



## Smallholder milk-quality awareness in Indonesian dairy farms

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### ABSTRACT

In most low- and middle-income countries, milk is produced by smallholders, thereby contributing to the livelihood of their households. With the increasing importance of milk production in these countries, it is essential that milk quality is of a high level to ensure a safe product for consumers. It is, however, unclear whether smallholder dairy farmers are aware of the quality of their milk. The aim of this cross-sectional study was to gain insight on Indonesian smallholder dairy farmer awareness of milk quality parameters and to identify factors associated with the total plate count (TPC) and somatic cell count (SCC). A stratified sampling method was used to select smallholder farms in 4 districts in West Java, Indonesia, that were interviewed between August and September 2017. Factors putatively associated with awareness of TPC were investigated with multinomial regression models, whereas a Firth-type logistic regression was applied to identify factors associated with SCC awareness. Of the total 600 farmers surveyed, 264 (44%), 109 (18%), 170 (28%), 111 (19%), and 23 (4%) farmers were aware of TPC, total solid, fat content, milk density, and SCC, respectively, but did not know its value. Those that were conceptually aware of these quality parameters were generally unaware of their value. Furthermore, this study revealed that the following variables were significantly associated with dairy farmers' awareness of TPC: cooperative to which the farmer belonged, distance to neighboring dairy farmer, technology adoption index, TPC as the most important quality factor for the buyer, milk production information from coopera-

tives, and cow health information from veterinarians. Similarly, cooperative, dairy business experience, and milk quality test adoption were significantly associated with dairy farmers' awareness of SCC. Cooperative was the only variable that was significant in both final statistical models. This indicates that cooperatives play an important role in increasing farmer awareness of milk quality parameters in these smallholder dairies. This may be valid for other regions in the world also where milk production is dominated by smallholder dairy farmers.

**Key words:** risk factor, udder health, Firth-type logistic regression, multinomial logistic regression

### INTRODUCTION

There are considerable differences in the level of milk consumption between countries and regions, with an average world milk consumption of around 100 kg per capita per year (in milk equivalents; Hemme et al., 2010; Gerosa and Skoet, 2012). The average consumption level of milk in some Asian and African countries may be as low as 10 kg per capita per year, while the average milk consumption level in some European countries may reach more than 300 kg per capita per year (Hemme et al., 2010). Global population growth, increasing income, and improving economic prosperity in low- and middle-income countries are expected to further raise the global demand for milk and dairy products (Salter, 2017).

In most low- and middle-income countries, milk is commonly produced by smallholders, in which it contributes to household livelihoods in rural areas (Jahroh et al., 2020). Low- and middle-income countries have increased their share in world milk production from 50% in 2011 to 53% in 2020 (OECD-FAO, 2021). Smallholder milk production not only improves the food security of milk-producing households but also helps to

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create numerous employment opportunities throughout the dairy chain, such as for small-scale rural processors and intermediaries (Hemme et al., 2010).

Indonesia's dairy sector is also dominated by smallholder farms and therefore provides for a valuable opportunity for research on milk quality. Farmers, on average, own less than 6 milking cows (Guntoro et al., 2016). The Indonesian dairy sector, as well as many other dairy sectors in low- and middle-income countries, is constrained by several aspects. It is mostly small scale, without grazing, and has a high stocking density per unit of land (De Vries and Wouters, 2017). The relatively low milk production level per cow leads to food insecurity, an underutilization of resources, and a higher emission intensity of greenhouse gases. An improvement of the productivity of the current dairy population has been proposed as a solution because less animals are needed to meet the demand, leading to a more efficient dairy production system from a greenhouse gas, land use and economic perspective (De Vries et al., 2017; De Vries and Wouters, 2017).

Increasing milk production can be achieved through improving dairy cow health, which can also lead to improvements in dairy product quality, food safety, and farmers' livelihoods, and, in the case of zoonotic diseases, public health. Milk quality measurements are also needed to improve animal health and prevent animal diseases on farms. Raw milk quality measurements most often considered, focusing on potential effects on processed product quality, are SCC and the total plate count (TPC). At higher levels, increased enzyme activities that damage components of milk and potentially result in product defects are related to bacteria and somatic cells (Murphy et al., 2016). Milk quality programs in developed countries have been shown to be effective (e.g., Dekkers et al., 1996). With the increasing importance of milk production in low- and middle-income countries and their smallholder dominated dairy sectors, it is essential that effective milk quality programs are available throughout the dairy sector worldwide.

Improvement of animal health and milk quality starts with the farmer being aware of the relevant milk quality parameters. Frequent measurements of quality parameters when milk is delivered, for example through milk quality programs, may help to raise awareness. Such parameters can include TPC and SCC, which are commonly measured in developed countries. However, it is unknown whether smallholder farmers in Indonesia are aware of these parameters as there is currently no standard infrastructure for monitoring milk quality, animal diseases, and management practices in place.

The aim of this study is to gain insight into the awareness of smallholder dairy farmers in milk quality

parameters and to understand the factors associated with awareness levels. We used an Indonesian smallholder population for this study.

## MATERIALS AND METHODS

### *Study Design and Farm Selection*

A cross-sectional study of 600 smallholder dairy-farming households was conducted in West Java, Indonesia, from August to September 2017. After extensive consultation with key stakeholders in the dairy sector, including national and local government, universities, milk processing companies, and dairy co-operatives, a survey instrument was designed to collect a wide range of useful information from dairy-farming households. Data were collected on socio-demographic, farm characteristics, farmer awareness of milk quality parameters, and dairy farm management practices. Ethical approval for this study was obtained from Human Research Ethics Committee at the University of Adelaide (Adelaide, Australia) with approval number H-2014-188.

Established smallholder dairy value chains and a strong presence of village-level dairy cooperatives (Koperasi Unit Desa; **KUD**) are present in West Java. Potential cooperatives were therefore approached first by convenience sampling for inclusion in the study. Cooperatives were included based on the following inclusion criteria: shared interest and commitment to participate in the study, willingness to share information, low level of interventions from other related projects, an interest in extension programs, likelihood of spillover effects to more farmers, and willingness of the KUD to improve milk quality and incentivize farmers. Five KUD across 4 districts were selected and identified to collaborate.

A purposive proportional random sampling method was subsequently utilized to select farms based on the membership size of the KUD. A list of active farmer members was collected from the KUD of each district. All active member farmers of the KUD were the population for sampling. The dairy farms were randomly selected from each dairy cooperative using simple random sampling. The number of farms selected from cooperative I, II, III, IV, V were 300, 140, 80, 15, and 65 farms, respectively (Table 1).

To improve the quality and efficiency of data collection, a mobile data collection platform (CommCare, Dimagi) was used to administer the survey. The mobile-based applications enabled data to be monitored and inputted in almost real-time. The data were collected by a trained team of 12 enumerators that visited the selected farms. Enumerators were fluent in Bahasa Indonesia and the local language, Sundanese.

**Table 1.** Description of the sampling distribution of the dairy herd survey in 4 districts in Indonesia

District	Dairy cooperative	Number of farms in the sample	Percentage of total sampled farms <sup>1</sup> (%)
Bandung	I	300	50
Garut	II	140	23.3
Cianjur	III	80	13.3
Bogor	IV	15	2.5
Bogor	V	65	10.8
Total		600	100

<sup>1</sup>Percentages do not add to 100 due to rounding.

### Explanatory Factors

For the purpose of the current study, 35 variables putatively associated with farmer milk quality awareness were selected from a total of 6,921 variables in the full data set. The selection of these variables was based on a literature review of factors affecting milk quality and the experience of the current research team with milk quality programs and udder health. The variables for this study were divided into 6 categories:

1. Demographics (gender, age, education, main occupation, and dairy business experience),
2. Farm characteristics (herd size, milk production, number of hired labor, district, and cooperative identification),
3. Geographical distance (distance to cooperative, milk collection point, livestock clinic or veterinary doctor, local livestock or services offices, veterinary technician, dairy farmer leader, and nearest neighbor dairy farmer),
4. Farmer access to information (receives (1) milk quality information, (2) milk sales information, (3) mastitis information, (4) milk production information, and (5) cow health information from cooperatives, and receive cow health information from veterinary doctor),
5. Farmer technology awareness and adoption (using California Mastitis Test, applying teat dip after milking, improving drinking water availability, using detergents to clean milking equipment, improved milking hygiene, availability of milking machines, cooling milk in water tanks, using stainless steel milking equipment, and conducting milk quality test), and
6. Market (milk quality-based payment and the most important quality factors for the buyer).

Most of the selected variables were used directly in the analysis, except for the variables quantifying technology adoption. The 9 technology adoption variables had 4 categories and each category was assigned a score: not

aware (score 1), aware but not adopt (score 2), stopped adopting (score 3), and currently adopting (score 4). For the identification of factors associated with TPC awareness, a technology adoption index was created by summing the scores of the 9 individual technology adoption variables. The sum was finally divided into 3 total score categories based on the 33rd and 66th percentile scores.

### Milk Quality Awareness Variables

The following 5 milk quality awareness parameters were defined: farmer awareness of TPC (cfu/mL), SCC (cells/mL), TS (%), fat content (FC; %), and milk density (MD; g/cm<sup>3</sup>). These variables were created based on 2 other binary variables, namely whether farmers were aware of the milk quality parameter and whether they knew the value of the parameter for their milk. Farmer milk quality awareness was thus defined in 3 categories (not aware of parameter, aware of parameter without knowing its value, and aware of parameter and knowing its value).

### Statistical Analysis

Factors associated with farmer milk quality awareness of SCC and TPC were analyzed using a complete case analysis separately. Factors putatively associated with farmer TPC awareness were identified using multinomial logistic regression models, because this dependent variable had 3 nominal categories (Frankena and Graat, 2017). Farmer awareness on SCC was analyzed based on the original binary variable describing whether farmers were aware of the SCC parameter given the small number of farmers that were aware of SCC. Also given this rare event distribution, factors associated with farmer TPC awareness were identified using penalized maximum likelihood estimation models (also named Firth-type logistic regression method; Heinze and Schemper, 2002).

Regression modeling began by checking continuous variables for a linear relationship with the outcome variables. They were subsequently classified into biological and meaningful categories if their relationship was not linear. Variable selection started with a univariate regression analysis in which 35 variables were tested for their association with farmer awareness on TPC and SCC. Variables that had a *P*-value below 0.20 in the likelihood-ratio test were selected for the multivariable models. Correlation among pairs of selected explanatory variables was assessed thereafter. If 2 categorical variables had a Cramers's V correlation coefficient above 0.5, 1 of the variables was selected to be included in multivariable regression analysis. The milk

**Table 2.** Descriptive statistics of 600 Indonesian smallholder dairy farms

Category	Variable	Mean	Median	SD	Minimum	Maximum
Farmer characteristic	Age (year)	46.2	45	11.5	21	84
	Education (year)	6.4	6	3.1	0	18
	Dairy business experience (year)	19.1	17	10.4	1	52
	Technology adoption index	18.4	18	3.9	9	32
Farm characteristic	Herd size (cows)	2.8	2	2.6	1	28
	Milk production (liter/cow/day)	14.8	15	3.9	2	26.3

quality-based payment variable in the multivariable analysis was excluded because it had a strong correlation with cooperatives (Cramers's  $V = 0.83$ ). Similarly, the distance to the cooperative and the distance to the milk collection point variables were strongly correlated (Cramers's  $V = 0.79$ ). Distance to the milk collection point was included in the multivariable analysis for TPC awareness because it likely contributed stronger to the model based on its  $P$ -value in the univariable analysis.

After this screening, a backward selection process was used for model selection in the multivariable regression analysis until all variables were significantly contributing to the model based on the likelihood ratio test. Confounding was examined by evaluating the change in the effect estimates when removing a variable from the model. Confounding variables were retained in the final model, while interaction terms were not evaluated. Model estimates were exponentiated to obtain odds ratios. Statistical significance was defined at  $P < 0.05$ . All statistical analyses were conducted in STATA/SE version 17.0 (StataCorp LLC).

## RESULTS

### Descriptive Statistics

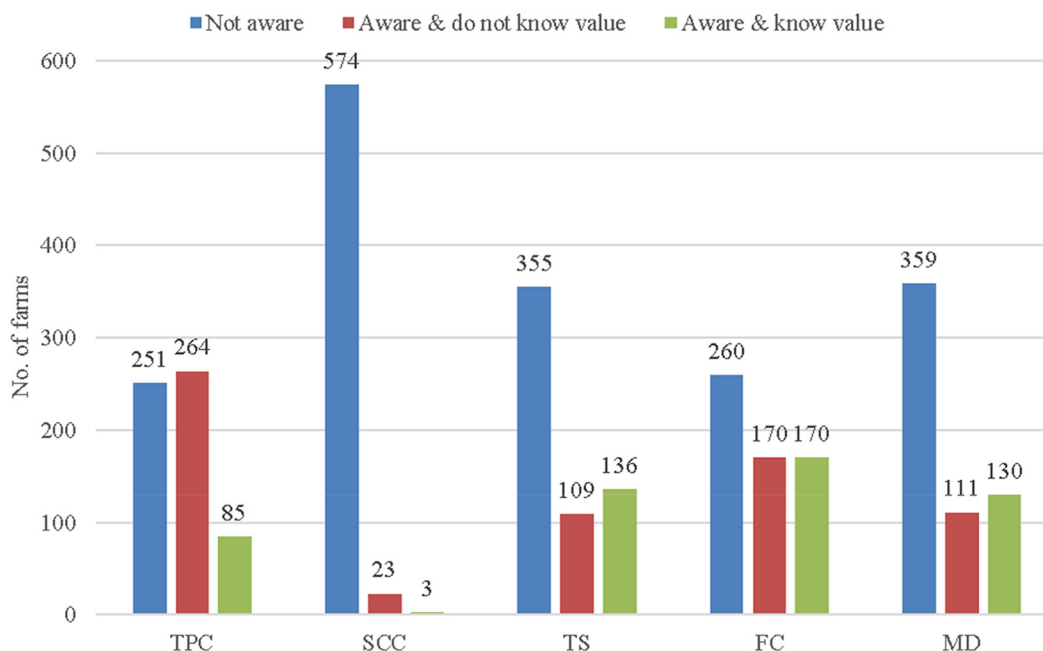
In total, 600 dairy farms were included in the analysis. Of the 35 selected explanatory variables, 8 variables had missing values. The implication of the missing values resulted in a lower number of observations, especially for the farm location variable and milk quality-based payment variables. The general household and farm characteristics of the 600 participating farms are provided in Table 2. The average age, education, and dairy business experience of dairy farmers were 46, 6, and 19 yr, respectively. The average technology adoption index of dairy farmers was 18 (SD 3.9). Dairy farming in West Java, Indonesia, is dominated by smallholders who only have an average of 3 cows per herd and an average production of 14.8 L/cow per day.

The level of knowledge and awareness of Indonesian dairy farmers on milk quality parameters was low (Figure 1). Of the total 600 farmers, only 85 (14%), 136

(23%), 170 (28%), and 130 (22%) farmers were aware and knew the value of the milk quality parameters TPC, TS, FC, and MD, respectively. The number of farmers that were aware of the TPC, TS, FC, and MD parameters but did not know their values were 264 (44%), 109 (18%), 170 (28%), and 111 (19%) farmers, respectively. Farmer awareness of SCC was the lowest of all parameters considered. Only 23 farmers (4%) were aware of SCC but did not know their value, and only 3 farmers (0.5%) were aware of SCC and knew its value.

### Factors Associated with TPC Awareness

Six factors were associated with dairy farmer awareness of TPC in the final multivariable multinomial logistic regression model as shown in Table 3. Differences between cooperatives were observed. The odds of farmers being aware of the TPC milk quality parameter but did not know its value were 2.2 times (95% CI: 1.04–4.46) higher when they belonged to cooperative V compared with farmers that belonged to cooperative I. Farmers belonging to cooperative II, IV, and V were 4.3 (95% CI: 1.36–13.63), 12.9 (95% CI: 1.63–101.34), and 9.5 (95% CI: 2.23–40.69) times, respectively, more aware and also knew the TPC value compared with farmers belonging to cooperative I. Furthermore, farmers living 0.5 to 2.0 km from their neighboring farmers were less aware and knew the TPC value (OR = 0.3; 95% CI: 0.16–0.70) compared with farmers living close (<0.5 km) to their neighboring farmers. Farmers that adopted many (index score >20) technologies were 4.4 (95% CI: 2.58–7.58; not knowing the TPC value) and 6.0 (95% CI: 2.65–13.45; knowing the TPC value) times more aware about TPC than farmers having a low technology uptake (index score <18). Those that moderately adopted new technologies (index score 18–20) were 2.6 (95% CI: 1.64–4.16) and 2.4 (95% CI: 1.09–5.14; knowing the TPC value) times more aware. When TPC was the most important quality factor for the buyer, farmers were 20.7 (95% CI: 9.81–43.56; know the value) and 6.2 (95% CI: 3.7–10.26; not knowing value) times more aware about TPC than farmers where the buyer considered other quality factors more important. When



**Figure 1.** Indonesian smallholder farmer awareness of total plate count (TPC), SCC, TS, fat content (FC), and milk density (MD).

farmers were not visited by the cooperative in the last 12 mo to receive information to improve their milk production, they were 3.0 (95% CI: 1.50–5.83) times more aware but did not know the value compared with farmers that were visited more than 2 times. Finally, farmers that were visited 1 to 2 times in the last 12 mo by their veterinarian were 3.3 (95% CI: 1.39–7.95) times more aware about TPC and knew the value compared with farmers that were attended more than 2 times.

### Factors Associated with SCC Awareness

In Table 4, the results of the final multivariable Firth-type logistic regression model are presented, showing 3 factors significantly associated with dairy farmer awareness of SCC. These factors were cooperative, dairy business experience, and milk quality test adoption. The odds for being aware of SCC were 5.5 (95% CI: 1.75–17.09) times higher when farmers belonged to cooperative III and 3.6 (95% CI: 1.27–9.97) times higher when they belonged to cooperative V, in comparison to farmers belonging to cooperative II. The odds for being aware of SCC were 11.6 (95% CI: 2.73–49.43) times higher for farmers with a dairy business experience above 23 years category compared with those farmers who had less than 14 yr of dairy business experience. The odds for farmers to be aware of SCC were 5.2 (95% CI: 2.16–12.25) times higher when they were aware of the milk quality test but did not adopt it

when being compared with those farmers that were not aware of the milk quality test.

## DISCUSSION

Milk quality and animal health awareness is generally of a higher standard in larger commercial dairy farms compared with smallholder dairy farms (Mosalagae et al., 2011). This study confirmed that the level of awareness of milk quality parameters was generally low among smallholder farmers. Moreover, awareness of milk quality parameters was not uniform. The share of farmers aware of TPC, TS, fat content, and milk density were higher than the proportion of farmers that were aware of SCC. This was expected because SCC is not included in the determinants of the milk quality payment schemes of the milk collection points and cooperatives included in our study, whereas other milk quality parameters are included. Most of the smallholder dairy farmers are thus likely aware of milk quality parameters due to buyers' (cooperative and processors) demands and regulations (Nyokabi et al., 2021). Awareness of the problems that can be caused by poor udder health leads to the intention to improve udder health management (Mekonnen et al., 2017). Financial incentives also lead to a change in milk quality as observed for TPC and SCC (Nightingale et al., 2008; Botaro et al., 2013). Regarding SCC, or udder health in general, poor udder health is associated with financial losses, which may be

**Table 3.** Overview of the significant variables in the final multivariable multinomial logistic regression model associated with the awareness of the total plate count (TPC) of 600 Indonesian smallholder dairy farmers

Variable and category	Aware and do not know TPC value vs. not aware			Aware and know TPC value vs. not aware			Overall <i>P</i> -value <sup>1</sup>
	Odds ratio	95% CI	Wald <i>P</i> -value	Odds ratio	95%CI	Wald <i>P</i> -value	
Cooperative							0.02
I	Referent			Referent			
II	1.2	0.71–1.95	0.52	4.3	1.36–13.63	0.01	
III	1.3	0.67–2.48	0.45	1.9	0.42–8.58	0.41	
IV	1.2	0.34–4.30	0.77	12.9	1.63–101.34	0.02	
V	2.2	1.04–4.46	0.04	9.5	2.23–40.69	0.002	
Distance to neighbor dairy farmer (km)							0.04
<0.5	Referent			Referent			
>0.5–2	0.9	0.55–1.41	0.6	0.3	0.16–0.70	0.004	
>2	0.8	0.49–1.38	0.46	0.6	0.29–1.39	0.25	
Technology adoption index							<0.001
Score <18	Referent			Referent			
Score 18–20	2.6	1.64–4.16	<0.001	2.4	1.09–5.14	0.03	
Score >20	4.4	2.58–7.58	<0.001	6	2.65–13.45	<0.001	
Total plate count as the most important quality factors for the buyer							<0.001
No	Referent			Referent			
Yes	6.2	3.70–10.26	<0.001	20.7	9.81–43.56	<0.001	
Receive milk production information from cooperatives (no. of visits)							<0.001
>2	Referent			Referent			
1–2	1.6	0.75–3.19	0.24	0.4	0.15–1.03	0.06	
0	3	1.50–5.83	0.002	0.7	0.30–1.59	0.38	
Receive cow's health information from veterinarians (no. of visits)							0.03
>2	Referent			Referent			
1–2	1	0.50–1.84	0.89	3.3	1.39–7.95	0.01	
0	1.3	0.77–2.34	0.3	1.8	0.77–3.94	0.18	

<sup>1</sup>*P*-value based on the  $-2$  Log-likelihood ratio test.

relatively large on smallholder farms (Getaneh et al., 2017; Mekonnen et al., 2019). This means that training programs and awareness campaigns in combination with incentive programs will likely result in a behavioral change of smallholder dairy farmers and subsequently in an improved milk quality. This is fully in-line with

studies in larger commercial dairy farms (e.g., Sargeant et al., 1998; Lam et al., 2017; De Vries et al., 2020). As the largest milk producing countries in the world are dominated by smallholder dairies, such programs need to be adapted to the local circumstances and should include farmer knowledge and characteristics about milk

**Table 4.** Overview of the significant variables in the final multivariable Firth-type logistic regression model associated with SCC awareness of 600 Indonesian smallholder dairy farmers

Factor and category	Odds ratio	95% CI	Wald <i>P</i> -value	Overall <i>P</i> -value <sup>1</sup>
Cooperative				0.03
II	Referent			
I	1.8	0.49–6.81	0.38	
III	5.5	1.75–17.09	0.003	
IV	0.8	0.04–15.41	0.88	
V	3.6	1.27–9.97	0.02	
Dairy business experience (yr)				<0.001
<14	Referent			
14–23	4.2	0.95–18.26	0.06	
>23	11.6	2.73–49.43	0.001	
Milk quality test adoption				<0.001
Not aware	Referent			
Aware, not adopt	5.2	2.16–12.25	<0.001	
Aware and adopt	1.3	0.06–29.32	0.87	

<sup>1</sup>*P*-value based on the  $-2$  Log-likelihood ratio test.

quality adoption practices (Nyokabi et al., 2021). The identified factors associated with awareness of TPC and SCC as identified in this study will be helpful to develop such programs.

The cooperative to which farmers belonged was the only variable that was associated with a higher level of awareness of both TPC and SCC. This indicates that cooperatives play an important role in increasing farmer awareness of milk quality parameters through their programs. Cooperatives are the main buyers of dairy farmers' milk in West Java and some have milk quality parameters included in their payment scheme. When TPC was the most important factor for their buyer it was associated with a higher awareness of the same parameter. Hence, cooperatives are likely the essential players in improving milk quality on smallholder dairy farms. Extension programs should, therefore, be developed and delivered in close collaboration with the farmers' cooperative. As cooperatives are locally organized, aware of the regional opportunities and limitations, and aware of the expectations of milk processors, this is both logical and valuable in developing extension programs. However, the criteria for cooperatives to be included in this study may have excluded cooperatives that had different characteristics and priority programs, potentially limiting the generalizability of the study's findings. Farmers belonging to the here-studied cooperatives are not believed to be different in their milk quality awareness compared with farmers belonging to other cooperatives though because they may have a shared understanding and knowledge about milk quality through the Indonesian Dairy Cooperatives Association (Gabungan Koperasi Susu Indonesia).

Not surprisingly, technology adoption was a strong predictor of awareness of TPC because a good maintenance of milking equipment, hygiene in storing milk, and access to cooling conditions to keep milk at low temperature are important reasons for a low TPC (Özkan Gülzari et al., 2020; Akzar et al., 2022). Temperature control is one of the critical and essential factors for achieving a high hygienic quality of raw milk (Nada et al., 2012).

Some of the variables on knowledge transfer were significantly associated with farmers awareness of TPC, including receiving information from cooperatives to increase milk production and dairy health information from the veterinarian. Surprisingly, this study revealed that the odds of farmers being aware of TPC (but did not know the value for their milk) was lower when they received 2 or more visits from their cooperatives to increase milk production compared with having fewer and no visits. Because causal relationships cannot be identified with the applied cross-sectional study design, it may be possible that the better performing farm-

ers regarding TPC do not need additional information on milk production, whereas the farms with a poorer TPC status may need the additional information. Additionally, the identified association indicates that education programs should also focus on improving milk quality rather than having a more singular focus on increasing milk production. A similar kind of reasoning might apply for the variable describing the reception of information on cow health from the veterinarian. An increased consciousness among dairy farmers regarding the relation between milk production, milk quality and animal health through extension programs must be a priority of cooperatives (Groot and van't Hooft, 2016). Education programs do play an important role in addition to financial incentives. Examples of activities that can raise farmer awareness of milk quality and animal health include the offering of consulting services to individual farmers that aim to improve their knowledge, recognizing farmers who have well-performing herd, and developing mass media communication campaigns about the importance of specific management practices and technologies (Lam et al., 2017; van den Borne et al., 2017).

As only 14% of farmers were aware of SCC as a milk quality parameter and only 0.5% knew the actual SCC value of the milk they were selling, much needs to be done to improve smallholders' capacity (e.g., knowledge and understanding) of how to improve udder health and milk quality. Again, the cooperative appears to be critical in driving awareness of the importance of SCC. Interestingly, 1 of the cooperatives associated with higher awareness of SCC was also associated with a higher awareness of TPC (cooperative V), while the second cooperative associated with a higher SCC awareness (cooperative III) was not associated with a higher TPC awareness. Further investigation into the processes and programs of these 2 cooperatives may be helpful in designing future programs to improve udder health. The regression model for SCC awareness also revealed that milk quality test awareness and adoption of these tests had higher odds for being aware of SCC compared with not being aware of milk quality tests. The awareness of SCC among farmers is expected to result in the uptake of these tests. Relatively simple milk quality tests, such as the California Mastitis Test, are available worldwide and can be used on smallholder dairy farms to improve udder health. Finally, the years of dairy business experience turned out to be an important predictor of SCC awareness. Farmers having more experience in farming are more aware of SCC and probably have experienced the issues and problems associated with high SCC and poor udder health. It appears valuable to include senior dairy farmers in the development and delivery of udder health programs. Such experienced individuals

may be able to convince their younger colleagues of the importance of udder health when operating a successful dairy farm. The observation in the TPC model that a close distance (<0.5 km) to neighboring farms was associated with both a higher awareness and knowledge of TPC values would confirm the importance of farmer-to-farmer communication. Dairy farmers' mindset, awareness, and behavior on animal health management can be affected by communication strategies (Jansen and Lam, 2012), in which communication to peers is not only effective but also highly valued (Lam et al., 2011; Tschopp et al., 2015).

Our survey represents the 2017 situation in West Java dairy herds. Since then, 2 major changes have occurred in the Indonesia dairy industry. First, a larger research project was conducted between 2017 and 2021 to improve milk supply, including the quality and hygiene in West Java smallholder dairy through training and extension programs and quality-based incentives. As a result, mastitis and milk quality management of the farms improved. For example, the adoption of postmilking teat disinfection and mastitis testing was 31 and 23% higher among program beneficiaries compared with nonbeneficiaries (Hetherington et al., 2023). Second, 2 transboundary and highly infectious diseases have emerged in Indonesia in 2022, resulting in major outbreaks. The diseases included foot-and-mouth disease and lumpy skin disease outbreaks have occurred. The outbreak of foot-and-mouth disease virus has caused many animal deaths and both outbreaks resulted in significant production losses, culminating in a large social-economic impact for the farmers (Sutawi et al., 2023). These changes make the survey less representative of the current situation but the study results are still helpful in improving the dairy production and milk quality.

It is imperative that much work is done to continuously improve milk quality worldwide. This is particularly true for low- and middle-income countries, such as Indonesia, that are dominated by smallholder dairies. Milk production in countries dominated by smallholder dairies is among the highest in the world in terms of total kilograms, therefore, focusing development activities on improving milk quality and addressing udder health issues in these countries will have a truly global impact. We would argue that collaborations between international dairy and veterinary experts with experts knowledgeable on educational programs and economics of local dairy production would be crucial in the successful implementation of such programs. Further work in this field is important to be able to provide a continuously growing worldwide population with healthy dairy products.

## CONCLUSIONS

The aim of this study was to gain insight in the awareness of smallholder dairy farmers in milk quality parameters and its associated factors. This study revealed that the level of knowledge and awareness of Indonesian smallholder dairy farmers on milk quality parameters was low. Furthermore, some of the evaluated variables, including cooperative identification number, distance to neighbor dairy farmer, technology adoption index, TPC as the most important quality factors for the buyer, receiving milk production information from cooperatives, and receiving cow's health information from a veterinarian, were significantly associated with dairy farmers awareness of TPC. Although the cooperative to which the farmer belonged, dairy business experience, and milk quality test adoption significantly contributed to dairy farmer awareness of SCC. Cooperatives thus play an important role in increasing Indonesian smallholder farmer awareness of milk quality parameters through their programs. They are locally organized and aware of the regional opportunities, limitations, and expectations of milk processors. The study's findings may be applicable to other regions of the world where milk production is also dominated by smallholder dairy farmers and where cooperatives play a similar role in the dairy value chain.

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