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Farm management and economic factors associated with bulk tank total bacterial count in Holstein dairy herds in Iran

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Research Article

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Abstract

The objectives of this research were (1) to study different factors affecting milk total bacterial count (TBC) and (2) to estimate the economic value associated with TBC in Holstein dairy herds in Iran. The relationships between bulk tank TBC and farm management and economic factors were examined on 56 randomly selected intensive dairy farms. Herd management factors associated with bulk tank TBC were determined using mixed linear models. The median bulk tank TBC for the sample herds was 299 (range 81–1185) × 10^3 cfu/ml. The average economic premium opportunity from bulk tank TBC was US$ 1.32 per ton of milk ranging from US$ 0.02 per ton of milk for herds applying wet tissue procedures as teat cleaning material and washing the water troughs three times per day to US$ 5.20 per ton of milk for herds with dirty barns. Results showed that the following management factors were associated with low TBC and high economic value: frequency of cleaning water troughs, teat cleaning material, the frequency of milk delivery to the processor, bedding material, herd size, education level of workers, udder washing material, material of milking parlor wall, frequency of disinfection of the calving area, presence of veterinarian, water quality control, having a hospital pen and barn hygiene. In conclusion, our findings highlight the need to pay more attention to farm management issues, particularly farm hygiene practices to reduce milk TBC and so reduce the economic burden of TBC in dairy herds in Iran.

Milk provides an excellent growth environment for microorganisms, and their propagation in milk leads to spoilage, decreased nutritional value, altered sensory and physicochemical properties of milk and increased risk of foodborne diseases (Claeys *et al*., 2013; Boor *et al*., 2017; Porcellato *et al*., 2018). The hygienic profile, characterized by contamination levels and distributions of microorganisms, is a critical parameter of raw milk quality (Zucali *et al*., 2011). Total bacterial count (TBC) has been used as an index of microbial quality of milk for over 100 years because of its direct correlation to spoilage (Boor *et al*., 2017). High TBC milk should be avoided since some bacteria (*Staphylococcus aureus, Escherichia coli,* and *Streptococcus agalactiae*) found in raw milk can cause diarrheal disease and food poisoning (Gilmour and Rowe, 1990). A high TBC may also be related to mastitis, environmental contamination, dirty milking equipment or refrigeration failure (Blowey and Edmondson, 1995). Jayarao *et al*. (2004) showed that herd size and farm management practices influenced bacterial counts in bulk tank milk. Furthermore, Magnusson *et al*. (2007) reported that the bedding material may promote spore transmission to the udder and then to raw milk. Kelly *et al*. (2009) reported that the use of heated water in the milking parlor and participation in a milk recording scheme were associated with low TBC in herds. According to the regulations in Iran, the maximum allowable TBC in raw milk is 300 × 10^3 cfu/ml. European Union regulations dictate that the bacterial count of milk must not go beyond the average value of 100 × 10^3 cfu/ml over two months with at least two tests per month. Quality premiums targeted at reducing TBC have had a strong influence on milk quality in a number of countries. For some countries, including Iran, the effects of high TBC on milk quality and other dairy products might not yet be well-appreciated by farmers.

Farmers are often not aware of the positive economic impacts of reducing the TBC. To ensure an impact at the farm level, there is a strong case to provide farmers with the information that would enable them to reduce the TBC burden. In most studies, the impact of different factors on the production and composition of milk under a range of management conditions has been noted (Jayarao *et al*., 2004; Magnusson *et al*., 2007; Kelly *et al*., 2009). However, to date, there is little information on the economic impact of a high TBC in raw milk in herds in Iran. The principle objective of this study was to develop a bio-economic model to analyze the impact of farm factors on TBC, to assess the potential benefits and then provide the information to farmers to help them realize new marketing opportunities should they be able to reduce the TBC in their raw milk. For these purposes, the study is based on the following two hypotheses:

Hypothesis 1: That bulk tank TBC on Holstein dairy farms is independent of routine farm management practices

Hypothesis 2: That a reduction in milk TBC has no economic benefit for dairy farmers.

Materials and methods

Sampling procedure and experimental design

Data were obtained in cooperation with one of the major milk processors of Iran's dairy industry, Kalleh Dairy Company (Amol, Iran). The processor provided data on milk volume and bulk tank TBC on a collection basis from January 2016 to December 2017, including a total of 23 694 observations. Milk was collected from the farms at a frequency of one to four days. The TBC of milk was measured by flow cytometry technology (Murphy *et al.*, 2016), with a BactoScan machine (Foss Electric, Hillerød, Denmark) at the Solico Kalleh Central Laboratory. At first, a total of 100 herds were chosen randomly, with the percentage selected from each stratum being weighted by the frequency of herds within strata relative to the sample population. These farms were invited to participate in a questionnaire survey, and 56 of them decided to participate. The farms were visited and a face-to-face interview conducted and the questionnaire completed. The questionnaires covered a range of management factors and included questions about the condition, hygiene practices, level of development of the farms and also factors (based on the literature and knowledge of farming practices) that might be expected to impact milk quality. The data were managed in Microsoft Excel (2013). Due to the nature of the TBC data, a logarithmic transformation was used to normalize these data.

Statistical analyses

Statistical procedures were conducted using SAS/STAT 9.4 (SAS Institute Inc. Software License 9.4, 2013). The distribution of management practices across herds was determined using the frequency procedure (PROC FREQ). The following mixed linear model (PROC MIXED) with class statements for management factor, province, year, and the season and herd as a random effect were used to study the effect of TBC on milk yield under various management factors:

$$y_{\mathrm{ijklm}} = \mu + \mathrm{Prov_j} + \mathrm{Year_k} + \mathrm{Season_l} + \mathrm{MF_m} + (\mathrm{Year} \times \mathrm{Season})_{\mathrm{kl}} + (\mathrm{Year} \times \mathrm{MF})_{\mathrm{km}} + (\mathrm{Season} \times \mathrm{MF})_{\mathrm{lm}} + (\mathrm{Year} \times \mathrm{Season} \times \mathrm{MF})_{\mathrm{klm}} + \mathrm{Herd_i} + e_{\mathrm{ijklm}} \quad (1)$$

where y_{ijklm} = logarithm of TBC ijklm; μ = the overall mean; $\mathrm{Prov_j}$ = the fixed effect of province j; $\mathrm{Year_k}$ = the fixed effect of year k; $\mathrm{Season_l}$ = the fixed effect of season l; $\mathrm{MF_m}$ = the fixed effect management factor m; $(\mathrm{Year} \times \mathrm{Season})_{\mathrm{kl}}$ = the interaction between year k and season l; $(\mathrm{Year} \times \mathrm{MF})_{\mathrm{km}}$ = the interaction between year k and management factor m; $(\mathrm{Season} \times \mathrm{MF})_{\mathrm{lm}}$ = interaction between season l and management factor m; $(\mathrm{Year} \times \mathrm{Season} \times \mathrm{MF})_{\mathrm{klm}}$ = the interaction between year k, season l, and management factor m; $\mathrm{Herd_i}$ = the random effect of herd i; e_{ijkl} = the random residual effect with mean 0 and homogenous variance σ^2. In all statistical analyses, least-squares means were calculated and significance was declared at $P < 0.05$ and trends at $P \geq 0.10$. The Shapiro–Wilk test showed that the logarithm of bulk tank TBC and residuals were normally distributed.

Economic calculations

Currently, the milk pricing system in Iran is based on a price per kilogram of base milk and a differential premium based on milk fat and protein content. The premium/penalty system for TBC of milk determined by Iran Dairy Industry (IDI) to encourage farmers to improve milk quality, is based on the following categories with a differential from the base milk price (+2%, 0%, −1%, −2%, and −5% respectively) as follows: (1) $<300 \times 10^3$ cfu/ml, (2) 300 to 500×10^3 cfu/ml, (3) 500 to 1000×10^3 cfu/ml, (4) 1000 to 2000×10^3 cfu/ml, and (5) $>2000 \times 10^3$ cfu/ml. Thus, the premium in 2017 for milk with a TBC of $<300 \times 10^3$ cfu/ml was US$ 6.20 per tonne on a raw milk price of US$0.31 per kg (1000 kg × 0.31 × 2% = US$ 6.20 per tonne). Similarly, a penalty of US$ 15.50 per ton was set when the TBC of milk exceeded 2 million cfu/ml (economic calculations are in US dollars at an exchange rate of 1 US$ = 42 000 Rial IRR).

For the economic analysis, the bulk tank TBC was categorized into groups of 50×10^3 cfu/ml to 3 million cfu/ml. As noted above, logarithmic transformation was used to normalize TBC. The value of US$ 6.20 per ton of milk premium was applied for a TBC of 50 to 300×10^3 cfu/ml. A penalty of – US$ 15.50 per ton was applied for a TBC of $>2000 \times 10^3$ cfu/ml. To achieve the best method for economic analysis of bulk tank TBC, the second-order regression equation was fitted as follows:

$$Y = -39.488\ \mathrm{X}^2 + 152.88\ \mathrm{X}\text{-}121.64\ (R^2 = 0.893)$$

where Y represents the premium and penalty of TBC, and X is the least-squares means corrected for each management factor as described in the statistical analysis section. This equation has been chosen due to the simplicity and magnitude of its coefficient of determination; premium and penalty for TBC were calculated for each management factor based on this equation.

Based on the frequency of TBC classes of milk tanks and the amount of premium and penalties considered for each qualitative milk class in terms of health, Economic Premium Opportunity (EPO) was calculated for each herd individually. Calculation of the EPO from TBC per kilogram of milk was as follows:

$$\mathrm{EPO\,(US\ /ton\ of\ milk)} = [\mathrm{Maximum\ TBC\ premium\ payment\ (US\ 6.20) - EPE\ (US\ /\ ton\ of\ milk)}]$$

where EPE is the economic premium earned calculated as percentage differential premium multiplied by US$ 1000 × 0.31 kg of milk (raw milk price).

Results

The variation associated with on-farm factors was studied using data from the questionnaire. Across the 56 study herds, the

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mean and median TBC were $325 \times 10^3$and 299×10^3 cfu/ml (range $81–1185 \times 10^3$ cfu/ml), respectively (online Supplementary Table S1). A number of factors were associated with TBC namely the province ($P < 0.05$) and the year, season, and interactions between them and each of them with management factors ($P < 0.01$). The 3-way interactions among year, season and management factors were also significant ($P < 0.01$). As can be seen in Table 1, farms with ≥500 adult cows had lower TBC than farms with ≤500 adult cows ($P < 0.01$), therefore, these larger herds received a higher economic premium. Thirteen (23%) herds with sand bedding had lower TBC and received a higher premium than herds with bedding of dried manure, straw, or combined ($P < 0.01$). The results indicated that farms that used an on-farm veterinarian had lower TBC and received a higher premium from dairy company than those where the veterinarian visited regularly. The farms with ≥500 cows that delivered milk multiple times per day had lesser TBC than those who delivered milk on less than a daily basis ($P < 0.05$). Farms performing water quality control (microbial and chemical) during a year had a lower TBC and received significantly greater ($P < 0.05$) premiums, compared to the other farms. Cleaning water troughs as often as three times a day resulted in low TBC and a higher premium ($P < 0.05$). The farms with clean barns had the lowest TBC ($P < 0.01$) compared with those that were relatively dirty (with higher coliforms). The results of this study showed there was no significant difference for the switch trimming factor in the reduction of milk TBC. Most farms (75%) used warm water to wash udders and had higher TBC than herds using wet paper towels (Table 1). Among teat cleaning materials, the use of a wet paper towel had the highest positive effect on the reduction of milk TBC. Through the use of this method, most farms could increase their premium opportunities from dairy companies ($P < 0.01$). Also, some factors such as the education level of workers and material of milking parlor wall (tiles) had a significant ($P < 0.01$) positive effect on TBC. Finally, two factors, a hospital pen and disinfection of calving area once a day had a significant effect ($P < 0.05$) on TBC and premiums (Table 1).

Discussion

The objective of this study was to determine the association between improved herd management practices and the quality of milk in terms of TBC. In the dairy industry, milk production and milk quality are of paramount importance. Therefore, it is necessary to observe the herd management factors associated with milk quality. Because of the framework of the study, it should be noted that the relationships reported do not indicate cause and effect relationships and should not be interpreted as such. In larger herds, the total bacterial count was low. In large farms, consultants and veterinarians are usually employed to advise on management practices and system design. Therefore, increased farmer knowledge about the production system was likely associated with lower TBC found in larger herds. This is consistent with the findings of Van Schaik *et al.* (2002), who found that milk samples from larger herds had a lower bacterial count in comparison to milk obtained from smaller herds. Miller *et al.* (2015) also found that lower mesophilic spore count accompanied a larger herd size. Depending on the nutrients in bedding materials, a range of microorganisms can be observed, consequently, the total bacterial count of the herds on different types of bedding materials also varies (Zdanowicz *et al.*, 2004). Bacterial counts in inorganic bedding are typically lower than the organic ones, depending on the bacterial strain and the type of material (Fairchild *et al.*, 1982). The results of this study showed that herds which used sand as bedding for cows had the lowest TBC. As reported by Zdanowicz *et al.* (2004), when cows were bedded on sawdust, the number of coliforms and Klebsiella spp. on the teats was greater than the number of *Streptococcus* spp. when the cows were on the sand bed. The results of this study indicated that farms which employed on-farm veterinarians showed a lower herd TBC. In addition to timely diagnosis and treatment of veterinary diseases, the presence of an on-farm veterinarian can lead to better health management and positively influence TBC reduction in herds. Farms that delivered milk to the company multiple times per day had the lowest TBC. Storing raw milk under refrigeration for a long time at the dairy farm and its delivery to the processor can create an environment suitable for the growth of microorganisms and increase the TBC of milk (Silva *et al.*, 2015). For example, a Brazilian study recommended a maximum storage time of up to 24 h (Silva *et al.*, 2015). Nonetheless, O'Connell *et al.* (2017) indicated that milk could be stored for up to 96 h at temperatures between 2° and 6°C with a negligible effect on its composition or properties.

Water itself can be a source of contaminated bacteria, so water used in any part of the milking procedure must be of good quality (O'Brien, 2008). Our results have shown that water quality control was associated with a decrease in the herd TBC. Water hardness refers to the calcium carbonate ($CaCO_3$) content, which is known to have a negative effect on disinfection. Furthermore, it causes mineral sediments on surfaces and biofilm formation (Gleeson *et al.*, 2013). Providing good quality water is essential for producing quality milk. Water used in washing equipment must be as clean and healthy as drinking water (Bekuma and Galmessa, 2018). Bacterial contaminants in cow water troughs may be generated from various sources. Cows may contaminate the water troughs with cud or fecal material and peripheral materials such as dust, feed, or bedding (LeJeune *et al.*, 2001). Based on our results, increasing the frequency of cleaning of water troughs was associated with lower TBC. A cleaning program (three times a day) that seeks to prevent algae and microbial growth is important.

The hygiene in the cow's environment is critical in the production of high-quality milk (Bartlett *et al.*, 1992; Bekuma and Galmessa, 2018). Kelly *et al.* (2009) reported that long tail-hair can transmit contamination from the cow's body to the teat, thus cows' tails should always be clipped. They found that switch trimming effectively reduced TBC if done more than once a year. However, the present study did not show any significant relationship between switch trimming and a decrease in TBC.

Pre-milking udder washing with warm water procedure affected TBC adversely compared with the use of a wet paper towel. These findings agree with those of Elmoslemany *et al.* (2009) who found that the use of water for pre-milking udder preparation caused an increase in the total aerobic bacteria count. Koster *et al.* 2006 showed that water fluxing along the udder can transmit bacteria to the teat and as a result increase the risk of milk contamination. According to Murphy *et al.* (2005), teat preparation is one of the critical factors impacting TBC. Various methods of teat cleaning have been evaluated to determine their effect on the presence of spores in milk. Rowe *et al.* (2019) suggested that cloth udder towels may act as a fomite for non-aureus *Staphylococcus* spp. (NAS) and *Streptococcus* spp. or *Streptococcus*-like organisms (SSLO). They recommended that laundered towels be completely dried in a hot air dryer. Burtscher *et al.* (2023) showed that the use of disposable cleaning materials

Table 1. Least-squares means of factors associated with total bacterial count and estimated economic premium opportunity on 56 dairy farms in Iran

Management variables	Herd (%)	LTBC (TBC)[1]	EPO[2]	SE[3]	*P*-value
Herd size (adult cows)					0.0008
<200	30	2.36 (231)[a]	1.7	0.04	
200–500	34	2.22 (165)[a]	0.7	0.08	
500–1000	7	2.11 (128)[b]	0.2	0.08	
>1000	11	2.13 (136)[b]	0.3	0.06	
Bedding material					0.0009
Sand	23	2.10 (125)[c]	0.2	0.06	
Dried manure	30	2.25 (180)[b]	0.9	0.06	
Straw	6	2.56 (364)[a]	3.6	0.12	
Combined[4]	41	2.32 (209)[ab]	1.3	0.05	
Presence of veterinarian					0.0703
On-farm	76	2.19 (156)[a]	0.5	0.04	
Visiting regularly	24	2.31 (203)[b]	1.2	0.06	
Milk delivery to the processor					0.02
Once a day	9	2.22 (166)[ab]	0.7	0.11	
Multiple times per day	7	2.05 (112)[b]	0.1	0.11	
Multiple times per week (Less than daily)	84	2.36 (232)[a]	1.6	0.03	
Water quality control (interventions)					0.05
Less than a year	48	2.24 (172)[b]	0.8	0.04	
More than a year	34	2.38 (240)[a]	1.8	0.05	
Never done	18	2.33 (212)[a]	1.4	0.07	
Frequency of cleaning water troughs					0.02
After each milking time	13	2.32 (208)[a]	1.3	0.08	
Once a week	37	2.38 (242)[a]	1.8	0.05	
Whenever needed	34	2.28 (192)[a]	1.1	0.05	
Three times a day	16	2.04 (110)[b]	0.02	0.1	
Barn hygiene					0.001
Clean	84	2.28 (192)[b]	1.1	0.03	
Relatively dirty	14	2.52 (327)[a]	3.1	0.08	
Dirty	2	2.69 (487)[a]	5.2	0.19	
Switch trimming					0.37
Less than a year	61	2.29 (193)[a]	1.1	0.04	
More than a year	33	2.35 (224)[a]	1.6	0.07	
Never done	6	2.45 (280)[a]	2.4	0.11	
Udder washing material[5]					0.001
Warm water	75	2.37 (234)[a]	1.7	0.04	
Wet tissue	25	2.15 (140)[b]	0.3	0.06	
Teat cleaning material[6]					0.0007
Tissue paper	37	2.34 (219)[a]	1.5	0.05	
Straw paper	18	2.30 (199)[a]	1.2	0.07	
Washable towel	14	2.34 (219)[a]	1.5	0.07	
No cleaning	20	2.34 (219)[a]	1.5	0.06	
Wet tissue	11	2.05 (111)[b]	0.02	0.08	

(*Continued*)

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Table 1. (*Continued.*)

Management variables	Herd (%)	LTBC (TBC)[1]	EPO[2]	SE[3]	*P*-value
Having a hospital pen					0.03
Yes	59	2.25 (178)[a]	0.9	0.04	
No	41	2.38 (239)[b]	1.8	0.05	
Frequency of calving area disinfection					0.03
Once a day	34	2.18 (152)[b]	0.5	0.05	
Twice a week	15	2.41 (259)[a]	2.1	0.07	
Once a week	34	2.33 (216)[a]	1.4	0.05	
Once a month	11	2.41 (260)[a]	2.1	0.08	
Never	6	2.37 (237)[a]	1.7	0.13	
Education level of workers					0.007
Illiterate	47	2.40 (249)[a]	1.9	0.05	
Elementary education	27	2.27 (184)[ab]	0.9	0.06	
Secondary education	13	2.13 (136)[b]	0.3	0.08	
Diploma and higher	7	2.28 (190)[a]	1	0.10	
Different levels of education	6	2.30 (199)[a]	1.2	0.14	
Material of milking parlor wall					0.005
Cement	49	2.33 (215)[a]	1.4	0.04	
Tile	44	2.17 (148)[b]	0.4	0.04	
Two types of materials	7	2.44 (276)[a]	2.3	0.11	

[1]LTBC, log10 (TBC) (TBC = total bacterial count, TBC (× 10^3/ml)); [2] Economic premium opportunity from total bacterial count US$ per ton of milk;[3] SE, standard error; [4] Dried manure combined with sawdust or sand or straw; [5] Conducted before cluster attachment; [6] All materials were disposable (except washable towel), single-use, and dry before use; [a,b,c,d] Means in a column with the same letter are not significantly different ($P < 0.05$).

resulted in lower spore counts of Clostridial butyric acid producers than cleaning with reusable towels. Also, our results showed that using tissue paper and washable towels is not recommended for teat cleaning. The optimum, in this case, is to use wet tissue and specifically; the best choice was to use straw paper for drying in post-milking.

This study revealed that lower TBC was found in herds with hospital pens. Therefore, the existence of a hospital in the farm is beneficial, presumably as it enables more timely treatment of animals. Increasing the frequency of disinfection of the calving area had a positive impact on reduction in TBC ($P < 0.05$). However, as Kelly *et al.* (2009) reported, the number of calving area disinfections was not significant in decreasing bacterial count. Paying attention to hygiene, in general, can reduce the risk of environmental pathogens exposure at the cubicles and calving parlor, and thus prevent the transmission of these contagious pathogens to milk during milking (Barkema *et al.*, 1998).

Higher levels of education of workers were associated with a lower TBC of herds. The farms with illiterate workers had higher TBC than farms employing literate workers (elementary, secondary, diploma and higher education). However, there was no pattern between increasing education and TBC reduction among other farms with literate workers of different educational levels. The lining material of the milking parlor is important. Our results suggested that tiles are the best type of material to decrease TBC, possibly as tiles are easier to keep clean and non-porous material.

A total of 14 herd management practices including 48 levels of health were studied, as shown in Table 1. Only two management factors (straw bedding, dirty barns) were associated with higher TBC and so these provided the greatest opportunity for an economic premium by reducing TBC (Table 1). The production systems that used dirty barns had the greatest opportunity to improve returns At the same time, the lowest EPO (US$) belonged to the systems in which the water troughs were washed three times a day and wet tissue was used for teat cleaning ($0.02) per kg of milk. It should be noted that an EPO close to zero indicates that the practice almost reached the highest standard. With the assessed EPO, farmers can only identify which processes provide the greatest opportunity for improvement, although it is important to recognize that achieving a better level could take different amount of effort and investment. Therefore, furthermore economic analysis is needed for each practice to identify the top priority in terms of cost-effectiveness.

The TBC threshold of 300 000 cfu/ml of milk is high by international standards. It limits the country's dairy industry as the international legal constraints for TBC are usually lower than this. As determined by European law (EEC, 1992, Council Directive 92/46/EEC), in the case of at least two tests per month, the maximum total bacterial count is not legally permitted to surpass a geometric average of 100 000 per ml over two months.

A total of twenty-eight of the study farms had EPO < $ 2.2 per metric ton of milk, twenty-three farms had US$ 2.2 < EPO < US$ 4.7 per metric ton of milk whilst the others had EPO > US$ 4.7 per metric ton of milk, as shown in Fig. 1. Among study herds, only one farm had the lowest economic premium opportunity (EPO = 0) because the farm could not reduce the TBC (less than 300 000 cfu/ml), hence, they already earned the highest

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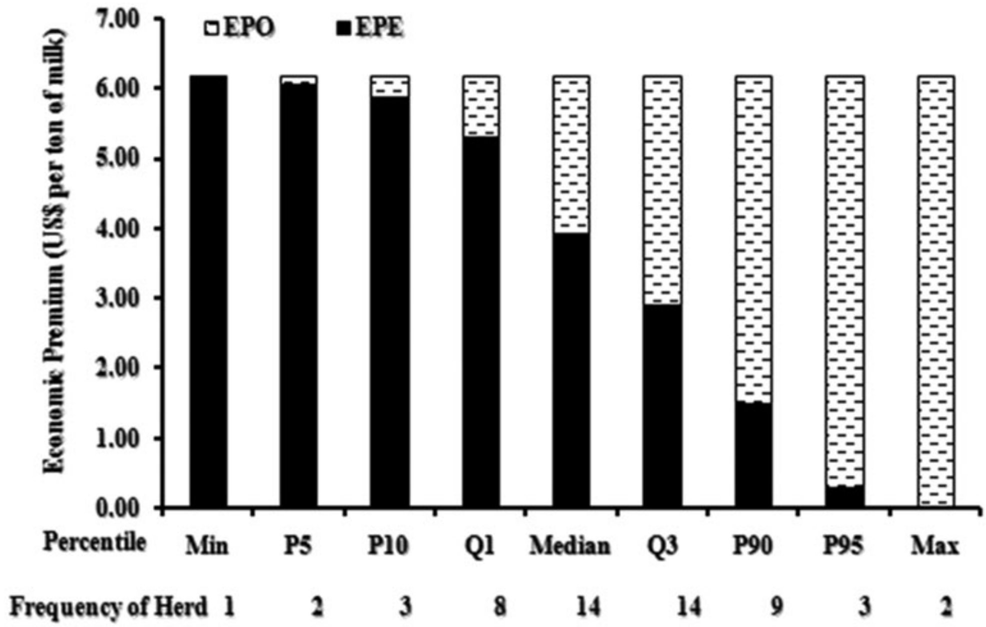

Figure 1. Economic premium opportunity (US$) and economic premium earned (US$) from total bacterial count per metric ton of milk on Iran dairy farms. Min, the minimum; P5, P10, P90, P90 and P95, 5th, 10th, 90th and 95th percentiles, respectively; Q1 and Q3, the lower and upper quintiles; Max, the maximum.

Table 2. Characteristics and management practices of farms with minimum and maximum economic premium opportunity for Total Bacterial Count (TBC) on 56 dairy farms in Iran

Management factors	Minimum economic premium opportunity	Maximum economic premium opportunity
Herd size (adult cows)	2200	30
Bedding material	Sand	Combined
Presence of veterinarians	On-farm	Part-time
Frequency of milk delivery	More than once a day	More than once a day
Water quality control	Less than a year	More than a year
Frequency of cleaning water troughs	Three times a day	Once a week
barn hygiene	Clean	Clean
Udder washing material	Wet tissue	Warm water
Teat cleaning material	Wet tissue	Tissue paper
Having a hospital pen	Yes	No
Frequency of calving area disinfection	Once a day	Twice a week
Education level of workers	Secondary education	Illiterate
Material of milking parlor wall	Tile	Tile

economic premium payment (US$6.20 per metric ton of milk) by adopting the most appropriate management practices and observing health factors. However, there were two farms at the highest level of TBC which had the greatest EPO.

Characteristics and management practices of farms with minimum and maximum economic premium opportunity for TBC are presented in Table 2. These farms were similar in their barn hygiene, frequency of milk delivery and material of milking parlor wall. The major differences between farms with minimum and maximum economic premium opportunity for TBC were in herd size (2200 *v.* 30 head), bedding material (sand *v.* combined), presence of veterinarian (on-farm *v.* part-time), water quality control (less than a year *v.* more than a year), frequency of cleaning water troughs (three times a day *v.* once a week), udder washing material (wet tissue *v.* warm water), teat cleaning material (wet tissue *v.* tissue paper), having a hospital pen (yes *v.* no), frequency of calving area disinfection (once a day *v.* twice a week) and education level of workers (secondary education *v.* illiterate).

To conclude, recognizing that bacterial count of milk is one of the chief factors impacting milk pricing and directly influences milk sales revenue for farmers, we attempted to provide an insight for dairy producers on economic premium opportunities associated with TBC under different management practices. The median bulk tank TBC and the average economic premium opportunity for the sample herds were 299×10^3 cfu/ml and US

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$ 1.32 per ton of milk, respectively. There were multiple management practices that were associated with low TBC and high economic bonus that provide important information that can be applied in dairy farming routines in Iran to improve the hygienic quality of raw milk.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0022029923000547

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