Preventive Veterinary Medicine 124 (2016) 9–14

Contents lists available at ScienceDirect

Preventive Veterinary Medicine

journal homepage: www.elsevier.com/locate/prevetmed

Milk production, quality, and consumption in Jimma (Ethiopia): Facts and producers', retailers', and consumers' perspectives

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ARTICLE INFO

Article history:
Received 3 August 2015
Received in revised form
18 December 2015
Accepted 22 December 2015

Keywords:
Dairy farming
Ethiopia
Jimma
Milk consumption
Milk quality
Staphylococcus aureus

ABSTRACT

Four studies were performed to quantify milk production, quality and consumption in the town Jimma, Ethiopia. First, 47 dairy farmers and 44 milk retailers were interviewed to gain more insights in dairy farming and marketing, and associated constraints. Second, bulk milk samples ($n = 188$) were collected for 4 consecutive weeks to investigate milk quality [Total Bacterial Counts (TBC), Coliform Counts (CC), Somatic Cell Counts (SCC), and antimicrobial residues]. Third, (bulk) milk samples from 32 farms, 46 milk retailers and the 3 local milk collection centers were collected to determine the presence of oxacillin susceptible–and oxacillin resistant *Staphylococcus aureus*. Fourth, 208 adult inhabitants were interviewed to gain more insight in milk consumption and associated concerns of consumers. The average dairy farm included in the studies consisted of 5 lactating cows, produced 43 liters of milk per day and was owned by male, literate adults. Milk was sold to retailers (71% of the production) and directly to customers (25%) without any quality control, whereas 4% was self-consumed. Shortage of animal nutrition and adulteration of the milk were the main constraints for farmers and retailers, respectively. The median TBC, CC and SCC were 122,500 CFU/mL, 1,005 CFU/mL and 609,500 cells/mL, respectively. Antimicrobial residues were detected in 20% of all samples. In general, the milk quality was considered to be poor (TBC > 10,000 CFU/mL, and/or CC > 100 CFU/mL, and/or SCC > 400,000 cells/mL and/or presence of antimicrobial residues) in 97% of all samples. *S. aureus* was isolated from 12 (38%), 13 (33%), and 2 out of 3 of the milk samples originating from the dairy farms, the milk retailers, and the milk collection centers, respectively. Seven (26%) of the isolates were resistant to oxacillin suggesting the presence of MRSA (Lee, 2003). Local milk is occasionally consumed by adults but more frequently by children. Adults mainly drink spontaneously fermented milk (57% of 105 interviewees consuming local milk) whereas most milk for children is boiled (86% of 110 households with children consuming local milk). Most consumers are concerned about adulteration and milk borne diseases but not about antimicrobial residues. Educated consumers (secondary school or higher) were more likely to boil milk for own consumption, to be concerned about antimicrobial residues in milk, to be concerned about milk borne diseases and to be willing to pay more for milk with proven good quality compared to poorly educated consumers.

We conclude that milk quality incentives should be introduced in Jimma, and investments should be made in knowledge transfer, training, milk collection systems and a central milk quality lab.

1. Introduction

The demand for milk in cities of developing countries increases due to population growth and urbanization (Narrod et al., 2011). In response, smallholder dairy farms are mushrooming in e.g. Jimma and other Ethiopian towns (Mekonnen et al., 2006). Typically, Holstein–Zebu crossbreed dairy cows are milked with limited or no access to pasture (Tolosa et al., 2013). The smallholders are responsible for 98% of the milk produced. The milk flow and supply chain in Ethiopia is quite complex and in many cases still immature in terms of capacity, organization and infrastructure (Yilma et al., 2011). Only a limited proportion of the milk is bought and sold by the 3 local milk collection centers that have been established by the dairy cooperatives in Jimma in 2011. Most the milk is directly sold

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http://dx.doi.org/10.1016/j.prevetmed.2015.12.016
0167-5877/

to retailers and/or consumers, most often in producer-owned milk shops.

Intramammary infections (IMI) lead to an increase in somatic cell count (SCC), (in) directly affecting milk shelf-life and components (Ma et al., 2000). High-quality milk has a low SCC and bacteria count, and is free of foodborne pathogens and antimicrobial residues (Oliver et al., 2009). Although milk has a high nutritional value (Gaucheron, 2011), it constitutes a good growth medium for bacteria of which some are pathogenic for humans (Jayarao and Henning, 2001). Bacteria in milk originate from shedding cows with IMI, unclean milking practices or improper milk handling (Hayes et al., 2001; Zadoks et al., 2004). Among other pathogens in milk, *Staphylococcus aureus* can cause severe disease in humans, and is difficult to treat in case of the presence of antimicrobial resistance (Xu et al., 2014). Accurate information on milk quality in Jimma and the whole of Ethiopia is scarce.

Western consumers are highly concerned about the quality of milk and other animal products (Aumaître, 1999; Noordhuizen and Metz, 2005). Whether consumers in African cities such as Jimma share this concern is largely unknown. The risk of milkborne diseases does not only depend on microbiological characteristics but also on milk processing before consumption (Lejeune and Rajala-Schultz, 2009). In Ethiopia, milk is often not pasteurized but consumed after spontaneous fermentation at the household level (Gonfa et al., 2001). Spontaneous fermentation helps in extending the storage life of the milk. During the spontaneous fermentation, the lactic acid bacteria present in the raw milk convert the lactose into lactic acid, lowering the pH of the milk and thus resulting in a reduced bacterial count. Some of the lactic acid bacteria also produce bacteriocins that inhibit the growth of disease-causing pathogens (Gillor et al., 2008). Yet, the frequency and type of milk consumed by adults and children, being more susceptible to milk borne diseases, is unknown in cities such as Jimma.

The objectives of this research were to characterize dairy farming and marketing, to study milk quality, to detect the presence of (oxacillin resistant) *S. aureus* in raw (bulk) milk and to quantify milk consumption in Jimma, Ethiopia.

2. Materials and methods

2.1. Study area

Jimma is a medium-sized town with approximately 140,000 inhabitants located in Oromia Regional State, Jimma Zone, 352 km South-West of the capital, Addis Ababa in Ethiopia. Jimma has an altitude of about 1780 m above the sea level and an annual rainfall ranging from 1400 to 1900 mm. Temperature varies between 6 °C and 31 °C (Alemu et al., 2011). The area is mainly known for its coffee production but crop and livestock production are important agricultural activities as well.

2.2. Questionnaire on dairy farming, milk production and marketing

As (dairy) farmers and retailers are not registered in Ethiopia, their exact total number is unknown, also in Jimma. Yet, 47 smallholder dairy farmers and 44 milk retailers were selected based on their willingness to cooperate, encompassing a large majority of those present in Jimma (total number estimated at 60). All were interviewed face-to-face by the first author between July and August 2009. Closed and open questions were asked to gain more insight in dairy farming and marketing, and associated constraints (Table 1).

In all 47 herds, different types of antimicrobials were used to treat sick animal against different infectious diseases including mastitis. With a cow level prevalence of clinical and subclinical mastitis of 11 and 62%, respectively, and a blind quarter prevalence of 6%, mastitis is one of the most common infectious diseases for which antimicrobials are used (Tolosa et al., 2013; Tolosa et al., 2015). All except from one herd used Lactaclox® (i.e., a combination of ampicillin and loxacillin) for the intramammary treatment of mastitis. Sixteen (34%), 13 (28%), 10 (21%), and 8 (17%) herds used Lactaclox® and oxytetracycline, Lactaclox®, Lactaclox®,oxytetracycline and penicillin–streptomycin, and Lactaclox® and penicillin–streptomycin, respectively. On 54% of the herds, antimicrobials and other drugs used for the treatment of diseases were prescribed and administered by a veterinarian on the herd, on 24% of the participating herds sick animals were treated at a veterinary clinic in the neighbourhood and 22% of the farmers treated their animals themselves based on their own experiences. Animals suffering from clinical mastitis are treated for a maximum of 3 consecutive days. No precise information was available on the treatment strategies applied for other diseases than mastitis.

2.3. Longitudinal study on milk quality

Bulk milk samples of the aforementioned dairy farms were aseptically collected once a week for four consecutive times between December 2009 and January 2010. For the enumeration of TBC and CC, serial dilutions (10^{-1},10^{-2}, 10^{-3} and 10^{-4}) were plated on Petrifilm Aerobic Count Plates (3 M, Saint Paul, MN, US) and Petrifilm Coliform Count Plates (3 M, Saint Paul, MN, US) according to the manufacturer's instructions. After 24 h of incubation at 37 °C, plates were read using a semi-automated colony counter (Stuart, Bibby Sterilin, Stone, UK). The SCC was measured with a DeLaval Direct Cell Counter (DeLaval, Tumba, Sweden). The Copan Milk Test (Copan Italia, Brescia, Italy) was used to determine the presence or absence of antimicrobial residues in the milk samples according to the manufacturer's instructions.

Table 1
Questions asked to 47 dairy farmers and 46 milk retailers on dairy farming and marketing in Jimma (Ethiopia) using a face-to-face questionnaire.

Farmers/retailers	Question
Farmers	Age (in years) Gender (male/female) Education (elementary school or lower/secondary school or higher) Herd size (number of lactating animals) Total daily milk production in liters Proportion of milk for own consumption, sold directly to customers and sold to milk retailers
Both	Average selling price of milk per liter in Birr Concerns about antimicrobial residues (yes/no) Concerns about milk quality (yes/no) Interest in the establishment of a central milk quality laboratory (yes/no) Main constraint (open question)

2.4. Cross-sectional study on Staphylococcus aureus occurrence and oxacillin resistance

Additional bulk milk samples were aseptically collected between October 2012 and May 2013 to determine the occurrence of oxacillin resistant and susceptible *S. aureus*. Besides 32 of the aforementioned 47 dairy farms (conveniently selected), samples were collected at 46 milk retailers and the 3 milk collection centers established in Jimma in 2011. Ten μL of milk was plated on blood-esculin agar and incubated aerobically for 24–48 h at 35 °C (National Mastitis and Council, 1999). Round colonies with hemolysis were transferred to a new plate. They were identified as *S. aureus* or other bacteria based on Gram-staining, a catalase test, growth on mannitol salt agar, a DNase test, a coagulase test and polymyxin susceptibility. Subsequently, Oxacillin Resistance Screening Agar Base (ORSAB, Oxoid, Basingstoke, England) was used to test for oxacillin resistance (Simor et al., 2001).

2.5. Questionnaire on milk consumption and associated concerns of consumers

A total of 208 adult inhabitants of Jimma were interviewed using closed questions (Table 2) on milk consumption, using systemic sampling at every 10th house in the main, secondary and tertiary roads in Jimma. The sample size was estimated using the following formula (Dohoo et al., 2003): $n = Z_{\alpha}^2/2pq/L^2 = \frac{1.96\square\times0.50\times0.50}{0.1^2} = 96$ with n being the number of consumers needed to estimate the concern for milk quality (a major research question), $Z\alpha_{/2}$ being the 95th percentile of a standard normal distribution, p being *a priori* estimate of the proportion of consumers concerned about milk quality intuitively set at 0.5, q being 1–p, and L being the margin of error set at 0.1. As half of the inhabitants were expected to regularly buy milk, the number of interviewees was doubled. Age of the interviewee was recorded.

2.6. Statistical analysis

Descriptive statistics were calculated using Microsoft Excel 2010 (Microsoft Corporation, Redmond, Washington, USA). Because TBC and CC were not normally distributed, the median, interquartile range (IQR) and number of measurements above thresholds as suggested by Jayarao et al. (2004) were calculated.

Associations between educational level of the consumer (secondary school or higher vs. elementary school or lower) and answers to the questions on milk consumption were analysed with SAS 9.4 (SAS Institute Inc., NC, USA). Because of low frequencies in some cells, exact logistic regression models were fit. Answers to the questions "How often do you(r children) drink local milk?" were categorized as daily or weekly vs. less often and "How do you(r children) drink local milk?" as boiled vs. raw or fermented. Odds ratio's (OR) and 95% confidence intervals (CI) of the significant associations are reported.

3. Results

3.1. Questionnaire on dairy farming, milk production and marketing

The interviewed dairy farmers were on average 45 years old (range 15–68). Thirty-five (74%) were male and 30 (64%) finished secondary school. Average herd size was 5 lactating cows (range 1–23), producing on average 43 liters of milk per day (range 9–203) on herd level. Four% of the produced milk was self-consumed, 71% was sold to milk retailers, and 25% was sold directly to customers. In 2011, the Jimma town dairy cooperative established 3 milk collection centers that are currently buying and selling a limited proportion of the produced milk. The milk collection centers test sourness and adulteration of milk using an alcohol test and a lactometer. Quality of milk sold to retailers or directly to customers is, however, not tested in Jimma. Farmers received an average of 6.1 Ethiopian Birr (1 Ethiopian Birr = 0.05 $) per liter (range 4–8) whereas the milk retailers charged 12.7 Ethiopian Birr per liter (range 8–21). Forty-four (94%) of the farmers were concerned about the presence of antimicrobial residues in milk whereas only 8 (18%) of the milk retailers were. All dairy farmers and 41 (93%) milk retailers were concerned about the milk quality and all were interested in the establishment of a central milk quality lab. Low demand of milk during fasting (30%), shortage of animal nutrition (23%) and low milk price (15%) were the main constraints for the dairy farmers whereas adulteration and poor quality of supplied milk (23 and 20%, respectively) were the main constraints for the milk retailers (Table 3).

3.2. Longitudinal study on milk quality

The median TBC, CC and SCC were 122,500 CFU/mL (IQR 12,700–2,850,000), 1,005 CFU/mL (IQR 0–22,750) and 609,500 cells/mL (range 300,000–1,003,000), respectively. Antimicrobial residues were detected in 38 samples (20%) and on 26 farms (55%). The milk quality was considered to be poor (TBC > 10,000 CFU/mL and/or CC > 100 CFU/mL and/or SCC > 400,000 cells/mL and/or antimicrobial residues) in 182 of the total number of samples (97%). The proportion of herds with 0, 1, 2, 3 or 4 milk samples exceeding milk quality thresholds are presented in Table 4.

3.3. Cross-sectional study on Staphylococcus aureus occurrence and oxacillin resistance

S. aureus was isolated from 12 (38%) of the milk samples taken from the dairy farms, 13 (33%) of the samples taken at the milk retailers and 2 of the 3 samples taken from the milk collection centers. Seven (26%) of the isolates were resistant to oxacillin (3 from dairy farms and 4 from retailers).

3.4. Questionnaire on milk consumption and associated concerns of consumers

The interviewees were on average 37 years old (range 18–80). Eighty-two (39%) were male and 148 (71%) finished secondary school. Of the 105 interviewees consuming local milk daily or weekly, 11, 57 and 31% mainly consumed raw, fermented and boiled milk, respectively. Of the 145 interviewees having children below the age of 10, 110 gave local milk to their children daily or weekly. In 4, 11 and 86% of the households, children mainly consumed raw, fermented and boiled milk, respectively. Of the 150 interviewees drinking milk daily or weekly and/or having children below age 10 drinking milk daily or weekly, 87, 16, 84 and 76% were concerned about milk quality, antimicrobial residues, adulteration and milk borne diseases, respectively. Eighty-nine% would pay more for milk with proven good quality (Table 2). Educated consumers (secondary school or higher) were more likely to boil milk for their own consumption [OR with 95% CI: 6.91 (1.51–64.27)], to be concerned about antimicrobial residues in the milk [OR: 9.15 (1.37–389.33)], to be concerned about milk borne diseases [OR:5.87 (2.40–14.73)] and to be willing to pay more for milk with proven good quality [OR:14.39 (4.01–65.94)] compared to poorly educated consumers (Table 5).

4. Discussion

Four studies were performed to gain more insights in dairy farming and milk quality in Jimma (Ethiopia). Unfortunately, as farms are not registered and the total number of dairy farms in Jimma is unknown, we cannot be sure the sample is fully representative. Yet, we believe a large majority of farmers has been included.

The majority of farmers in Jimma is literate, male elders. Although dairy herds are relatively small, employees milk the cows rather than the owners (Tolosa et al., 2013). The milk chain in Jimma is decentralized with limited to no quality control, which is clearly reflected in the milk quality results. Surprisingly, most farmers but few retailers declared to be concerned about antimicrobial residues. Yet, milk adulteration and poor milk quality were identified as the main constraints faced by retailers demonstrating the need for more milk quality control in Jimma. On-farm testing of the milk composition via a lactometer or measuring the freezing point via a cryoscope before the milk is sold to the retailers and/or customers would certainly lower the prevalence of adulteration though is at this moment not realistic due to a lack of infrastructure and resources.

Milk quality was found to be very poor in Jimma. The high TBC and CC suggest unhygienic practice around milking whereas implementation of hygienic measurements such as proper cleaning and disinfection of the milk containers and cooling throughout the milk chain could help to improve the milk quality (Bonfoh et al., 2006). The availability of a range of high quality branded pre-milking and post-milking teat dips would make a significant difference. Also, some farmers do have electricity which could be used to run a small bulk milk tank, though these are the exceptions. Some try to keep the milk cool after milking by placing the milk bucket or churn in water in an attempt to ensure the milk does not spoil.

Table 2
Closed questions asked to 208 adults on milk consumption in Jimma (Ethiopia) using a face-to-face questionnaire and their answers.

Question	Answer	*n*	% (95% CI[a])
Gender	Male	82	39 (33–46)
	Female	126	61 (54–67)
Education	Elementary school or lower	60	29 (23–35)
	Secondary school or higher	148	71 (65–77)
How often do you drink local milk?	Daily	29	14 (9–19)
	Weekly	76	37 (30–43)
	Less often	103	50 (43–57)
How do you drink milk?[b]	Raw	12	11 (5–18)
	Fermented	60	57 (48–67)
	Boiled	33	31 (23–40)
How often do your children drink local milk?[c]	Daily	80	55 (47–63)
	Weekly	30	21 (14–27)
	Less often	35	24 (17–31)
How do your children drink milk?[d]	Raw	4	4 (0–8)
	Fermented	11	11 (5–17)
	Boiled	95	86 (80–93)
Are you concerned about milk quality?[e]	Yes	130	87 (81–92)
	No	20	13 (8–19)
Are you concerned about antimicrobial residues?[e]	Yes	24	16 (10–22)
	No	126	84 (78–90)
Are you concerned about adulteration? [e]	Yes	126	84 (78–90)
	No	24	16 (10–22)
Are you concerned about milk borne diseases? [e]	Yes	114	76 (69–83)
	No	36	24 (17–31)
Would you pay more for milk with proven good quality? [e]	Yes	133	89 (84–94)
	No	17	11 (6–16)

[a]95% confidence interval;
[b]Recorded for adults drinking milk daily or weekly.
[c]Recorded for adults having children below age 10 ($n = 145$).
[d]Recorded for adults having children below age 10 drinking milk daily or weekly ($n = 110$).
[e]Recorded for adults drinking milk daily or weekly and/or having children below age 10 drinking milk daily or weekly ($n = 150$).

Table 3
Main constraints faced by 47 dairy farmers and 44 milk retailers in Jimma (Ethiopia) as mentioned during a face-to-face interview (open question).

Constraints	Dairy farmers	Milk retailers
No constraints	13 (28%)[a]	12 (27%)
Low demand for milk during fasting	14 (30%)	4 (14%)
Shortage of animal nutrition	11 (23%)	–
Low milk price	7 (15%)	–
Adulteration of supplied milk	–	10 (23%)
Poor quality of supplied milk	–	9 (20%)
Shortage of milk supply	–	3 (7%)
Other constraints	2 (4%)	4 (9%)

[a]% between brackets indicates proportion of farmers and retailers, respectively.

Table 4
Bulk milk quality of 47 dairy farms in Jimma (Ethiopia) measured in 4 consecutive samples (188 samples).

Quality parameter	Threshold	Samples > threshold (%)	% herds with 0, 1, 2, 3 or 4 samples > threshold				
			0	1	2	3	4
Total bacterial count	5,000 CFU/mL	165 (88)	0	0	6	36	57
	10,000 CFU/mL	145 (77)	0	4	21	36	38
Coliform count	50 CFU/mL	133 (71)	0	19	19	21	40
	100 CFU/mL	132 (70)	0	19	19	23	38
Somatic cell count	200,000 cells/mL	159 (85)	0	4	11	28	57
	400,000 cells/mL	120 (64)	4	19	21	28	28
Antimicrobial residues	Detected	38 (20)	45	32	21	2	0
Medium–poor quality milk	Combination[a]	184 (98)	0	0	0	9	91
Poor quality milk	Combination[b]	182 (97)	0	0	0	13	87

[a]Total bacterial count > 5,000 CFU/mL, coliform count > 50 CFU/mL, somatic cell count > 200,000 cells/mL or antimicrobial residues detected.
[b]Total bacterial count > 10,000 CFU/mL, coliform count > 100 CFU/mL, somatic cell count > 400,000 cells/mL or antimicrobial residues detected.

Table 5
Associations between level of education and answers on closed questions asked to 208 adults on milk consumption in Jimma (Ethiopia) using a face-to-face questionnaire.

Question	Percentage		OR (95% CI)[a]
	Low education[b]	High education[c]	
Boiling of milk before consumption[d]	8	39	6.91 (1.51-64.27)
Concerned about antimicrobial residues[e]	3	20	9.15 (1.37-389.33)
Concerned about milk borne diseases[e]	49	85	5.87 (2.40-14.73)
Willing to pay more for milk with proven good quality[e]	65	96	14.39 (4.02-65.94)

[a]Odds ratio with 95% confidence interval.
[b]Elementary school or lower.
[c]Secondary school or higher.
[d]Recorded for 24 lowly educated and 80 highly educated adults drinking milk daily or weekly.
[e]Recorded for 37 lowly educated and 113 highly educated adults drinking milk daily or weekly and/or having children below age 10 drinking milk daily or weekly.

Of course, particularly in the heat of the summer this is less likely to be successful in keeping the bacterial growth low enough. The high SCC is in accordance with the previously reported high prevalence of subclinical mastitis in Jimma (Tolosa et al., 2013 and 2015). Although, most farmers declared to be concerned about antimicrobial residues, 20% of the bulk milk samples and more than half of the farms tested positive indicating many farmers do not respect withdrawal times, or are not aware of the concept. As the Copan Milk Test has a low sensitivity for certain antimicrobials (Le Breton et al., 2007) and farmers were aware of the sampling taking place, the actual occurrence of antimicrobial residues might be even higher. Routine antimicrobial testing of the milk is not realistic due to costs and time. The often small volumes of milk do generally not add up the economics of carrying out such antimicrobial residue tests. Still, the risk of residue failures can be drastically minimized by a good identification and marking of all treated cows before treatment is administered, by the use of a standardized treatment protocol, and by milking all treated cows last or separately. Providing a written guide on how to avoid antimicrobial residues in the milk on every dairy farm could be a first step towards a lower number of residue failures. The availability of a range of licensed veterinary medicinal products could also make it easier to predict and respect the correct withdrawal period and thus to reduce the number of residue failures.

Most retailers bought milk from one specific farm, most likely explaining why the occurrence of *S. aureus* differed little between samples from farms (38%) and retailers (33%). A similar occurrence of *S. aureus* (43.5%) was reported in smallholder dairy farms in Debre Zeit, close to the Ethiopian capital (Makita et al., 2012). A relatively high proportion of isolates was resistant to oxacillin suggesting the presence of MRSA (Lee, 2003). Detection of enterotoxin and resistance genes could increase our knowledge on the risk of food poisoning and resistance mechanisms (Silveira-Filho et al., 2014) and remain to be studied.

Children consume milk more often than adults. Most but not all interviewees declared to boil milk prior to giving it to children. Given the high bacterial load in the milk and the high susceptibility of children to milk borne diseases (American Academy of Pediatrics, 2014), consumption of raw milk should be discouraged in Jimma. Many adults drink spontaneously fermented milk. Yet, under laboratory conditions, pathogens such as *Listeria monocytogenes* and *Escherichia coli* O157:H7 survived spontaneous fermentation (Ashenafi, 1994; Tsegaye and Ashenafi, 2005). The prevalence of the latter pathogens in spontaneously fermented milk might be high but remains to be studied.

Very low concentrations of antibiotics can select for antimicrobial resistance (Huttner et al., 2013), being a threat for global health (Gullberg et al., 2011). Similar to the retailers, few of the consumers were concerned about antimicrobial residues. However, the high concern about milk adulteration and milk borne diseases indicate the need for more milk quality control. As many consumers were willing to pay more for milk with proven high quality, producers could benefit from more milk quality control. Differences with highly educated consumers indicate a lack of knowledge on the risks associated with antimicrobial residues and milk borne diseases in poorly educated consumers.

5. Conclusions

Jimma has a decentralized milk chain with limited to no quality control. Milk quality was very poor in all 47 sampled farms. *S. aureus* was frequently isolated with many strains showing oxacillin resistance suggesting the presence of MRSA. The majority of the adults drink unpasteurized milk whereas most but not all children drink pasteurized milk. Consumers are concerned about adulteration and milk borne diseases but not about antimicrobial residues. Based on the results, milk quality incentives should be introduced in Jimma

and efforts should be put in awareness programs for farmers and consumers.

Conflict of interests statement

No conflict of interest exists for any of the authors.

Acknowledgements

This study was financed by the Institutional University Cooperation project IUC-JU of the Flemish Interuniversity Council (VLIR-UOS). We would like to thank the dairy farmers in Jimma town for their cooperation during the study period and Lars Hulpio for his excellent technical backup.

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