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A Food Safety Laboratory Curriculum Significantly Improves Knowledge, Behaviors, Attitudes, and Handwashing Skills of Laboratory Personnel in East and South Africa

ABSTRACT

In 2017, a needs assessment conducted in Africa reported that personnel in food safety testing laboratories have deficiencies in lab safety, quality assurance, validation of test methods, metrics, sampling protocols, management, accreditation, methodologies, data analyses, and interpretation. The purpose of this study was to develop and deliver a curriculum on the basis of the identified needs for laboratory personnel in East Africa (Ethiopia, Uganda) and South Africa (Mozambique) and gauge the impact of the training on several attributes. Prior to and immediately after the workshop, laboratory personnel were evaluated for knowledge, behavior, attitudes, and handwashing skills. A significant increase was found in participants' knowledge, on the basis of the results of the pre- and posttests on the topics delivered by the curriculum ($P \leq 0.05$). Additionally, behaviors of laboratory personnel positively changed concerning good laboratory practices and quality management systems and participants' attitudes toward general laboratory practices, regulations, and understanding of continuous

training improved significantly. Moreover, handwashing skills were significantly improved after the workshop. This curriculum and results may be used to develop continuous education programs for personnel of food testing laboratories to enhance the safety of a global food supply.

INTRODUCTION

Food safety is a relevant discipline that connects people around the world. Food produced and packaged in one geographical area may significantly impact people living on the opposite side of the world. The global agricultural trade has a value worth more than US\$1.1 trillion, and food trade is important to fulfill every country's food demand (2). This observation makes the global food system highly connected and intertwined (2). The trade value of a global food system will increase in years to come to feed an ever-growing population. Globalization also carries a significant benefit to countries with developing economies that can pick cheaper, but safe, food products. However, the safety of food that is being produced, packaged, shipped, and consumed by the end user is of primary concern.

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In 2015, foodborne hazards were responsible for 137,000 deaths and 91 million acute illnesses affecting African children under the age of 5 (20). The burden of foodborne illness is most severe in low- and middle-income African countries. Consumption of unsafe food leads to gastroenteritis and other food poisoning symptoms, mostly affecting infants, young children, pregnant women, and the elderly with a diminished immune system (20). Therefore, a safe and nutritious food supply is key to a healthy lifestyle. However, many Africans lack safe and nutritious food (1, 6, 7, 19). Given these limitations, African countries are slowly adopting global food safety systems and modernizing international trade. Yet, many countries still lack the resources, including those from the government sectors, to ensure safe consumption of food products (1, 6). In such instances, the Global Food Safety Initiative capacity-building programs in the African region become beneficial (1, 7). For the international food trade, food safety standards and modern practices are reviewed and verified by the importer to be in compliance. Given these approaches, training, education, and assessment of laboratory practices are an essential foundation for a global food safety system (1).

Recently, a study assessed practices and procedures in African food safety testing laboratories in three African nations, Ethiopia, Uganda, and Mozambique. Several issues, such as lab safety, quality assurance, validation of test methods, sampling protocols, data management, data analysis, training, and accreditation were addressed (14, 18). Several gaps and issues were identified in laboratory infrastructure, sample handling, testing methodologies, data analysis, and professional development (14). General findings on food standard systems, inspection mechanisms, and laboratory capabilities of several African Nations can be found at an annex provided by Food and Agriculture Organization of the United Nations (5). On the basis of the results, it was determined that identified food safety gaps and issues could be addressed through face-to-face training in testing laboratories. Hence, this study aims to develop, deliver, and evaluate a needs-based curriculum that can be used to train food safety laboratory personnel in East and South Africa.

MATERIALS AND METHODS

Human subjects research protocols

The institutional review board at Pennsylvania State University (IRB STUDY00008250) approved the recruitment process, project design, consent forms, lectures, laboratories, activities, pre- and postexams, surveys, and handwashing protocols.

Recruitment process

In 2017, phase I of this study involved an on-site comprehensive needs assessment of food safety laboratories in East and South Africa: Ethiopia, Uganda, and Mozambique (14).

After approval by Pennsylvania State University Institutional Review Board, potential employees or personnel from food safety testing laboratories, identified in phase I of the study (in-person visit) and located in East and South Africa, were contacted via e-mail. The interested personnel in those laboratories who were fluent in English, were 18 years or older, and who expressed an interest in participating in this training were recruited for this research project. As a result of this recruitment process, 19 participants from Ethiopia, 11 participants from Uganda, and 11 participants from Mozambique completed the training program.

Consent

Personnel from participating food safety testing laboratories in East and South Africa received a consent form to be part of the research via e-mail prior to the training (December 2018) and a paper version of the consent form in person and on-site from the principal investigator (C. N. Cutter) in January or February 2019. All participants were fluent in writing, reading, and speaking English and did not require additional translation to participate in the program; additional clarification was provided to participants that this research would have no impact on employment status. The consent form disclosed the procedures to be performed, participation was voluntary, and there were adequate provisions to maintain the privacy interests of subjects.

Completed consent forms, paper-based surveys, and a memory card with handwashing videos resulting from the research will be stored for 3 years, following the completion of the study, and will be destroyed and/or removed from the card at that time.

Development and delivery of the Food Safety

Laboratory Workshop

During the needs assessment portion of the study (14), laboratory personnel expressed interest in improving laboratory practices via additional training. On the basis of the needs assessment, we developed a comprehensive curriculum (Table 1) to address a number of topics, including, but not limited to, lab safety, quality assurance, validation of test methods, sampling protocols, management, lab safety (including handwashing), accreditation, methodologies, data analyses and interpretation, maintenance, and troubleshooting. Table 1 outlines the schedule of the 5-day Food Safety Laboratory Workshop. The curriculum was administered in English in each country (Ethiopia, Mozambique, and Uganda) in Africa in January and/or February 2019. The workshop included face-to-face instruction and breakout sessions for laboratory personnel. The first 2 days of the curriculum were designed to deliver fundamentals of microbiology, aseptic sampling techniques, and pathogen detection methods. On the third day, the importance of International Organization for Standardization and the International Electrotechnical Commission (ISO/IEC) 17025 and quality

management steps in a food safety laboratory were discussed. Then, the key steps to generate technically valid results were discussed. These key steps included statistical methods to create sampling plans, guidelines for the validation of microbial detection methods, as well as guidelines for the calibration and validation of laboratory equipment (4, 17, 18). On the fourth day, statistical process control tools that can be used in a food safety laboratory were explained to achieve process stability and variance reduction (11). Moreover, the importance of record keeping and education was emphasized to maintain or improve good laboratory practices (GLP). On the fifth day, food laws and regulations, such as Codex Alimentarius, hazard analysis and critical control point, ISO standards, British Retail Consortium, International Featured Standard were addressed.

To facilitate the lectures, different breakout sessions were designed. For example, in one of the breakout sessions, the participants were asked to prepare standard operating procedures (SOP) for a selected food item to include (i) transport (how the sample was packaged and sent to the lab for analyses); (ii) preparation or processing of the sample (time frame for sampling, homogenization of food sample [stomaching, blending, rinsing, and swabbing], sample size and measurement [volume versus weight], and choice of buffer); (iii) dilution scheme and reagents; (iv) choice of media and/or technique (standard plate counts, molecular, immunological) for determining which microorganisms are present in the sample; (v) atmosphere and temperature for incubation of media; and (vi) presence or absence and/or enumeration or quantitation of organisms (manual versus automatic). Participants were also asked to design a continuous training plan for the laboratory by answering the following questions: Which training tools can be used? Who will be included in the training program? What kind of competency assessment can be used? How often will the training program be implemented? The details of the curriculum and breakout session activities can be found in *Table 1*.

Participants' demographics, evaluation of knowledge, behavior, attitude, and handwashing skills

Participants completed a demographic questionnaire after signing the consent form and agreeing to participate in the Food Safety Laboratory Workshop. This questionnaire included 14 questions to assess the participants' age, sex, marital status, educational background, proficiency in testing methods and laboratory instruments, and their English proficiencies. Prior to and immediately after the curriculum was delivered, the participants were evaluated for knowledge, behavior, attitudes, and handwashing skills, as a means of gauging the impact of the training on the participants. To evaluate the change in the participants' knowledge, we conducted pre- and posttests. The pre- and posttests included the same 30 true or false and multiple choice questions. Moreover, participants completed the same behavior and attitude

surveys before and after the delivery of the curriculum. The behavior survey had 24, 6-point Likert scale questions, and the attitude survey included 18, 6-point Likert scale questions. Moreover, participants' handwashing techniques were monitored to assess their representative skills before and after the completion of the workshop. The handwashing activity videos were recorded by using a Canon Powershot (Tokyo, Japan) and saved to an external memory card (Samsung Flash, Seoul, South Korea). Then, the handwashing techniques were scored, on the basis of the timing, movements, and sounds produced during the handwashing procedure. The scoring system (*Table 2*) was developed by using the method of the Consensus Measurement in Hand Hygiene project, with some modifications (12, 16).

Data analysis

The total number of responses to each question in the demographic questionnaire, behavior, and attitude surveys was counted and reported as percentages. The pre- and posttests were evaluated on a 100-point scale. Moreover, the handwashing skill data were calculated over 12 maximum points. Microsoft Office Excel 2013 (Microsoft Corp., Redmond, WA) was used to calculate data points and basic descriptive statistics (e.g., mean, standard deviation, standard error of the mean, percentage of responses, and observations). Statistically significant differences in pre- and posttest results and handwashing skill scores were calculated by using paired *t* test ($\alpha = 0.05$; Minitab, State College, PA).

RESULTS AND DISCUSSION

The topics and agenda for the Food Safety Laboratory Workshop were developed and based on the needs assessment conducted by Pokharel et al. (14). The workshop was delivered in Uganda, Mozambique, and Ethiopia in January and February 2019. The Food Safety Laboratory Workshop agenda is provided in *Table 1*. The aim of the workshop was to improve the knowledge, behavior, attitude, and handwashing skills of participants who work in food testing laboratories.

Demographic characteristics of participants

Table 3 demonstrates the demographic characteristics of participants from the food safety testing laboratories in East and South Africa. In Uganda, 60% of participants were between 30 to 39 years old. In Mozambique and Ethiopia, the ages of participants ranged from 21 to 59 years. In all three countries, most of the participants had bachelor's (4-year college) degrees. In Uganda, most of the participants had biology or agriculture backgrounds. In Mozambique and Ethiopia, the participants' educational backgrounds were more diverse. Similarly, most of the participants in the needs assessment study conducted by Pokharel et al. (14) also had biological and agricultural backgrounds, with an average age of 39 years. In Uganda and Mozambique, most participants (80%) indicated they were "proficient" with lab instruments. However, 37% of

TABLE 1. Food Safety Laboratory Workshop topics, delivery methods, and agenda

| | | Agenda |
|--------------|---|--|
| Day 1 | | Food microbiology: part 1 (type of delivery: face-to-face lectures) |
| 10:00 a.m. | Introductions | Instructors and class participants |
| 10:30 a.m. | Data collection | Demographic data collection and pretest assessments |
| 11:00 a.m. | | Introduction to food microbiology |
| 1:00 p.m. | | Spoilage and indicator microorganisms |
| 1:45 p.m. | | <i>Escherichia coli</i> and other Shiga toxin-producing <i>E. coli</i> |
| 2:45 p.m. | | <i>Staphylococcus aureus</i> and <i>Listeria monocytogenes</i> |
| 3:45 p.m. | | <i>Salmonella</i> and <i>Campylobacter</i> |
| 4:30 p.m. | Activity | Glo Germ and handwashing exercise |
| Day 2 | Food microbiology: part 2 (type of delivery: face-to-face lectures and breakout sessions) | |
| 9:00 a.m. | | Molds and mycotoxins |
| 9:45 a.m. | | Parasites, viruses, and additional bacterial pathogens |
| 11:00 a.m. | | Methods for sampling food products |
| 1:00 p.m. | | Methods for bacterial dilution and enumeration |
| 2:00 p.m. | | Immunological-based methods for pathogen detection |
| 3:30 p.m. | | DNA-based methods for pathogen detection |
| 4:00 p.m. | Activity | Breakout session I: sample preparation |
| Day 3 | | Quality assurance, validation of laboratory test methods, data analyses, data interpretation (type of delivery: face-to-face lectures and breakout sessions) |
| 9:00 a.m. | | Basic laboratory practices |
| 10:00 a.m. | | ISO/IEC 17025 and control points in microbiology lab |
| 11:00 a.m. | | Sampling plans: data analysis |
| 1:00 p.m. | | Data analysis: formulas |
| 2:00 p.m. | Activity | Breakout session II |
| | | Dilution and plating calculation example |
| 3:00 p.m. | | Validation of microbiological methods and calibration of equipment |
| 4:00 p.m. | | Guidance on laboratory equipment calibration |
| Day 4 | | Statistical process control for laboratory personnel, record keeping, troubleshooting (type of delivery: face-to-face lectures and breakout sessions) |
| 9:00 a.m. | Activity | Introduction to ATP bioluminescence |
| | | Hands-on exercise: ATP bioluminescence |
| 10:00 a.m. | | Microbiological troubleshooting |
| 10:45 a.m. | | Introduction to statistical process control |
| 1:00 p.m. | | Statistical process control tools |
| 2:00 p.m. | | Record keeping |
| 3:00 p.m. | Activity | Breakout session III |
| | | Group exercise: developing continuous training programs |
| 4:00 p.m. | | Group presentation: developing continuous training programs |

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TABLE 1. Food Safety Laboratory Workshop topics, delivery methods, and agenda (cont.)

| | | Agenda |
|------------|--|---|
| Day 5 | | Accreditation, wrap-up, FAQs, evaluation of program (type of delivery: face-to-face lectures and breakout sessions) |
| 9:00 a.m. | | Accreditation: the environment of food safety standards |
| 10:00 a.m. | | Codex Alimentarius standards |
| 11:00 a.m. | | Question and answer session with instructors |
| 11:15 a.m. | Data collection | Posttest and assessments |
| 12:00 p.m. | Evaluations and awarding of certificates | |

TABLE 2. Rubric to assess hand-washing skills of participants

| Steps | Action (points awarded) |
|---------------------|---|
| 1. Wet hands | No (0); partial (1); all (2) |
| 2. Soap application | No (0); yes (2) |
| 3. (i) Lather | (i) No vigor (0); minimal vigor (1); vigorous (2) |
| (ii) Lather time | (ii) 5 s or less (0); 6 to 10 s (1); more than 10 s (2) |
| 4. Rinse | No (0); partial (1); all (2) |
| 5. Dry | No (0); partial (1); all (2) |

the participants in Ethiopia stated their proficiency level with the instruments as “somewhat proficient,” and 16% of them were not sure about proficiency level. The number of participants conducting microbiological testing was higher in Uganda (80%) and Ethiopia (63%), with only 20% in Mozambique, due, in part, to the high volume of chemical testing that is performed in foods (50% participants). Participants in all three countries were exposed to English as a second language in elementary and middle schools. As a result, participants describe English language proficiency as good to very good for reading, speaking, writing, and listening. Moreover, the participants’ household members also speak English as a second language in Uganda. However, only 30% of the participants’ household members speak English as a second language in Mozambique, where the major spoken language is Portuguese. Similarly, the percentage of household members speaking English as a second language is higher in Ethiopia (63%) when compared with Mozambique. This last demographic aspect is important, given that the training materials and lectures were presented in English.

Evaluation of knowledge and skills before and after the training program

On the basis of the results of the needs assessment (14), we developed the course curriculum to address the

following topics: general food microbiology; microbial detection methods; lab safety (including handwashing); quality assurance; validation of test methods and equipment; metrics; sampling protocols; data management; accreditation process; development of continuous training programs; understanding the need for record keeping and international laboratory and food safety standards (Table 1).

To assess the changes in participants’ skills as a result of the workshop, hand-washing activities were monitored and evaluated by using the scoring rubric provided in Table 2. Hand-washing skill was observed before the start of the food safety laboratory workshop and immediately after the workshop delivery. When pre- and postscores of hand-washing skills were compared (Table 4), Ugandan participants had increased their scores (46%) significantly, followed by participants from Mozambique (40%) and Ethiopia (34%). Overall, the hand-washing score increased significantly ($P \leq 0.05$) by 40% for all participants, from 8.1 ± 0.40 to 11.4 ± 0.35 after the training program. Hand-washing skills are important to prevent cross-contamination. Johnston et al. (9) found that poor hand-washing can result in failure to remove transient pathogens on laboratory personnel’s hands. Therefore, understanding the standard soap and water hand-washing technique is important in preventing pathogen transmission in the laboratory.

TABLE 3. Demographic characteristics of participants from the food safety testing laboratories in East and South Africa

| | Uganda | | Mozambique | | Ethiopia | |
|---|-----------|-----------|------------|-----------|-----------|-----------|
| | Responses | Total (%) | Responses | Total (%) | Responses | Total (%) |
| 1. Age | | | | | | |
| <input type="checkbox"/> 17 or younger | 0 | 0 | 0 | 0 | 0 | 0 |
| <input type="checkbox"/> 18–20 | 0 | 0 | 0 | 0 | 0 | 0 |
| <input type="checkbox"/> 21–29 | 3 | 30 | 1 | 10 | 7 | 37 |
| <input type="checkbox"/> 30–39 | 6 | 60 | 3 | 30 | 5 | 26 |
| <input type="checkbox"/> 40–49 | 0 | 0 | 4 | 40 | 5 | 26 |
| <input type="checkbox"/> 50–59 | 1 | 10 | 2 | 20 | 2 | 11 |
| <input type="checkbox"/> 60 or older | 0 | 0 | 0 | 0 | 0 | 0 |
| 2. The highest level of education | | | | | | |
| <input type="checkbox"/> Middle school | 0 | 0 | 1 | 10 | 0 | 0 |
| <input type="checkbox"/> High school degree or equivalent (General Educational Development) | 0 | 0 | 1 | 10 | 0 | 0 |
| <input type="checkbox"/> Some college level education, but no degree | 1 | 10 | 1 | 10 | 2 | 11 |
| <input type="checkbox"/> A.A. or A.S. degree (associate: 2-yr college degree) | 0 | 0 | 0 | 0 | 3 | 16 |
| <input type="checkbox"/> B.A. or B.S. degree (bachelor's 4-yr college degree) | 6 | 60 | 6 | 60 | 6 | 32 |
| <input type="checkbox"/> M.S., M.A., or M.B.A. (master's: graduate degree) | 3 | 30 | 1 | 10 | 5 | 26 |
| <input type="checkbox"/> Ph.D. (doctoral degree) | 0 | 0 | 0 | 0 | 3 | 16 |
| 3. The year of school for continuing education cases | | | | | | |
| <input type="checkbox"/> Freshman, first year | 0 | 0 | 0 | 0 | 1 | 5 |
| <input type="checkbox"/> Sophomore, second year | 0 | 0 | 0 | 0 | 0 | 0 |
| <input type="checkbox"/> Junior, third year | 0 | 0 | 0 | 0 | 0 | 0 |
| <input type="checkbox"/> Senior, fourth year | 0 | 0 | 0 | 0 | 3 | 16 |
| 4. Expectation to enroll in an advanced degree after graduation | | | | | | |
| <input type="checkbox"/> No | 0 | 0 | 0 | 0 | 3 | 16 |
| <input type="checkbox"/> Yes | 2 | 20 | 2 | 20 | 5 | 26 |
| 5. Educational background | | | | | | |
| <input type="checkbox"/> Agriculture (animal science, food science, food microbiology, or food safety) | 7 | 70 | 2 | 20 | 6 | 32 |
| <input type="checkbox"/> Biological/life sciences (biology, biochemistry, botany, or zoology) | 6 | 60 | 2 | 20 | 7 | 37 |
| <input type="checkbox"/> Agribusiness | 2 | 20 | 0 | 0 | 0 | 0 |
| <input type="checkbox"/> Business (accounting, business administration, marketing, or management) | 0 | 0 | 1 | 10 | 3 | 16 |
| <input type="checkbox"/> Communication (speech, journalism) | 1 | 10 | 0 | 0 | 0 | 0 |
| <input type="checkbox"/> Education | 0 | 0 | 0 | 0 | 0 | 0 |
| <input type="checkbox"/> Engineering | 0 | 0 | 1 | 10 | 1 | 5 |
| <input type="checkbox"/> Health related fields (nursing, physical therapy, health technology, radiology, or pathology) | 0 | 0 | 1 | 10 | 3 | 16 |
| <input type="checkbox"/> Others | 0 | 0 | 3 | 30 | 3 | 16 |

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TABLE 3. Demographic characteristics of participants from the food safety testing laboratories in East and South Africa (cont.)

| | Uganda | | Mozambique | | Ethiopia | |
|--|-----------|-----------|------------|-----------|-----------|-----------|
| | Responses | Total (%) | Responses | Total (%) | Responses | Total (%) |
| 6. Proficiency with lab instruments | | | | | | |
| [] I do not know | 0 | 0 | 0 | 0 | 3 | 16 |
| [] Somewhat proficient | 1 | 10 | 1 | 10 | 7 | 37 |
| [] Proficient | 8 | 80 | 8 | 80 | 6 | 32 |
| [] Very proficient | 1 | 10 | 1 | 10 | 3 | 16 |
| 7. The testing methods that currently performing in the lab | | | | | | |
| [] Microbiological | 8 | 80 | 2 | 20 | 12 | 63 |
| [] Fungal | 3 | 30 | 0 | 0 | 2 | 11 |
| [] Toxicological (including insecticides and pesticides) | 0 | 0 | 1 | 10 | 1 | 5 |
| [] Chemical | 2 | 20 | 5 | 50 | 5 | 26 |
| [] Other | 3 | 30 | 1 | 10 | 4 | 21 |
| 8. Previous participation in a food safety training course | | | | | | |
| [] Yes | 6 | 60 | 5 | 50 | 10 | 53 |
| [] No | 4 | 40 | 5 | 50 | 9 | 47 |
| 9. Access to Internet | | | | | | |
| [] Phone | 10 | 100 | 9 | 90 | 19 | 100 |
| [] Home | 2 | 20 | 9 | 90 | 9 | 47 |
| [] Work | 10 | 100 | 10 | 100 | 19 | 100 |
| 10. English language proficiency | | | | | | |
| Reading | | | | | | |
| Very poor | 0 | 0 | 0 | 0 | 0 | 0 |
| Poor | 0 | 0 | 2 | 20 | 0 | 0 |
| Fair | 0 | 0 | 2 | 20 | 0 | 0 |
| Good | 1 | 10 | 6 | 60 | 3 | 16 |
| Very good | 9 | 90 | 0 | 0 | 16 | 84 |
| Speaking | | | | | | |
| Very poor | 0 | 0 | 1 | 10 | 0 | 0 |
| Poor | 0 | 0 | 3 | 30 | 0 | 0 |
| Fair | 0 | 0 | 5 | 50 | 4 | 21 |
| Good | 4 | 40 | 1 | 10 | 6 | 32 |
| Very good | 6 | 60 | 0 | 0 | 9 | 47 |
| Writing | | | | | | |
| Very poor | 0 | 0 | 1 | 10 | 0 | 0 |
| Poor | 0 | 0 | 1 | 10 | 0 | 0 |
| Fair | 0 | 0 | 6 | 60 | 0 | 0 |
| Good | 1 | 10 | 2 | 20 | 4 | 21 |
| Very good | 9 | 90 | 0 | 0 | 15 | 79 |

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TABLE 3. Demographic characteristics of participants from the food safety testing laboratories in East and South Africa (cont.)

| | Uganda | | Mozambique | | Ethiopia | |
|---|-----------|-----------|------------|-----------|-----------|-----------|
| | Responses | Total (%) | Responses | Total (%) | Responses | Total (%) |
| Listening | | | | | | |
| Very poor | 0 | 0 | 0 | 0 | 0 | 0 |
| Poor | 0 | 0 | 1 | 10 | 0 | 0 |
| Fair | 0 | 0 | 8 | 80 | 2 | 11 |
| Good | 3 | 30 | 1 | 10 | 7 | 37 |
| Very good | 7 | 70 | 0 | 0 | 10 | 53 |
| 11. Household members speaking English as a secondary language | | | | | | |
| <input type="checkbox"/> Yes | 10 | 100 | 3 | 30 | 12 | 63 |
| <input type="checkbox"/> No | 0 | 0 | 7 | 70 | 7 | 37 |
| 12. Started learning to speak English language in | | | | | | |
| <input type="checkbox"/> Elementary or middle school | 10 | 100 | 4 | 40 | 10 | 53 |
| <input type="checkbox"/> High school | 0 | 0 | 2 | 20 | 6 | 32 |
| <input type="checkbox"/> College | 0 | 0 | 1 | 10 | 3 | 16 |
| 13. Took English as a secondary language classes in the past | | | | | | |
| <input type="checkbox"/> No | 5 | 50 | 9 | 90 | 5 | 26 |
| <input type="checkbox"/> Yes | 5 | 50 | 1 | 10 | 14 | 74 |

TABLE 4. Hand-washing skills of participants before (pretest) and immediately after (posttest) the delivery of the Food Safety Laboratory Workshop

| Location of activity | Hand-washing skill scores (maximum = 12) | | | | | |
|----------------------|--|----------|---------|----------|------------|----------|
| | Ethiopia | | Uganda | | Mozambique | |
| | Pretest | Posttest | Pretest | Posttest | Pretest | Posttest |
| Time of activity | | | | | | |
| Average score | 8.60 B ^a | 11.50 A | 8.00 B | 11.67 A | 7.83 B | 11.00 A |
| Standard deviation | 2.55 | 0.84 | 2.00 | 0.50 | 1.72 | 1.10 |

^aDifferent letters (A and B) within a row shows statistically significant data ($P \leq 0.05$).

To assess the changes in participants' knowledge, pre- and posttests were given. This test included 30 questions on the topics covered during the workshop, such as fundamentals of food microbiology, GLP, regulations and standards, statistical methods to prepare sample plans, interpretation of the results, and process control. The average test results are provided in (Table 5). As a result of this educational program, the participants' knowledge increased significantly in all countries ($P \leq 0.05$). Overall, the average knowledge on several of the topics covered during the workshop increased by 28%. Recent studies have demonstrated a

similar effect when training has improved the food handlers' food safety knowledge (3, 8). The increase in knowledge significantly affected the posttest given afterwards. This observation is important because continuous training is needed to keep laboratory personnel's knowledge up to date, especially when new analytical techniques are evolving rapidly (15).

Participants' behaviors and attitudes

Workshop participants were asked questions related to behaviors and attitudes (see Tables 6 and 7). Behavioral

TABLE 5. Knowledge of participants before (pretest) and immediately after (posttest) the delivery of the Food Safety Laboratory Workshop

| Location of activity | Pretest | | Posttest | |
|----------------------|----------------------|-------|----------|-------|
| | Average | SD | Average | SD |
| Ethiopia | 55.37 B ^a | 14.06 | 63.52 A | 9.67 |
| Uganda | 44.33 B | 9.03 | 63.94 A | 6.47 |
| Mozambique | 57.22 B | 9.19 | 73.33 A | 15.13 |

^aDifferent letters (A and B) within a row shows statistically significant data ($P \leq 0.05$).

questions (Table 6) were evaluated by using a 5-point Likert scale, with the opportunity to answer, “I do not know.” More than half of the participants (70% in Uganda, 80% in Mozambique, and 58% in Ethiopia) strongly agreed that GLP affect the quality of the tests they conduct in the facilities; by the end of the training, most participants strongly agreed with this statement (100% in Uganda, 82% in Mozambique, and 72% in Ethiopia). For questions, such as the effect of protective coverings (e.g., lab coats, shoe coverings, and gloves) on the impact of quality in laboratory testing, participant responses were different for each country. After the program, participants from Mozambique “strongly” believe (85%) that protective coverings have some impact; however, the responses from the Ugandan (55%) and Ethiopian (41%) participants were less encouraging when compared with Mozambican participants. As a result of the workshop, participants also strongly agreed with the importance of “quality management systems” (e.g., ISO/IEC 17025), with 80, 70, and 53% in agreement before in Uganda, Mozambique, and Ethiopia and 100, 91, and 67% afterwards, respectively. Similar responses were observed for equipment calibration: participants from Uganda and Mozambique agreed or strongly agreed (100%) to the process, except for the participants from Ethiopia (89%). Likewise, participants clearly understand the importance of training (70% before); however, interest grew because of the workshop (90%), with many wishing to participate in similar types of training in the future. Similarly, participants strongly agreed on the value of lab work and its economic impact for their country, the region, and the world.

The attitude of participants before and after the program is reported in Table 7. Similar to behavioral questions, attitudinal questions were asked on a 5-point Likert scale, including “I do not know.” Questions asked were related to general food safety practices, implementation, policies, inspection, and training. Before the program, 69% of the participants in Ethiopia, 80% in Uganda, and 100% in Mozambique agreed or strongly agreed on the effect of knowledge on SOP and the impact on the quality of the

tests being conducted. After the program, agreed and strongly agreed responses increased to 100% in Uganda. Ethiopian participants also increased agreement to 95% after the program. The Mozambique participant responses remained the same throughout the workshop (100%). Likewise, participant responses on training-related statements were evaluated. When asked if “this food testing laboratory has a responsibility to train individuals working in this lab on standard operating procedures,” participant agreements increased from 90 to 100% in Uganda and 56 to 80% in Mozambique, while the Ethiopians responses remained the same (79%) before and after the training. There were participants who did not provide an opinion related to “written SOP, good manufacturing practices (GMP) are equally important for the best results” in Uganda (10%) and Ethiopia (5%). After the delivery of the program, the strongly agreed responses for this statement increased from 90 to 100% in Uganda and 79 to 89% in Ethiopia. In Mozambique, 100% of the participants strongly agreed or agreed with the statement before and after the program. Initially, Ethiopians did not agree with the importance of local, regional, state or governmental regulations to keep food safe (5%), but after the training, 100% strongly agreed. Participants from other countries responded similarly after the program. Likewise, most participants’ attitudes toward the role of different agencies on certification of testing methods increased after the program: 90 to 100% in Uganda and from 84 to 90% in Ethiopia. However, Mozambicans agreed 100% before and after the program.

Another training program conducted in Africa (13) also demonstrated the positive effects of a training program on participants’ good hygiene practices. To observe constant improved behavior and attitudes, training programs should be conducted continuously and be incorporated with a competency-based training curriculum framework (10) for food and feed testing laboratory personnel. This type of framework can serve as professional development by encouraging laboratory personnel participation in trainings. Finally, establishing

TABLE 6. Behavior of participants before and after the delivery of the Food Safety Laboratory Workshop^a

| GLP | Uganda before (%) | | | | | | Uganda after (%) | | | | | |
|--|-------------------|----|----|----|-----|------|------------------|----|----|----|-----|------|
| | SD | D | N | A | SA | IDNK | SD | D | N | A | SA | IDNK |
| My level of knowledge on GLP affects the quality of the tests I conduct. | 0 | 0 | 0 | 30 | 70 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| My behavior about GLP affects the quality of the tests I conduct. | 0 | 0 | 0 | 50 | 50 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| Frocks, lab coats, or other coverings designated for the testing area only prevent errors in laboratory testing. | 10 | 30 | 0 | 40 | 20 | 0 | 10 | 0 | 0 | 50 | 40 | 0 |
| Separate shoes or shoe coverings designated for the testing area only prevent errors in laboratory testing. | 10 | 30 | 0 | 40 | 20 | 0 | 10 | 0 | 0 | 20 | 70 | 0 |
| Use of gloves prevents errors in laboratory testing. | 10 | 30 | 0 | 50 | 10 | 0 | 0 | 10 | 0 | 20 | 70 | 0 |
| Handwashing prevents errors in laboratory testing. | 0 | 10 | 10 | 50 | 20 | 10 | 0 | 10 | 0 | 0 | 90 | 0 |
| It is important to sanitize my working area (e.g., benchtop) before starting my laboratory activities. | 0 | 0 | 0 | 20 | 80 | 0 | 0 | 0 | 0 | 10 | 90 | 0 |
| Quality management systems | | | | | | | | | | | | |
| Quality management systems (e.g., ISO/IEC 17025) are cumbersome. | 10 | 40 | 30 | 20 | 0 | 0 | 20 | 40 | 0 | 20 | 20 | 0 |
| Quality management systems (e.g., ISO/IEC 17025) are necessary. | 0 | 0 | 0 | 20 | 80 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| Quality management systems (e.g., ISO/IEC 17025) prevent testing errors. | 0 | 0 | 10 | 30 | 60 | 0 | 0 | 10 | 0 | 10 | 80 | 0 |
| Equipment calibration prevents testing errors. | 0 | 0 | 0 | 40 | 60 | 0 | 0 | 0 | 0 | 10 | 90 | 0 |
| I follow all instructions in the quality management system my laboratory has in place. | 0 | 0 | 10 | 60 | 30 | 0 | 0 | 0 | 10 | 40 | 50 | 0 |
| My manager makes the objectives of the quality management system clear to employees. | 0 | 0 | 0 | 60 | 40 | 0 | 0 | 0 | 0 | 20 | 80 | 0 |
| Training | | | | | | | | | | | | |
| I received training on GLP before I started working in this laboratory. | 0 | 10 | 0 | 60 | 30 | 0 | 0 | 10 | 0 | 10 | 80 | 0 |
| I receive refresher training on GLP annually. | 0 | 50 | 20 | 30 | 0 | 0 | 20 | 20 | 20 | 20 | 20 | 0 |
| Refresher trainings on GLP are a waste of time for experienced technicians. | 50 | 50 | 0 | 0 | 0 | 0 | 80 | 20 | 0 | 0 | 0 | 0 |
| I enjoy training new technicians. | 0 | 0 | 10 | 80 | 10 | 0 | 0 | 0 | 0 | 30 | 70 | 0 |
| I am confident in my ability to generate reliable results. | 0 | 0 | 0 | 70 | 30 | 0 | 0 | 0 | 0 | 20 | 80 | 0 |
| I would like to receive more training than I do. | 0 | 0 | 0 | 40 | 60 | 0 | 0 | 0 | 0 | 10 | 90 | 0 |
| International | | | | | | | | | | | | |
| The work my laboratory conducts is important for the economic success of my region and country. | 0 | 0 | 0 | 20 | 80 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| The work my laboratory conducts is important for the economic success of my country, especially in international and global terms. | 0 | 0 | 0 | 30 | 70 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| Having reliable testing laboratories means that the food products produced in the country and region are safe. | 0 | 10 | 0 | 20 | 70 | 0 | 0 | 0 | 0 | 30 | 70 | 0 |
| Cooperation among counties, especially testing laboratory standards and techniques, increases food safety. | 0 | 0 | 0 | 40 | 60 | 0 | 0 | 0 | 0 | 10 | 90 | 0 |
| Reliable testing laboratories are important for imported and exported food. | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |

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TABLE 6. Behavior of participants before and after the delivery of the Food Safety Laboratory Workshop^a (cont.)

| GLP | Mozambique before (%) | | | | | | Mozambique after (%) | | | | | |
|---|-----------------------|----|----|----|----|------|----------------------|----|----|----|-----|------|
| | SD | D | N | A | SA | IDNK | SD | D | N | A | SA | IDNK |
| My level of knowledge on GLP affects the quality of the tests I conduct. | 0 | 0 | 0 | 10 | 80 | 10 | 0 | 0 | 0 | 18 | 82 | 0 |
| My behavior about GLP affects the quality of the tests I conduct. | 0 | 0 | 0 | 10 | 80 | 10 | 0 | 0 | 0 | 9 | 91 | 0 |
| Frocks, lab coats, or other coverings designated for the testing area only prevent errors in laboratory testing. | 0 | 0 | 0 | 20 | 50 | 30 | 0 | 0 | 0 | 18 | 82 | 0 |
| Separate shoes or shoe coverings designated for the testing area only prevent errors in laboratory testing. | 0 | 0 | 0 | 30 | 60 | 10 | 0 | 0 | 0 | 9 | 91 | 0 |
| Use of gloves prevents errors in laboratory testing. | 0 | 0 | 0 | 40 | 60 | 0 | 0 | 0 | 9 | 9 | 82 | 0 |
| Handwashing prevents errors in laboratory testing. | 0 | 0 | 0 | 30 | 70 | 0 | 0 | 0 | 0 | 9 | 91 | 0 |
| It is important to sanitize my working area (e.g., benchtop) before starting my laboratory activities. | 0 | 0 | 0 | 10 | 80 | 10 | 0 | 0 | 0 | 27 | 73 | 0 |
| Quality management systems | | | | | | | | | | | | |
| Quality management systems (e.g., ISO/IEC 17025) are cumbersome. | 0 | 10 | 10 | 20 | 50 | 10 | 0 | 36 | 27 | 9 | 27 | 0 |
| Quality management systems (e.g., ISO/IEC 17025) are necessary. | 0 | 0 | 0 | 20 | 70 | 10 | 0 | 0 | 0 | 9 | 91 | 0 |
| Quality management systems (e.g., ISO/IEC 17025) prevent testing errors. | 0 | 0 | 0 | 10 | 80 | 10 | 0 | 0 | 0 | 9 | 91 | 0 |
| Equipment calibration prevents testing errors. | 0 | 0 | 0 | 10 | 80 | 10 | 0 | 9 | 0 | 9 | 82 | 0 |
| I follow all instructions in the quality management system my laboratory has in place. | 0 | 0 | 0 | 20 | 70 | 10 | 0 | 0 | 0 | 9 | 91 | 0 |
| My manager makes it clear to employees as to the objectives of the quality management system. | 0 | 0 | 0 | 20 | 70 | 10 | 0 | 0 | 9 | 27 | 64 | 0 |
| Training | | | | | | | | | | | | |
| I received training on GLP before I started working in this laboratory. | 0 | 0 | 30 | 20 | 30 | 20 | 0 | 0 | 18 | 27 | 55 | 0 |
| I receive refresher training on GLP annually. | 0 | 0 | 40 | 20 | 20 | 20 | 0 | 27 | 18 | 45 | 9 | 0 |
| Refresher trainings on GLP are a waste of time for experienced technicians. | 20 | 0 | 0 | 30 | 10 | 40 | 27 | 55 | 0 | 9 | 9 | 0 |
| I enjoy training new technicians. | 0 | 0 | 0 | 50 | 50 | 0 | 0 | 0 | 9 | 36 | 55 | 0 |
| I am confident in my ability to generate reliable results. | 0 | 0 | 10 | 0 | 70 | 20 | 0 | 0 | 0 | 0 | 91 | 9 |
| I would like to receive more training than I do. | 0 | 0 | 0 | 10 | 80 | 10 | 0 | 0 | 0 | 0 | 100 | 0 |
| International | | | | | | | | | | | | |
| The work my laboratory conducts is important for the economic success of my region and country. | 0 | 0 | 0 | 0 | 90 | 10 | 0 | 0 | 0 | 0 | 100 | 0 |
| The work my laboratory conducts is important for the economic success of my country especially in international and global terms. | 0 | 0 | 0 | 20 | 70 | 10 | 0 | 0 | 0 | 18 | 82 | 0 |
| Having reliable testing laboratories means that the food products produced in the country and region are safe. | 0 | 10 | 0 | 30 | 50 | 10 | 0 | 0 | 0 | 18 | 82 | 0 |
| Cooperation among counties, especially testing laboratory standards and techniques, increases food safety. | 0 | 0 | 0 | 10 | 80 | 10 | 0 | 0 | 0 | 0 | 100 | 0 |
| Reliable testing laboratories are important for imported and exported food. | 0 | 0 | 0 | 10 | 80 | 10 | 0 | 0 | 0 | 0 | 100 | 0 |

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TABLE 6. Behavior of participants before and after the delivery of the Food Safety Laboratory Workshop^a (cont.)

| GLP | Ethiopia before (%) | | | | | | Ethiopia after (%) | | | | | |
|--|---------------------|----|----|----|----|------|--------------------|----|----|----|-----|------|
| | SD | D | N | A | SA | IDNK | SD | D | N | A | SA | IDNK |
| My level of knowledge on GLP affects the quality of the tests I conduct. | 0 | 11 | 11 | 16 | 58 | 5 | 0 | 0 | 0 | 28 | 72 | 0 |
| My behavior about GLP affects the quality of the tests I conduct. | 5 | 11 | 5 | 16 | 53 | 11 | 6 | 0 | 0 | 28 | 67 | 0 |
| Frocks, lab coats, or other coverings designated for the testing area only prevent errors in laboratory testing. | 11 | 16 | 5 | 32 | 26 | 11 | 17 | 22 | 0 | 17 | 39 | 0 |
| Separate shoes or shoe coverings designated for the testing area only prevent errors in laboratory testing. | 11 | 21 | 21 | 11 | 37 | 5 | 22 | 17 | 6 | 11 | 44 | 0 |
| Use of gloves prevents errors in laboratory testing. | 0 | 0 | 5 | 26 | 58 | 5 | 11 | 0 | 0 | 28 | 61 | 0 |
| Handwashing prevents errors in laboratory testing. | 5 | 5 | 0 | 32 | 53 | 5 | 6 | 0 | 0 | 22 | 72 | 0 |
| It is important to sanitize my working area (e.g., benchtop) before starting my laboratory activities. | 0 | 0 | 0 | 5 | 63 | 32 | 0 | 0 | 0 | 0 | 72 | 28 |
| Quality management systems | | | | | | | | | | | | |
| Quality management systems (e.g., ISO/IEC 17025) are cumbersome. | 32 | 16 | 5 | 21 | 16 | 11 | 44 | 17 | 0 | 6 | 22 | 11 |
| Quality management systems (e.g., ISO/IEC 17025) are necessary. | 0 | 0 | 0 | 26 | 68 | 5 | 0 | 0 | 0 | 0 | 100 | 0 |
| Quality management systems (e.g., ISO/IEC 17025) prevent testing errors. | 0 | 0 | 0 | 21 | 63 | 16 | 6 | 0 | 0 | 17 | 67 | 11 |
| Equipment calibration prevents testing errors. | 0 | 0 | 0 | 11 | 74 | 16 | 6 | 0 | 0 | 22 | 67 | 6 |
| I follow all instructions in the quality management system my laboratory has in place. | 0 | 0 | 11 | 21 | 58 | 16 | 0 | 0 | 0 | 11 | 83 | 6 |
| My manager makes the objectives of the quality management system clear to employees. | 5 | 0 | 11 | 26 | 37 | 16 | 0 | 6 | 6 | 17 | 67 | 6 |
| Training | | | | | | | | | | | | |
| I received training on GLP before I started working in this laboratory. | 5 | 5 | 21 | 37 | 16 | 16 | 0 | 0 | 17 | 17 | 61 | 6 |
| I receive refresher training on GLP annually. | 21 | 11 | 11 | 26 | 16 | 16 | 0 | 17 | 11 | 28 | 39 | 6 |
| Refresher trainings on GLP are a waste of time for experienced technicians. | 58 | 16 | 11 | 5 | 0 | 5 | 50 | 17 | 0 | 6 | 22 | 6 |
| I enjoy training new technicians. | 0 | 0 | 26 | 16 | 47 | 11 | 0 | 0 | 6 | 22 | 67 | 6 |
| I am confident in my ability to generate reliable results. | 0 | 5 | 11 | 26 | 47 | 11 | 0 | 0 | 6 | 28 | 56 | 11 |
| I would like to receive more training than I do. | 5 | 0 | 11 | 11 | 58 | 16 | 0 | 0 | 6 | 6 | 78 | 11 |
| International | | | | | | | | | | | | |
| The work my laboratory conducts is important for the economic success of my region and country. | 0 | 5 | 5 | 16 | 63 | 11 | 0 | 0 | 0 | 17 | 72 | 11 |
| The work my laboratory conducts is important for the economic success of my country, especially in international and global terms. | 0 | 5 | 0 | 16 | 63 | 16 | 0 | 0 | 0 | 22 | 67 | 11 |
| Having reliable testing laboratories means that the food products produced in the country and region are safe. | 11 | 5 | 11 | 16 | 53 | 5 | 17 | 0 | 0 | 11 | 61 | 11 |
| Cooperation among counties, especially testing laboratory standards and techniques, increases food safety. | 0 | 5 | 0 | 16 | 74 | 5 | 0 | 0 | 0 | 17 | 72 | 11 |
| Reliable testing laboratories are important for imported and exported food. | 0 | 0 | 5 | 21 | 68 | 5 | 0 | 0 | 0 | 17 | 72 | 11 |

^a SD, strongly disagree; D, disagree; N, neutral; A, agree; SA, strongly agree; IDNK, I do not know.

TABLE 7. Attitude of participants before and after the delivery of the Food Safety Laboratory Workshop^a

| General food safety practices | Uganda before (%) | | | | | | Uganda after (%) | | | | | |
|---|------------------------------|----|----|----|-----|------|-----------------------------|---|----|----|-----|------|
| | SD | D | N | A | SA | IDNK | SD | D | N | A | SA | IDNK |
| 1. My level of knowledge on SOP affects the quality of tests I conduct. | 0 | 10 | 10 | 20 | 60 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| 2. Good personal hygiene practice helps make food safe to eat. | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| 3. Good personal hygiene is always important to run safe tests in the laboratory. | 0 | 0 | 0 | 10 | 90 | 0 | 0 | 0 | 0 | 13 | 88 | 0 |
| 4. I believe my decisions impact the test results that I conduct in the laboratory. | 0 | 0 | 0 | 40 | 60 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| 5. This food testing laboratory has a responsibility to train individuals working in this lab on good personal hygiene. | 0 | 0 | 0 | 20 | 80 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| 6. This food testing laboratory has a responsibility to train individuals working in this lab on SOP. | 0 | 0 | 0 | 10 | 90 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| 7. It is important to record which employees in the laboratory handle food allergens. | 0 | 0 | 10 | 20 | 70 | 0 | 0 | 0 | 0 | 25 | 75 | 0 |
| Implementation, policies, inspection, and training | | | | | | | | | | | | |
| 8. Internal audits are necessary to observe the implementation of general food safety practices. | 0 | 0 | 10 | 20 | 70 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| 9. As a laboratory technician/manager, I am as equally responsible as others to produce the best results. | 0 | 0 | 0 | 0 | 80 | 20 | 0 | 0 | 0 | 0 | 100 | 0 |
| 10. I am a certified technician/manager, so my food testing results should be accurate. | 0 | 0 | 10 | 20 | 60 | 10 | 0 | 0 | 25 | 25 | 50 | 0 |
| 11. The more I use the instruments in the laboratory, the more I increase my skills. | 0 | 0 | 10 | 20 | 70 | 0 | 0 | 0 | 0 | 13 | 88 | 0 |
| 12. Written SOPs and good manufacturing practices are equally important for the best results. | 0 | 0 | 0 | 0 | 90 | 10 | 0 | 0 | 0 | 0 | 100 | 0 |
| 13. Every employee/staff member should be trained before working in this laboratory. | 0 | 0 | 0 | 20 | 80 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| 14. It is important to have local/regional/state/governmental regulations to keep food safe. | 0 | 0 | 0 | 20 | 80 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| 15. Local/regional/state/governmental regulatory authorities should inspect this facility on a regular basis. | 0 | 0 | 0 | 20 | 80 | 0 | 0 | 0 | 0 | 13 | 88 | 0 |
| 16. The food testing laboratory has a responsibility to train individual workers. | 0 | 0 | 0 | 10 | 90 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| 17. I believe it is important to have regular training sessions for employees. | 0 | 0 | 0 | 20 | 80 | 0 | 0 | 0 | 0 | 13 | 88 | 0 |
| 18. It is important to be certified by local/regional/governmental/international agencies on our testing methods. | 0 | 0 | 0 | 10 | 90 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| | Mozambique before (%) | | | | | | Mozambique after (%) | | | | | |
| General food safety practices | SD | D | N | A | SA | IDNK | SD | D | N | A | SA | IDNK |
| 1. My level of knowledge on SOP affects the quality of tests I conduct. | 0 | 0 | 0 | 22 | 78 | 0 | 0 | 0 | 0 | 30 | 70 | 0 |
| 2. Good personal hygiene practice helps make food safe to eat. | 0 | 0 | 0 | 22 | 78 | 0 | 0 | 0 | 0 | 20 | 80 | 0 |
| 3. Good personal hygiene is always important to run safe tests in the laboratory. | 0 | 0 | 0 | 22 | 78 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| 4. I believe my decisions impact the test results that I conduct in the laboratory. | 0 | 0 | 0 | 11 | 89 | 0 | 0 | 0 | 0 | 10 | 90 | 0 |

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TABLE 7. Attitude of participants before and after the delivery of the Food Safety Laboratory Workshop^a (cont.)

| General food safety practices | Mozambique before (%) | | | | | | Mozambique after (%) | | | | | |
|---|-----------------------|----|----|----|-----|------|----------------------|---|---|----|----|------|
| | SD | D | N | A | SA | IDNK | SD | D | N | A | SA | IDNK |
| 5. This food testing laboratory has a responsibility to train individuals working in this lab on good personal hygiene. | 0 | 0 | 0 | 33 | 67 | 0 | 0 | 0 | 0 | 30 | 70 | 0 |
| 6. This food testing laboratory has a responsibility to train individuals working in this lab on SOP. | 0 | 0 | 0 | 44 | 56 | 0 | 0 | 0 | 0 | 20 | 80 | 0 |
| 7. It is important to record which employees in the laboratory handle food allergens. | 0 | 0 | 0 | 56 | 44 | 0 | 0 | 0 | 0 | 20 | 80 | 0 |
| Implementation, policies, inspection, and training | | | | | | | | | | | | |
| 8. Internal audits are necessary to observe the implementation of general food safety practices. | 0 | 0 | 0 | 11 | 89 | 0 | 0 | 0 | 0 | 20 | 80 | 0 |
| 9. As a laboratory technician/manager, I am as equally responsible as others to produce the best results. | 0 | 0 | 0 | 11 | 89 | 0 | 0 | 0 | 0 | 20 | 80 | 0 |
| 10. I am a certified technician/manager, so my food testing results should be accurate. | 0 | 0 | 0 | 22 | 78 | 0 | 0 | 0 | 0 | 20 | 80 | 0 |
| 11. The more I use the instruments in the laboratory, the more I increase my skills. | 0 | 0 | 0 | 22 | 78 | 0 | 0 | 0 | 0 | 10 | 90 | 0 |
| 12. Written SOPs and good manufacturing practice are equally important for the best results. | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 20 | 80 | 0 |
| 13. Every employee/staff member should be trained before working in this laboratory. | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 30 | 70 | 0 |
| 14. It is important to have local/regional/state/governmental regulations to keep food safe. | 0 | 0 | 0 | 22 | 78 | 0 | 0 | 0 | 0 | 40 | 60 | 0 |
| 15. Local/regional/state/governmental regulatory authorities should inspect this facility on a regular basis. | 0 | 0 | 0 | 33 | 67 | 0 | 0 | 0 | 0 | 30 | 70 | 0 |
| 16. The food testing laboratory has a responsibility to train individual workers. | 0 | 0 | 0 | 22 | 78 | 0 | 0 | 0 | 0 | 40 | 60 | 0 |
| 17. I believe it is important to have a regular training sessions for employees. | 0 | 0 | 0 | 11 | 89 | 0 | 0 | 0 | 0 | 40 | 60 | 0 |
| 18. It is important to be certified by local/regional/governmental/international agencies on our testing methods. | 0 | 0 | 0 | 22 | 78 | 0 | 0 | 0 | 0 | 30 | 70 | 0 |
| General food safety practices | Ethiopia before (%) | | | | | | Ethiopia after (%) | | | | | |
| | SD | D | N | A | SA | IDNK | SD | D | N | A | SA | IDNK |
| 1. My level of knowledge on SOP affects the quality of tests I conduct. | 0 | 11 | 16 | 11 | 58 | 5 | 0 | 5 | 0 | 32 | 63 | 0 |
| 2. Good personal hygiene practice helps make food safe to eat. | 0 | 0 | 0 | 26 | 74 | 0 | 0 | 0 | 0 | 11 | 95 | 0 |
| 3. Good personal hygiene is always important to run safe tests in the laboratory. | 0 | 0 | 0 | 21 | 79 | 0 | 0 | 0 | 0 | 5 | 95 | 0 |
| 4. I believe my decisions impact the test results that I conduct in the laboratory. | 0 | 5 | 5 | 26 | 47 | 16 | 5 | 5 | 5 | 21 | 63 | 0 |
| 5. This food testing laboratory has a responsibility to train individuals working in this lab on good personal hygiene. | 0 | 0 | 0 | 11 | 89 | 0 | 0 | 0 | 0 | 11 | 89 | 0 |
| 6. This food testing laboratory has a responsibility to train individuals working in this lab on SOP. | 0 | 0 | 5 | 16 | 79 | 0 | 0 | 0 | 0 | 21 | 79 | 0 |
| 7. It is important to record which employees in the laboratory handle food allergens. | 0 | 0 | 11 | 11 | 79 | 0 | 11 | 0 | 0 | 21 | 68 | 0 |

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TABLE 7. Attitude of participants before and after the delivery of the Food Safety Laboratory Workshop^a (cont.)

| General food safety practices | Ethiopia before (%) | | | | | | Ethiopia after (%) | | | | | |
|---|---------------------|---|----|----|----|------|--------------------|---|----|----|----|------|
| | SD | D | N | A | SA | IDNK | SD | D | N | A | SA | IDNK |
| Implementation, policies, inspection, and training | | | | | | | | | | | | |
| 8. Internal audits are necessary to observe the implementation of general food safety practices. | 0 | 5 | 0 | 16 | 79 | 0 | 0 | 0 | 0 | 32 | 63 | 5 |
| 9. As a laboratory technician/manager, I am as equally responsible as others to produce the best results. | 5 | 0 | 0 | 21 | 74 | 0 | 0 | 0 | 0 | 5 | 89 | 5 |
| 10. I am a certified technician/manager, so my food testing results should be accurate. | 0 | 5 | 11 | 37 | 42 | 5 | 0 | 5 | 11 | 11 | 68 | 5 |
| 11. The more I use the instruments in the laboratory, the more I increase my skills. | 0 | 0 | 0 | 26 | 68 | 5 | 0 | 0 | 0 | 5 | 89 | 5 |
| 12. Written SOPs and good manufacturing practices are equally important for the best results. | 0 | 0 | 0 | 16 | 79 | 5 | 0 | 0 | 0 | 11 | 89 | 0 |
| 13. Every employee/staff member should be trained before working in this laboratory. | 0 | 0 | 5 | 16 | 79 | 0 | 0 | 0 | 0 | 11 | 89 | 0 |
| 14. It is important to have local/regional/state/governmental regulations to keep food safe. | 5 | 0 | 0 | 5 | 89 | 0 | 0 | 0 | 0 | 11 | 89 | 0 |
| 15. Local/regional/state/governmental regulatory authorities should inspect this facility on a regular basis. | 0 | 0 | 11 | 16 | 74 | 0 | 0 | 0 | 0 | 5 | 95 | 0 |
| 16. The food testing laboratory has a responsibility to train individual workers. | 5 | 0 | 5 | 11 | 79 | 0 | 0 | 0 | 0 | 5 | 95 | 0 |
| 17. I believe it is important to have regular training sessions for employees. | 0 | 0 | 0 | 21 | 79 | 0 | 0 | 0 | 0 | 11 | 89 | 0 |
| 18. It is important to be certified by a local/regional/governmental/international agencies on our testing methods. | 0 | 0 | 0 | 16 | 84 | 0 | 0 | 0 | 5 | 5 | 90 | 0 |

^aSD, strongly disagree; D, disagree; N, neutral; A, agree; SA, strongly agree; IDNK, I do not know.

equivalency of competencies among laboratories in the world has the potential to provide consistent, accurate, and reliable test results.

CONCLUSIONS

In this study, a curriculum was developed and disseminated to laboratory personnel of food safety laboratories on the basis of an earlier needs assessment (14). The curriculum included topics, such as lab safety, quality assurance, validation of test methods and equipment, sampling protocols, accreditation, data analysis, statistical process control, troubleshooting, record keeping, and training. The workshop was delivered to ~45 participants from food safety testing laboratories in Uganda, Mozambique, and Ethiopia.

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As a result of the workshop, the knowledge, hand-washing skills, behaviors, and attitudes of laboratory personnel were significantly improved. These types of training and improvements may provide increased confidence in personnel to obtain accurate and reliable test results, which may also have the potential to produce a safer food supply.

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