy worker effect" at the constitution of the cohort cannot be excluded: the modernization of farming activities, including the installation of barn fodder-drying facilities, is costly and farmers with health problems (especially respiratory) might not be particularly tempted to undertake the work necessary to modernize their farm.

Potential selection biases should be also discussed. Nonanalysed farmers (deceased, lost to follow-up or excluded) were more symptomatic and presented lower respiratory function parameters than included subjects. This selection of healthier subjects has already been noted in other studies [5, 21]. Moreover, they were, for the most part, traditional-drying farmers. This selective loss of less healthy, and more frequently traditional-drying farmers could have induced two consequences: a loss of power for the analysis and/or a reduction in the observed effect of barn fodder drying on symptoms and respiratory function. Within-subject variability is inevitable, but appears to be low [22]. Such variability could introduce a nondifferential measure bias, which could only reduce the power of our study, but not reverse the results found.

The annual decline of respiratory function parameters significantly increases with age. In this population of male dairy farmers, it is not possible to differentiate age effect from duration of exposure effect in that all the studied subjects were born on a farm. Baseline symptoms are predictive factors of a moderate accelerated decline of respiratory function; persistence and emergence of symptoms are associated with an accelerated decline of respiratory function. Some investigators have found the same results [23], others have not [24, 25].

Altitude appears to be one of the factors most influencing the acceleration in respiratory function decline. A previous study reported a nearly linear relation between the frequency of chronic bronchitis and farmer's lung disease, and altitude [26]. This could be explained by an increase in exposure to organic dust at higher altitudes; indeed, altitude and rainfall during haymaking are closely linked. The mean annual rainfall calculated for the last 20 yrs was about 1100 mm (285 during the haymaking season) in the two plains districts and 1700 mm (421 during the haymaking season) in the three tablelands districts (Regional Meteorological Centre, Besançon). Low temperatures, which are closely linked to altitude, could also be incriminated.

Hay and its micro-organisms constitute the main occupational exposure for Doubs dairy farmers, so cumulated exposure was evaluated by bale-years, which relate a quantitative, but not qualitative, aspect of exposure. No correlation appeared between bale-years and the annual decline of respiratory function. In a previous case-control study, we found no relation between bale-years and chronic bronchitis [27]. This may be explained by individual susceptibility; for equal exposure, some farmers develop a bronchial disease, while others do not. However, as there was no real measure of exposure, either quantitative or qualitative, this hypothesis must be put forward with caution.

No significant relation was observed between smoking habits and respiratory function evolution. This has already been observed in longitudinal studies [25, 28]. It may be due to the fact that our population contained few smokers (22%), and those were moderate smokers. Also, farmers in this region rarely inhale smoke (observed data not evaluated in this study). It might also reflect a "healthy smoker effect" [29], *i.e.*, the possibility that subjects who start and continue to smoke are particularly resistant to the effects of cigarette smoke. It may also be that the occupational exposure effect partly conceals the smoking effect as observed by PAHWA *et al*. [30] in grain workers exposed for more than 20 yrs in industry. In our study as well, all the farmers were exposed for a long period of time because they were born on a farm.

This study does not prove the preventive effect of barn fodder drying against long-term deterioration of lung function in dairy farming. Nevertheless, this longitudinal analysis supports the results of the initial cross-sectional study and suggests that this method of fodder storage may contribute to maintaining good respiratory health in male dairy farmers in the Doubs region of France. The negative influence of altitude justifies further studies in order to distinguish occupational exposure from climatical or other environmental effects.

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