A participant - led programme for field veterinary training to identify bacteriological quality of milk from the farmer to the retail outlet.

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Abstract

The training of field veterinarians in veterinary public health needs an in-depth understanding of the *in-situ* problems, social and economic barriers that prevent problem solving and a relevant pedagogical approach to suit the mature learner. A participatory approach is necessary to develop such training. A course designed on the principles of adult learning theory and utilizing the experience of the field veterinarian's local knowledge combined with the expertise of the training provider can be very effective. Forty-eight field veterinarians were trained using a collaborative, participatory approach to understand the issues in clean milk production in Sri Lanka. The veterinarians developed a Hazard Analysis Critical Control Point-based decision framework to identify and evaluate the evidence of bacterial contamination points in the milk chain from the farm to the processing plant. Samples and swabs were collected for bacterial culture and results showed high bacterial counts that showed contamination of milk starting from the farm, through milk collection and chilling centers ending with $2 \times 10^6 – 3 \times 10^7$ bacteria per ml of milk. Chemical and physical hazards were also identified. Lack of appropriate hygienic procedures, chilling at the

farm and at the collection center, together with the delays at the chilling center was identified as main contributing factors for high bacterial counts. This problem-based training approach facilitated collaborative inquiry, experiential learning and critical analytical skills. The training enabled the veterinarians to understand the scale of the problem and how they can intervene directly and indirectly to ensure clean milk production in Sri Lanka.

1. Introduction

With the advent of continuous professional development (CPD) of veterinarians in food safety and public health, new questions about training approaches have arisen. What are good pedagogical approaches to train field veterinarians in public health? A field veterinarian may have an understanding of the local context in public health and what the issues are. But they may lack the skills, knowledge and confidence in developing an effective problem-solving pathway to address the issues. The trainers who develop CPD for field veterinarians are often university based educators and researchers and they often lack the same in-depth understanding of *in-situ* issues. They are, however, well placed to develop the confidence and skills in field veterinarians to construct their own knowledge that can influence practice (Scales et al 2011).

Constructing own knowledge is considered an effective approach to learning (Vygotsky 1978). Learning is considered to be an active process, where what the student does is more important than what the teacher does (Biggs 1999). The field veterinarian therefore must process information actively, building on experience and existing knowledge to develop outcomes that are relevant. The trainer's, or the facilitator's, task is to guide the field veterinarian by providing a relevant framework and the environment to achieve this. However it should also be acknowledged that veterinarians, teachers and researchers could learn from each other based on knowledge developed from previous experiences. In the trainer and trainee relationship, the field veterinarians should have a participatory role in the *in-situ* identification of the problem, developing a problem solving pathway, collecting evidence and using the data to indicate how the problem can be solved (Baum, MacDougall & Smith 2006).

In tropical countries, food safety is an area that is beset with problems: particularly in the supply of dairy products to the consumer within the dairy sector (Aaku et al 2004; Kurwijila et al 2006; Uddin 2013). The inherent problem of warmer climates, lack of good infrastructure for transport, issues related to refrigeration and unhygienic practices of stakeholders in the milk chain are all contributing to this massive problem. The milk chain starting from cow's udder to the milk processing plant is inundated with many contamination points. Among the plethora of factors in addition to mastitis, lack of hygienic practices during milking, poorly disinfected milking utensils and use of low quality water, are key factors in determining the microbiological quality of bulk milk at the farm-level (Bonfoh et al 2006, Gran et al 2002). Milk, as the starting point in the dairy production chain is a nutritious food commodity: not only for humans and animals but also to a vast array of bacteria that can rapidly multiply in milk at high ambient temperatures and a neutral pH.

The microbiological quality of milk (in terms of the presence of bacteria) has direct influences on consumer safety and shelf life of milk products. On the one hand the presence of pathogenic bacteria in milk transfers milk borne zoonotic diseases (Evans et al 1996; Ayele et al 2004; Arimi et al 2005) and on the other hand high bacterial counts affect the physical and chemical quality of milk, in turn affecting milk products (MUIR 1996; Barbano, Ma & Santos 2006; Deshapriya & Silva 2006). Considering these facts, safety standards for raw milk have been imposed in some countries. The basic hygienic requirement for raw milk in the European Union (EU) is $\leq$. $1x10^{5}$ cfu/ml bacteria (Hillerton & Berry 2004). However, as illustrated in Table 1, in tropical countries, the bacterial counts identified in raw milk are far above this EU standard.

Table 1: Total bacterial counts of raw milk at the farm level in some tropical countries

Country	Standard plate count Number (CFU/ml)	Reference
Burkino Faso	1×10^7	Millogo et al 2010
India (Odisha)	5×10^8	Mini & Behera 2012
India (Madurai)	6×10^5	Lingathurai et al 2009
Malaysia	12×10^6	Chye, Abdullah & Ayobet 2004
Mali	5×10^6	Bonfoh et al 2003

Sri Lanka, is a tropical country with high environmental temperatures, a lack of immediate cooling facilities for milk at farm level and an already existing high prevalence of clinical and subclinical mastitis in dairy herds (Gunawardana et al 2014). Sri Lanka therefore faces difficulties in maintaining good hygienic standards of milk. Scant and scattered data available on milk hygiene have indicated poor quality of raw milk with high bacterial counts and its influence for product quality in the Sri Lankan market (Deshapriya, Silva et al. 2006, Ubeyratne, Jayaweera et al. 2014)(Deshapriya & Silva 2006; Ubeyratne, Jayaweera & Mangalika 2014).

The estimated milk production in Sri Lanka for the year 2013 was 320 million liters accounting for 41% of the total milk requirement of the country (Anonymous 2014). Many small-scale dairy farms contribute to milk production in the country and milk from these farms is collected by a number of different milk collecting networks. Generally, hand milking is practiced and the dairy farmer transports collected milk to a collecting center. The dairy processors transport milk from the collecting centers to the processing plant. Therefore, there are many stakeholders contributing to the hygienic quality of milk in Sri Lanka. Out of these stakeholders, field veterinary officers bear the highest responsibility and authority in improving the quality of milk at farm level. Training them on dairy quality assurance systems is therefore suggested to be a valuable exercise.

Hazard analysis critical control point (HACCP) is a well-developed systematic approach to the identification, evaluation and control of hazards (whether biological, physical or chemical) in a particular food operation system (Van Schothorst 1998). It is well accepted that quality assurance system such as HACCP can improve microbiological quality of milk and milk products (Ruegg, 2003, Lievaart et al 2005, Nada et al 2012). Developing a HACCP decision tree with key control and critical control points has to be done *in-situ* with detailed consideration and understanding of the local processes (Boccas et al 2001; Roberto, Brandão & da Silva 2006). It is likely that some veterinarians do not have the theoretical knowledge regarding HACCP or have never used this approach in their field practice. It is necessary to identify the physical, chemical (Singh & Gandhi 2015) and microbiological (Noterman, Zwietering & Mead 1994) hazards in the milk chain and the field veterinarians with their knowledge and experience of local situation and practices are best situated to develop such a HACCP plan. The CPD training providers on the other hand are competent in delivering the theoretical basis of HACCP and can guide the field veterinarians to develop a HACCP decision tree to enhance quality of milk and milk products to the consumer.

Overall this is anticipated to lead to an active approach to learning, problem solving and a participant-led CPD programme that encourages engagement with longer lasting impact. The aim of the current project was to develop the participant-led CPD for field veterinarians so that they would develop skills in critical thinking and become proficient in evidence collection for decision making to address local public health issues.

2. Materials and Methods

2.1 Course participants

A total of 48 field veterinarians working for the Department of animal Production and Health in nine provinces were recruited as participants. They were nominated by their provincial directors and represented a cross section of field veterinarians in Sri Lanka. Two workshops, each of four-day duration, were conducted with 24 participants per group.

2.2 The training programme

The training programme was designed as a face to face short course. To update theoretical knowledge, the course consisted of lectures, practical sessions and field training. The lectures were designed to explore problems associated with clean milk production in Sri Lanka, HACCP principles and application in the farm to the processing plant, milk testing and quality assurance in the UK (for comparison). Laboratory practicals were conducted to ensure that the veterinarians understand the routine milk testing at the collection points in Sri Lanka. Practicals included demonstration of milk sample collection and processing for bacteriology and checking for chemical hazards such as adulterants that are commonly added to milk. The tests included sugar, salt, starch, glucose, neutralizers, urea, formaldehyde and hydrogen peroxide. The practicals were mainly considered as a refresher activity as the participants have conducted these practicals in their undergraduate study programme.

The training programme was underpinned by a participatory action research approach (Baum et al 2006). The two researchers designed the training programme to enable the field veterinarians to explore the issues in clean milk production from the farm to the processing plant. The programme was intended to expand and update the theoretical knowledge required to address food safety issues in the milk chain. The pedagogy included adult learning theory to utilise participants existing knowledge and experience to foster self-directed learning (Knowles 1975), collaborative learning (Dillenbourg, 1999) and critical analysis for problem solving (Albanese and Dast 2010). The veterinarians worked in collaborative teams to develop a HACCP based decision tree. In summary, the participants themselves developed the training programme in an iterative manner through the identification of critical control points.

2.3 Developing the HACCP plan

At the end of the lecture sessions on the first day, the participants discussed their experiences and developed a preliminary HACCP based plan to collect evidence regarding milk contamination, from the farm to the retail outlets. In order to achieve this the participants agreed to verify contamination via bacteriology and which samples to collect. The objective was to expand the HACCP plan during and after the fieldwork. Guided by the facilitators, the participants developed the fieldwork to follow the milk chain.

2.4 Bacteriological data collection

The HACCP plan was focused on the identification of bacteriological and physical contamination points only. Based on the HACCP plan the participants collected samples for bacteriological counts. Milk (5 ml) was collected into sterile universal glass bottles and surface swabs were taken (1cm^2 surfaces) from milk containers at different points of the milk chain. All the samples were transported to laboratory under refrigerated conditions immediately after collection and the technician from the bacteriology lab cultured the samples for bacteriological analysis. A surface swab was mixed with 1 ml of buffered peptone water and considered as undiluted sample.
It was not possible to obtain milk samples:

1. From the chiller tank to measure temperature of chilled milk
2. Immediately after pasteurization due to safety protocols at the plant. It was therefore decided to take samples from pasteurized milk held at retail outlets.

Milk samples were also collected from retail outlets for bacteriology.

Total viable bacterial counts were determined by pour plate method. Each sample was serially diluted in buffered peptone water (Oxoid, UK) in triplicate and cultured in standard plate count agar (Oxoid, UK) and incubated at 30^0C for 48 hrs (SLS standard method). End of the incubation, plates containing colonies between 30-300 were counted and mean of the triplicate was noted to obtain total aerobic mesophilic bacterial count per ml of sample.

Table 2: The schedule of the 4-day training course

Day 1	Lectures on HACCP, practicals, developing the HACCP plan
Day 2	Following the milk chain from the farm, milk collection centre, milk chilling centre and taking samples and swabs for bacteriology, identification of physical contaminants, taking photographs, discussion and evaluating the HACCP plan
Day 3	Visiting the milk processing plant and retail outlets
Day 4	Collating the bacteriological data, analysing the HACCP plan, discussion on critical control points and developing an action plan

3. Results:

3.1 Tracking the milk chain and identification of contamination points

The starting points were small backyard farms before milking started in the early morning. The participants asked questions from the farmer to identify the milking practices and investigate milk contamination points. After milking was completed, the veterinarians followed the farmer to the milk collection point to observe the next stage of the process. The participants then followed the collected bulk milk to a chilling center and finally to the processing plant. Throughout this process the veterinarians were engaged in discussions with farmers, personnel at milk collection and chilling centers, recording their observations directly via field notes and taking photographs.

3.2 The farm

The participants, following their HACCP plan, observed the milking environment, udder cleanliness, utensils used for milk collection and obtained information regarding hygienic milking practices from the farmer. The farmers were very cooperative and described the hygienic practices they routinely adopt. The participants identified possible contamination points as the quality of the water used for washing the udder, the cloth used for wiping the udder and the utensils used for collecting milk. Water available in the vicinity included collected rainwater and the farmers used this source for hand washing before milking. Routine practice included teat dipping after milking and keeping the collected milk covered until taken to the collection point. All the farms practiced hand milking and on average there were 2 – 3 cows/farm.

3.3 Collection point

The farmers used a variety of utensils to bring milk to the collection point; these included plastic buckets, plastic bottles, and stainless steel and plastic milk containers. There were some utensils such as plastic bottles that were noticeably unclean. The timing between milking and arrival at the collection point varied from 30 minutes to two to three hours depending on the distance travelled. At the milk collection point, milk was measured using a metal jug (for volume) and a sample taken using a smaller cup. Milk was then poured to a large stainless steel tray. Milk from this tray was then filtered using a sieve and milk from different farms were pooled and collected to 40-liter milk containers. Bare hands were used at the collection point for measuring and sampling milk. In addition to the stainless steel equipment (trays, jugs and milk containers) the pooling of milk from different farms was considered a contamination issue.

3.4 Chilling center

The chilling center was less than a mile in distance to the collection point. The 40-liter milk containers were transported to the chilling center in a tractor and the milk containers were exposed to the sun (mid-day) increasing the temperature of milk. Here the participants observed how milk was tested for fat, solids-not-fat and a list of common adulterants. Before adding the milk to the chilling tank, milk was filtered from the 40-liter milk containers using a large sieve. The milk remained at room temperature until it was transferred to the chilling tank. The chilling tank was neither insulated nor kept in an air-conditioned room.

3.5 Processing plant

Chilled milk was then transferred to chilled large milk bowsers and was transported to the processing plant. The participants followed the milk bowser to a large milk processing plant. Cooled milk was immediately transferred to chilled tanks at the processing plant. Hygienic measures were observed throughout the processing plant. These included appropriately clothed employees, abundant hand washing facilities and display of standard operational procedures (SOP on HACCP). The processing of raw milk at the plant was followed to different products such as pasteurized milk, sterilized milk, yoghurt, cheese and ice cream. The various control and critical control points were detected and sterilization of equipment and utensils were noted.

3.6 Retail outlets

The processed milk products were then distributed to retail outlets and the participants explored a large supermarket to see how the products were maintained. Processed liquid milk products originating from the milk collection network and the processing plant that was studied in this project were obtained from retail outlets. In these outlets, pasteurized milk was kept at 4^0C and ultra heat-treated milk at room temperature.

3.7 Bacteriological results

The bacteriological results are from the samples collected during one workshop. Milk obtained from the containers from 4 different farmers showed bacterial counts that ranged from to 6.8×10^3 to 1.7×10^6 CFU/ml. The containers that were used to collect and transport milk to the center and the utensils used at the collecting center all had bacterial counts in the region of 10^6. So the milk that had lower counts at farm level were all exposed to more bacteria at these points. In addition, the on-going multiplication of bacteria led to the increased bacterial counts and pooled milk had up to 10^6 and 10^7 bacterial counts.

Table 2: Bacterial counts of milk and utensils used during the milk chain (CFU/ml)

Milk samples at the farm	
farm 1	1.7×10^{6}
farm 2	6.8×10^{3}
farm 3	1.5×10^{6}
farm 4	4×10^{5}
Swabs from Farmer’s milk collecting utensil 1	1.7×10^{6}
Swabs from Farmer’s milk collecting utensil 2	2.5×10^{6}
Utensils at the Collection center	
Metal jug	3.0×10^{6}
Collecting tray	3.0×10^{6}
Milk Strainer	1.2×10^{6}
Milk at the Collecting center	
	3.2×10^{7}
pooled sample 1	
pooled sample 2	2.4×10^{7}
pooled sample 3	1.6×10^{6}
pooled sample 4	2.1×10^{6}
Milk products purchased from retail outlets	
Pasteurised milk batch1	2.7×10^{7}
Pasteurised milk batch 2	5.1×10^{8}
Pasteurised milk batch 3	3.9×10^{7}
Ultra heat treated milk (batch 1,batch 2 and batch 3)	0

3.8 Observations on temperature measurements

On a separate occasion temperature measurements were taken during the same month and the region where the training workshop was held (Table 4). The ambient temperature at the time of milking was 26.6^{0}C. The temperature of milk just after milk at one farm with three cows was 37^{0}C +/- 0.35 (n = 3). The temperature of pooled milk from all three cows at the farm was 35^{0}C before the farmer took milk to the collection centre.

Samples were taken from a 40-litre milk container at hourly intervals at the collection centre before before milk was transported to the chilling centre. The results are given in table 3.

Table 3: The relationship between environmental temperature, sample temperature and bacterial count in milk samples

23/09/2015	Environmental temp: ˚C	Sample temp: ˚C	Bacterial counts in milk samples- cfu/ml
0hrs	26.6	31.1	2.12×10^{6}
1hr	27.0	32.7	2.9×10^{7}
2hrs	27.0	31.1	7×10^{7}
3hrs*	27.0	31.0	1.39×10^{8}

* The time taken from milking at the farm to the chilling centre

Table 4: The relationship between environmental temperature, sample temperature and bacterial count in milk samples

23/09/2015	Environmental temp: ˚C	Sample temp: ˚C	Bacterial counts in milk samples- cfu/ml
0hrs	26.6	31.1	2.12×10^{6}
1hr	27.0	32.7	2.9×10^{7}
2hrs	27.0	31.1	7×10^{7}
3hrs*	27.0	31.0	1.39×10^{8}

3.9 Physical contaminants

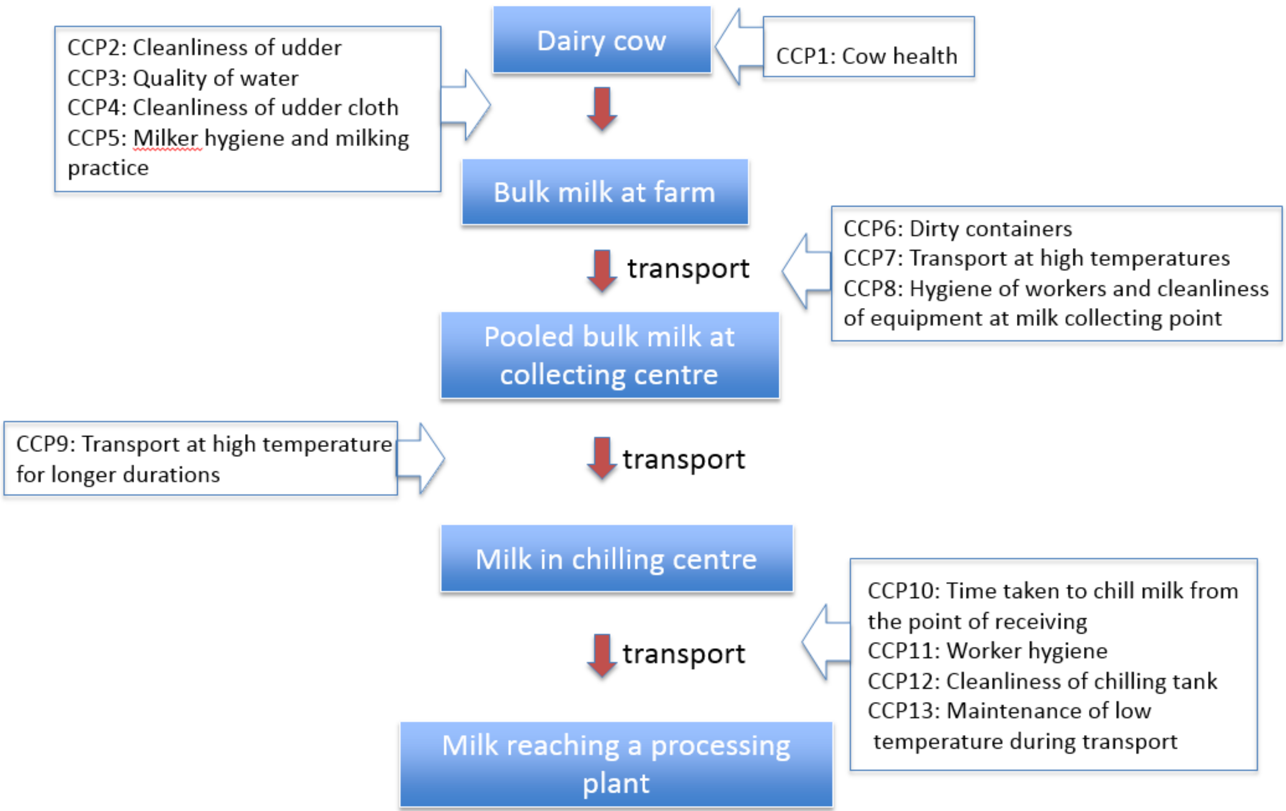
Physical hazards such as broken plastic and glass, physical contaminants such as hair, dirt, dead insects and all cleaning equipment were checked for possible contaminants. Insects such as flies were noticed at the collection point.

3.10 HACCP plan (Figure 1)

The participants developed the major steps in the milk chain and identified possible critical control points (CCP). The bacteriological counts were used in the identification of the CCP and further breakdown of contamination points was achieved through discussion.

Figure 1

The veterinarians developed the HACCP plan for clean milk production and identified the critical control points



4. Discussion

The training programme was underpinned by a participatory action research approach combined with adult learning theories to enable the participants to update their knowledge base and develop their skills in hazard identification. The participants addressed the issues in the milk production chain by developing an HACCP plan for bacteriology and collecting data to use as evidence to make decisions regarding the control and critical control points. The bacteriological counts were revelatory and the participants were able to identify the extent of the problem, and reach a good understanding regarding the control and critical control points. This experiential learning approach (Kolb & Kolb 2005) is highly suitable for mature veterinarians with field experience, as their local knowledge was taken in to account and they were made partners in the training course.

Although veterinary undergraduate training addresses the theoretical knowledge regarding food safety, *in-situ* training of field veterinarians is essential to solve local problems. Problem based learning (PBL), to develop skills in critical inquiry, collaborative and self-directed learning, is practiced in veterinary education today (Lane 2008). Extending this teaching method and using the principles of active learning to promote participant engagement and motivation is more effective than traditional teaching approaches (Biggs 1999). It is well known that using a real world problem that is local and within context additionally helps to drive learning (Kirschner, Sweller & Clark, 2006). This approach enhances both learning of the content and thinking strategies (Kirschner et al 2006). Practicing to develop an HACCP based decision process using a public health issue that the veterinarians experience in their day-to-day work is a useful way to embed learning. In PBL, students work collaboratively and are guided by a facilitator who may not be an expert on the topic (Hmelo-Silver 2004). Similarly the facilitators in this training programme were able to guide the veterinarians through the milk chain, to identify possible points of bacterial contamination of milk as a series of potential problems. The veterinarians as a result worked in a collaborative manner, observing, discussing and gathering evidence that helped them to understand contamination points. This is essential knowledge to make the decisions they are required to take given their role as advisors in controlling contamination and in making recommendations to policy makers to improve management processes; that has the ultimate power to improve bacteriological quality of milk.

Milk when leaves a healthy udder of a cow contains a low bacterial count but can get immediately contaminated with bacteria even within the udder i.e in clinical and sub clinical mastitis (Wallace 2008). It was surprising to see the varied bacterial counts of milk at the farm level, with some farm milk showing bacterial counts as low as 6.8 x 10^3, which is within the standards accepted by the countries in the EU. In the EU, there is no significant problem in the majority of farms to supply milk with less than 1 x 10^5cfu/ml with national average for bacterial counts frequently falling below 1 x 10^4cfu/ml (Hillerton and Berry 2004). In the UK monthly Bactoscan averages are in the region of 2.8 x ^{10} to 3.5 x 10^4 (Hillerton and Berry 2004). Another important point that emerged through the training process was the importance of lowering the initial bacterial load by controlling mastitis. Both subclinical and clinical mastitis prevalence could be high in certain farms and depending on the climate (Gunawardana et al 2014). Although most farmers are trained to use 'strip cup-test' to check for milk clots which is an indicator of mastitis (Miller and Porter 1945), it is the subclinical mastitis status that is undetected. The veterinarians identified the importance of preventing both clinical and sub clinical mastitis through improved hygiene and training of farmers, which is within their roles to implement.

The veterinarians identified 'pooling' of milk at the collecting centers as a key point of contamination, especially if the milk is 'clean' with less than 1 x 10^5cfu/ml. The relationship between the temperature of milk that is maintained for several hours at ambient temperature and the multiplication rate of bacteria was another important lesson learned. Similar training programmes in the future will include the effect of chilling of milk on bacterial counts from the farm to the chilling centre.

The next important lesson was learnt by testing the products purchased from retail outlets. Microbiological testing unveiled the poor quality of final products resulting from the studied milk collecting network. As detailed in Table 2, the bacterial counts found in pasteurized milk were unacceptable according to Sri Lanka standards (SLS 181:1983 Specification for raw and processed milk) for processed milk. Ultra high temperature treated milk was free of bacteria but heat stable toxins (Doyle et al 2015) were not analyzed. The negative influence of high bacterial loads in raw milk to pasteurization process in local dairy processing industry has been discussed previously (Deshapriya, Silva et al. 2006). However, the finding was an eye opener for participating veterinarians.

The comparison with processes in European countries including the UK helped to tease out the steps in developing the HACCP plan. Unlike in developed economies, many countries still manually collect milk at a collection center before being pooled and transported to processing plants. The high bacterial counts in collecting utensils, contamination at the collection centers via utensils and by humans were all identified as points that could be improved with training of farmers and personnel. However the delay in chilling of milk, which can have significant impact in bacterial multiplication, was not within the field veterinarians' power to manage. This was considered an essential target to work towards through the use of the bacteriological evidence in approaching relative authorities. The trainer-trainee team developed a report with recommendations. A joint discussion was held with the senior management of the milk processing plant to outline the findings and the importance of chilling to prevent bacterial multiplication was emphasized. Reducing the time lag between milking and chilling was identified as the most important target by the authorities. The written report was submitted to the milk processing plant and to the Department of Livestock Production with recommendations.

The HACCP plan was extended to cover non-biological hazards. Physical hazards such as broken plastic and glass, physical contaminants such as hair, dirt, dead insects and all cleaning equipment were checked as possible contaminants. There was some evidence of small particles, which could have been avoided by thorough cleaning of utensils and being more careful in the milking process. The chemical hazards include adulterants that are added to increase nitrogen (urea, melamine), density (salt, sugar) and preservatives (H_20_2). In Sri Lanka the most common adulterant appear to be water. Often sugar or salt is then added to mask the effects of adding water. By testing 582 milk samples for sugar, starch, salt, urea, formalin and H2O2, Ranawana and co-workers have identified sugar and salt as the common adulterants in the studied population in Sri Lanka (Ranawana & Mangalika 1996).

5. Conclusion:

The continuous professional development of field veterinarians in public health related issues is becoming more important as food safety issues threaten human health. A considerable emphasis is placed on promoting formal courses as the accepted form of CPD, as it is easy to record and audit. However, there are questions regarding the value of formal courses for field veterinarians with considerable experience and a comprehensive understanding regarding the local public health issues. It has become imperative to develop CPD courses to build on the existing knowledge and experiences of the field vet and to focus on renewing skills and knowledge as required. A training course designed with the field vet in the 'driving seat' is therefore more appropriate with educators and experts acting as facilitators. The training course described here has the pedagogical design to achieve that. From the outset the course was designed with the adult learner in focus and uses an inquiry-based approach to enable the veterinarians to work collaboratively and seek solutions to the issues they face in clean milk production in Sri Lanka. The veterinarians had the intrinsic motivation to explore the problem collaboratively and therefore by offering the educational environment to achieve this, a successful outcome was achieved.

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