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Training and tool supply to enhance food safety behaviors among ready-to-eat chicken vendors in informal markets in Ouagadougou, Burkina Faso: A randomized-controlled trial

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ABSTRACT

In Burkina Faso, street food vendors are key in ensuring food safety in urban markets, particularly within the poultry value chain. The sale of high-risk ready-to-eat chicken by these vendors poses substantial health hazards, emphasizing the urgency for capacity-building to enhance food safety practices. This study evaluated the effect of a participatory interactive three-day training program coupled with tool supply on self-reported and observed behavior, and knowledge, attitudes, and cognitions of vendors of ready-to-eat chicken meat in Ouagadougou's informal markets. A two-armed RCT was conducted, including pre- and post-training vendor surveys, along with direct outlet observations. Total sample size comprised 162 vendors, with 72 in the treatment group and 90 in the control group. Self-reported behavior - measured on a five-point scale - significantly improved in the treatment group including higher frequency of mask wearing (1.8 ± 0.8 vs 2.5 ± 1.2, $p < 0.001$) and inspecting nail hygiene (4.3 ± 0.8 vs. 4.7 ± 0.6, $p < 0.001$). Treatment outlets improved on securing adequate evisceration platforms (1.3 ± 0.6 vs. 1.0 ± 0.5, $p = 0.054$), regular carcass water renewal (61.8% vs. 36.4%, $p = 0.038$), and handwashing during carcass management (1.1 ± 0.5 vs. 0.9 ± 0.3, $p = 0.008$). Better adherence to handwashing (1.1 ± 0.4 vs. 0.9 ± 0.3, $p = 0.051$), fork use (58.9% vs. 41.8%, $p = 0.029$), proper handwashing facilities (38.4% vs. 20.9%, $p = 0.014$), and waste management (64.4% vs. 37.8%, $p < 0.001$) were observed in treatment outlets. Trained vendors scored significantly higher than controls on knowledge (effect size 0.75, $p < 0.001$). Vendors rated the perceived usefulness and perceived ease of use, trust in materials/tools - measured on a five-point scale - as high, and perceived mean increased daily profits (21,242 FCFA) and number of customers (8.3) following training. In conclusion, training combined with a tool package proved effective in fostering significant food safety behavior changes, underscoring its substantial impact beyond just knowledge enhancement. For lasting behavior changes, ongoing training and support, an enabling environment, and strong incentives that prioritize vendor food safety behaviors in informal markets are crucial.

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1. Background

Food safety is crucial for healthy food systems and public health (Grace et al., 2020, pp. 338–365; Vipham et al., 2020). Globally, foodborne disease (FBD), mostly caused by microbes, impact at least one in ten consumers, costing over $100 billion annually in low- and middle-income countries (LIMCs) alone (Grace, Dipeolu, & Alonso, 2019; Havelaar et al., 2022; Jaffee, Unnevehr, & Cassou, 2019). Africa faces the highest per capita burden with yearly economic losses exceeding $23 billion due to FBD (Havelaar et al., 2015). In LMICs, many food hazards prevail in urban informal, traditional markets that are characterized by limited regulation, infrastructure, access to information and resources (HLPE, 2017; Roesel & Grace, 2014). Informal markets, encompassing public markets, small shops, and eateries, are key sources of animal-based foods and vegetables, with up to 90% of these products sold through such channels. Additionally, these markets are increasingly popular for ready-to-eat food, which is a high-risk category (Asiegbu, Lebelo, & Tabit, 2016; Grace et al., 2019; Havelaar et al., 2022; Paudyal et al., 2017). High consumption of risky foods outside homes, amplifies the impact of unhygienic food handling by street vendors, a major factor behind foodborne illness in urban consumers (Hoffmann, Moser, & Saak, 2019; Landais et al., 2023). For instance, in seven African countries, ready-to-eat foods displayed notably high rates of major pathogens: *Escherichia coli* was present in a third of sold street food, while *Salmonella* spp. was found in 21.7% of samples (Paudyal et al., 2017). A review on vendor knowledge, attitudes, and practices in LMICs showed that food safety knowledge among vendors was generally limited, as evident in unsafe practices and low compliance with food safety regulations (Wallace, Mittal, Lambertini, & Nordhagen, 2022.)

In Burkina Faso, especially in the capital Ouagadougou, poultry is an integral part of everyday diets and the local economy (Dione et al., 2021; Nikiema et al., 2021; Somda et al., 2018). Chicken production significantly drives the agricultural economy, with 80% of households raising poultry, and 6% of the agricultural gross domestic product being based on poultry production (Dione et al., 2021; Dione, Ilboudo, Madjdian, et al., 2023). Poultry meat, mostly locally-produced, constitutes 16% of consumed meat and production is anticipated to grow by 302% between 2015 and 2050 (FAO, 2018). Over three quarters of poultry is consumed at street outlets ('maquis') (Somda et al., 2018). Safety concerns surround ready-to-eat chicken meat, with recent studies revealing unacceptably high microbial contamination levels: *Campylobacter* spp. (85%);, *Salmonella enterica* (55–57%), and *Escherichia coli* (up to 45%) were detected in chicken meat and slaughter wash water (Grace et al., 2018; Kagambèga et al., 2018; Somda et al., 2018). Moreover, a recent study among chicken meat vendors in Ouagadougou highlighted poor market and outlet sanitation and hygiene, including unhygienic slaughtering practices, poor waste management, and insufficient handwashing practices in-between chicken preparation activities, each of these practices potentially contributing to food hazards. For instance, 92% of vendors slaughtered chickens on a bare floor and most vendors did not keep practices such as scalding, plucking, evisceration and grilling practices separate, risking cross-contamination (Assefa et al., 2023). Whereas annual losses due to FBD-related deaths in Burkina Faso amount to about $3 billion (Grace et al., 2018), in 2017, the aggregated economic cost related to FBD associated with *Salmonella enterica* and *Campylobacter* spp. in chicken meat were estimated at $120 million (van Wagenberg & Havelaar, 2023). Hence, to curb FBD and enhance food safety in urban informal markets in Burkina Faso, urgent improvements in hygienic practices related to handling and preparing chicken meat are imperative.

Increasing knowledge and awareness through educational training has been one strategy to improve food safety among food vendors, assuming that it is a lack of knowledge that leads to unsafe practices (Insfran-Rivarola et al., 2020; Soon, Baines, & Seaman, 2012; Yeargin, Gibson, & Fraser, 2021; Young, Waddell, Wilhelm, & Greig, 2020). Such traditional educational efforts based on knowledge sharing have shown success in increasing knowledge, but less in changing attitudes and behavior (Egan et al., 2007; Insfran-Rivarola et al., 2020; Soon et al., 2012). For instance, a review highlighted persisting gaps between knowledge and reported practices, and between observed and self-reported food safety behavior among consumers and vendors in Nigeria (Nordhagen, 2022). Despite knowledge not being a guarantee for behavior change, numerous training programs in LMICs rely on information provision or increasing knowledge over enhancing vendor capacity for food safety practices. Reviews on food safety interventions in Asia and Sub-Saharan Africa, including interventions based on information sharing that involved informal vendors, showed positive impacts on knowledge (Grace et al., 2018; Kwoba et al., 2023). Although to a lesser extent, promising effects on food handling behavior were observed, the authors warn that the majority of study designs used were prone to bias and claims of impact could thus not be conclusively supported. Educational training focused solely on increasing knowledge does not guarantee behavioral success, as contextual factors such as the availability of clean water, market infrastructure, or financial resources, as well as behavioral determinants such as food safety risk perceptions, perceived control and responsibilities, motivation, and social norms impact behavior change (Global Alliance for Improved Nutrition, 2022). Aside from incentives to participate in training (Grace et al., 2018), trainings should therefore go beyond increasing knowledge and (theoretical) skills, to also consider individual and intrapersonal behavioral determinants including abilities and perceptions, and address contextual and physical factors in vendors' direct work environment that may hinder or facilitate behavior change (Yeargin et al., 2021).

The impact of risk-management capacity-building interventions targeting vendors in informal markets, remains uncertain (Ortega & Tschirley, 2017; Wertheim-Heck, Raneri, & Oosterveer, 2019). Studies assessing the impact of food safety interventions targeting vendors in informal markets often focus on traditional Knowledge-Attitude-Practice (KAP) pathways, in which a large focus is placed on assessing knowledge and self-reported practices post-training, despite the understanding that knowledge and self-reported practices do not necessarily result in or reflect improved observed practices (Grace et al., 2018; Nordhagen, 2022). Direct observations of behavior in particular are rare (Global Alliance for Improved Nutrition, 2022). Pressing research gaps moreover include understanding impacts of training programs on behavioral determinants, including vendor attitudes, beliefs, and cognitions concerning food safety behavior, because of a general lack of the use of behavioral theories in the design and impact assessment of such interventions (Lin & Roberts, 2020; Nordhagen, 2022; Wallace et al., 2022). Additionally, the majority of studies lack control groups, hindering causality statements (Bass et al., 2022; Young et al., 2020; Young, Greig, Wilhelm, & Waddell, 2019).Randomized Controlled Trials (RCTs) in Sub-Saharan Africa targeting food safety interventions are scarce compared to studies from high-income countries (Bass et al., 2022; Grace et al., 2018). Finally, similar to high-income contexts (Young et al., 2019) and to the best of our knowledge, in the African context there are very few RCTs that assessed the impact of interventions that support vendors in implementing food safety knowledge and skills in daily practice through training and resource supply (Heilmann, Roesel, Grace, Bauer, & Clausen, 2017; Hennessey et al., 2020; Roesel et al., 2023; Traoré et al., 2021).

The "Pull-Push project"[1] (2018–2023) led by the International Livestock Research Institute (ILRI) aimed to promote food safety in urban informal markets in Burkina Faso and Ethiopia. To address the prevalent hazards in ready-to-eat chicken sold in urban markets in Burkina Faso, a unique participatory vendor training program was developed after assessing value chains, conducting vendor surveys, and

[1] www.ilri.org/research/projects/urban-food-markets-africa-incentivizing-food-safety-using-pull-push-approach.

engaging national food safety stakeholders (Assefa et al., 2023; Dione et al., 2021; Gemeda et al., 2021). This intervention aimed to guide vendors of ready-to-eat chicken meat in street restaurants in Ouagadougou, in implementing best practices to enhance the safety of chicken at sale. The training program therefore included food safety education and training coupled with the distribution of tools that supported vendors to directly implement lessons learnt at their outlets after completing training.

The aim of this study is to assess the intervention's impact on: 1) vendors' observed and self-reported food safety behavior; and 2) behavioral determinants knowledge, attitudes, and cognitions. A combination of the KAP framework and the Technology Acceptance Model (TAM) (Ajzen, 1991; Davis, 1989) guided this study conceptually. KAP assumes that vendor knowledge and attitudes impact food safety practices, while TAM ties vendors' system acceptance (such as training and tools) to their attitudes, particularly regarding perceived usefulness (enhancing job performance) and ease of use (favoring minimal effort) (Davis, 1989). Ultimately, increased knowledge, attitudes, and intentions might prompt vendors to adopt safer food handling practices. Findings of this study may guide the design of effective food safety training for Burkina Faso's vendors and beyond, aiming for better food safety practices and ultimately, reducing FBD.

2. Methods

2.1. Study design and study population

A two-arm RCT was conducted (i.e., treatment and control group, not pre-registered) among vendors of ready-to-eat chicken in informal markets in Ouagadougou with or without an in-house slaughter place, and with a dining area or take-away facility. Sample size was derived from power calculations based on a recent meta-analysis showing Hedges' g effect sizes of 0.80 and 0.45 for self-reported and observed vendor practices (Insfran-Rivarola et al., 2020). G*Power computed a priori sample sizes for independent means differences at 80% power, two-sided hypothesis, 5% significance level, and 1:1 allocation ratio (Faul, Erdfelder, Buchner, & Lang, 2009), determining 79 vendors per RCT group. Accounting for a drop-out rate of 20% in each group, our total sample size was 95 outlets in each arm, totaling 190 outlets.

2.2. Sampling

The sampling frame for this study was established through a 2021 market census in Ouagadougou, identifying 622 outlets selling ready-to-eat chicken meat (Assefa et al., 2023) from which 190 outlets were selected for inclusion via simple random sampling. Selected outlets were then checked for closure and eligibility based on the following inclusion criteria: 1) permanent location; 2) offering take-away or on-site dining; 3) owner aged over 18 years; and 4) willingness to participate and provide written consent. In total, 192 outlets took part in the study, surpassing the planned number by two due to GPS location errors. As these two outlets met the inclusion criteria without affecting results, they were included in the study. After baseline data collection, 96 outlets each were randomly assigned to the treatment or control arm using similar random number generation in Excel. There were no significant differences between the two groups in terms of sociodemographic, economic, and outlet traits (see also Table 1), indicating a balanced distribution of participants and successful randomization. Vendors of treatment outlets were invited for training, while vendors of control outlets received an invitation for training two months after endline data collection. During the intervention phase, 21 outlets missed training despite reminders and efforts to reschedule their training slot. At endline, seven control outlets dropped out. After excluding drop-outs, the analytical sample included 164 outlets with complete observational data, and 162 outlets with complete survey data (Figs. 1 and 2).

Table 1
Sample descriptives and differences between arms at baseline.

		All (162)	Control (n = 90)	Treatment (n = 72)	p-value
		Mean (SD) or n (%)	Mean (SD) or n (%)	Mean (SD) or n (%)	
Sex	Female	1 (0.6)	0 (0)	1 (1.4%)	0.262
	Male	161 (99.4)	90 (100)	71 (98.6%)	
Mean Age		36.9 (9.9)	35.7 (9.8)	38.4 (9.8)	0.082
Education	No (formal)	83 (51.2)	41 (45.6)	42 (58.9)	0.114
	Primary	47 (29.0)	32 (35.6)	15 (20.8)	
	Secondary or higher	32 (19.8)	17 (18.9)	15 (20.8)	
Mean years in chicken business		9.1 (6.8)	9.0 (6.7)	9.2 (6.9)	0.834
Outlet is only income source		117 (72.2)	67 (74.4)	50 (69.4)	0.480
Other income sources	Agriculture/ livestock	5 (11.1)	4 (17.4)	1 (4.6)	0.170
	Non-food business	20 (44.4)	10 (43.5)	10 (45.5)	0.894
	Food business	15 (33.3)	7 (30.4)	8 (36.4)	0.178
	Other	9 (20)	5 (21.7)	4 (18.2)	0.089
Outlet has in-house slaughter space		82 (50.0)	43 (47.8)	38 (52.8)	0.527
No. of employees		3.3 (2.0)	3.4 (2.0)	3.2 (2.0)	0.451
Daily no. chicken slaughtered[a]		28.5 (24.2)	28.6 (25.7)	28.4 (22.6)	0.961
Daily no. carcasses processed		29.1 (22.3)	28.7 (23.6)	29.5 (20.7)	0.824
Daily no. served customers		26.1 (19.4)	26.7 (21.3)	25.2 (16.9)	0.621
Dish type	Flamed chicken (on firewood)	82 (50.6)	42 (46.7)	40 (55.6)	0.261
	Braised chicken (on charcoal)	73 (45.1)	45 (50.0)	28 (38.9)	0.158
	Fried chicken (oil)	17 (10.5)	9 (10.0)	8 (11.1)	0.819
	Cooked with vegetables	68 (42.0)	38 (42.4)	30 (41.7)	0.943
	Roasted chicken	24 (14.8)	17 (18.9)	7 (9.7)	0.103
	Other	14 (8.6)	9 (10)	5 (6.9)	0.492
Ever participated in food safety training		17 (10.5)	7 (0.8)	10 (0.14)	0.442

Notes.
[a] Only asked if outlet had in-house slaughter space (n's control: 46, treatment 39).

2.3. Training program & tool package

The interactive and participatory training program included the distribution of a tool package to facilitate the adoption of safe food practices at outlets directly upon completion of the training. The training was delivered by a diverse team of six trainers from the Ministry of Health, Livestock, Agriculture and Trade, and Ouagadougou's Food Hygiene department, who were trained by experts from Ouagadougou University and ILRI. The training consisted of nine interactive sessions conducted over three subsequent half days (lasting for max. five hours). Sessions addressed learning outcomes related to: 1) the importance and impact of hygienic practices; 2) sources of microorganisms; 3) live chicken management; 4) safe slaughter practices; 5) chicken carcass management; 6) food preparation; 7) seasoning and service; 8) personal hygiene and health; and 9) environment health and sanitation (Dione,

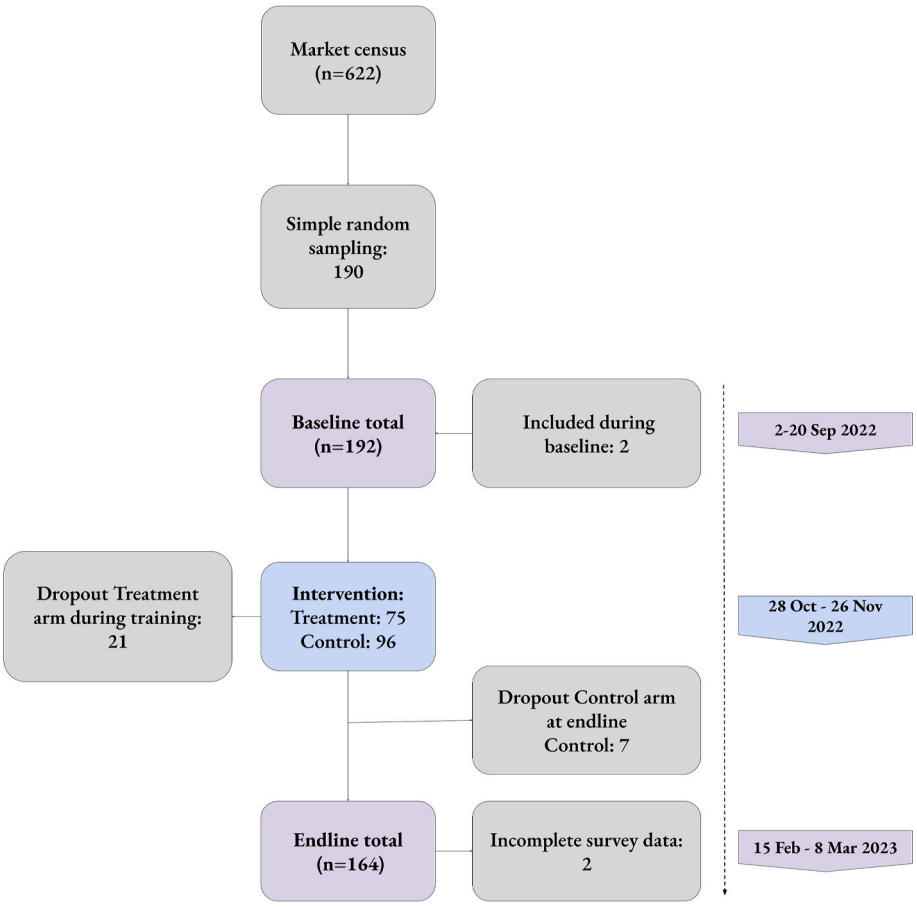

Fig. 1. Sampling flowchart.

Ilboudo, Kagambèga, & Knight-Jones, 2023). In addition, a business management skills session targeting participating outlet owners/managers only was delivered by an external consultant. This module focused on effective and informal business management and aimed to enhance the viability and sustainability of implementing food safety measures. The module included business management skills, business creation processes, and management principles. Ultimately, improved sales or expansion of business were assumed to act as an extra incentive for the implementation of food safety practices (Alonso, Muunda, Ahlberg, Blackmore, & Grace, 2018). Training sessions consisted of group and plenary discussions, lectures, quizzes, demonstrations, a lab experiment, and case stories. Upon completion, vendors received a certificate and a low-cost, renewable, and easy-to-use tool package including handwashing materials (i.e., kettle and basin), liquid soap, plastic cutting board and table cloth, cleaning sponge, plastic garbage bin, apron and a cap. A total of six trainings, each with a maximum of 20 participants, were held between 28 October and November 26, 2022. Control outlets received the same training program and tools in May 2023, after endline data collection.

2.4. Data collection

Data collection combined direct outlet observations with vendor surveys to offer a multifaceted exploration of the intervention's impact. Baseline data were collected between 2–20 September 2022 and endline data collection followed three months after the training, from 15 February to 8 March. Vendor knowledge, attitudes, and self-reported practices were measured before and after the training through vendor surveys, while actual practices were observed through direct observations. Items were developed by the authors and inspired by previous vendor KAP studies related to the safety of street foods sold in informal markets in LMICs (Abbot, Byrd-Bredbenner, Schaffner, Bruhn, & Blalock, 2009; Choudhury, Mahanta, Goswami, & Mazumder, 2011; Trafialek et al., 2018) and the United States (Abbot et al., 2009), and in accordance with WHO's Five Keys to Safer Food manual (WHO, 2006). Due to the absence of a standardized questionnaire, items were specifically tailored to ready-to-eat chicken food safety practices and aligned with the training modules. Vendors were informed about interviews and observations at two time points prior to the study, but were not informed about the exact times. Non-affiliated enumerator-observer pairs collected the data, having received training over a three-day session, which involved questionnaire and observation checklist pre-testing at the market. Surveys and observations occurred during outlet operating hours, lasting no more than an hour to minimize disruption to daily operations. Observation checklists and surveys were programmed in French in KoboToolbox and administered on mobile devices.

2.4.1. Primary outcomes: observed and self-reported food safety behaviors

Direct observations (known to vendors) were conducted before and after training to observe practices and outlet conditions. A total of 36 items were observed, including 16 matching observational and self-reported behaviors rated on a three-point scale ('2′ to '0′). 'Yes' ('1′) or 'No' ('0′) was used when none of these options fit. Where observation was not feasible, data were coded as missing. Additionally we collected general outlet details: staff count, dishes sold, consumer numbers, hygiene license visibility, and employee health cards. At endline, we noted the presence of training certificates and tool usage.

Simultaneous with observations, vendor surveys were conducted to assess self-reported behaviors. Self-reported behavior covered topics from training sessions three to nine (Supplementary Table A1) for which

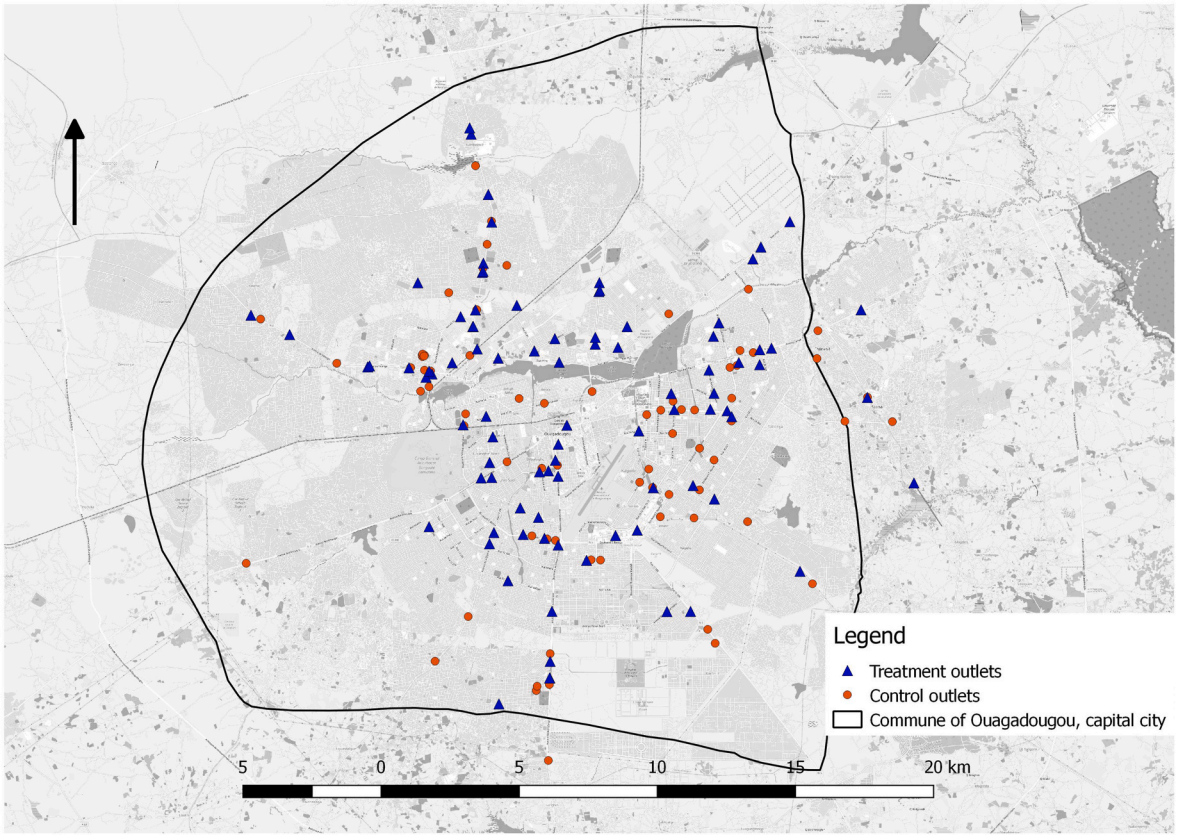

Fig. 2. Distribution of RCT outlets.

all vendors were asked ten questions about food safety practices and, if they had an in-house slaughter-site (n = 84), an additional eight questions about live chicken management and slaughter practices. All items were phrased as frequency questions (e.g., "how often do you use a fork and knife when cutting chicken") scored on five-point Likert scales ranging from never ('0') to always ('1'), or with 'daily' as minimum response category and 'less than once a week/month' as maximum response category. Two total self-reported behavior scores were calculated for items by summing the scores of items applicable to all outlets (max. score 50) and items applicable to outlets with in-house slaughter-site (max. score 40).

2.4.2. *Secondary outcomes: vendor knowledge, attitudes and cognitions*

Surveys moreover assessed knowledge, attitudes, and cognitions as important behavioral determinants. Attitudes and cognition items were inspired by studies on psychosocial and behavioral food safety indicators (Byrd-Bredbenner et al., 2007; Byrd-Bredbenner et al., 2007; Mullan, Allom, Sainsbury, & Monds, 2015), while knowledge indicators were inspired by Abbot et al. (2009) Knowledge was assessed using a set of ten close-ended true/false questions, each one related to one of the training modules. A 'don't know' option was included to limit the possibility of respondents inappropriately selecting other responses. We calculated total knowledge scores by assigning one point for each correct answer, while incorrect and 'don't know' responses received zero points, resulting in a maximum score of 10. Assessment of attitudes and cognition covered: risk perception (i.e., worry about selling contaminated chicken); perceived control and responsibility for food safety and consumer health outcomes with three items measuring vendors' perceptions on their role and responsibility in preventing foodborne disease in customers (Redmond & Griffith, 2004); self-efficacy in avoiding contamination during slaughtering, carcass management, chicken preparation and serving, indicating vendors' beliefs in their capability to perform behaviors (four items) (Mullan, Allom, Sainsbury, & Monds, 2016); four sets of a positive and negative attitudes regarding safe slaughtering, carcass management, chicken preparation and serving (eight items); and social perceived norms (one item). Items were rated on a five-point Likert scale from 'Strongly Disagree/Never/Not at all' ('1') to 'Strongly Agree/Always/Very Much' ('5'). Mean scores were computed for perceived control and responsibility (Cronbach's α = 0.804, high reliability), as well as for the four attitude items on slaughtering and carcass management (moderate reliability, Cronbach's α = 0.662), and four items on chicken preparation and serving (moderate reliability, Cronbach's α = 0.631), using reversed scores for negative items. Similar mean scores were derived for self-efficacy in slaughtering and carcass management (Cronbach's α = 0.871) and chicken preparation/serving (Cronbach's α = 0.825).

Socio-demographic and outlet-specific indicators were measured at baseline only, and included sex (i.e., male/female), age in completed years, educational attainment (i.e., no [formal] education, primary, secondary or higher), source of income, years running the chicken outlet, whether outlet was the vendor's only source of income (yes/no), number of employees working at the outlet, total years in business, daily number of chicken slaughtered, daily number of chicken carcasses processed and sold, daily number of customers ordering chicken, type of chicken dishes sold (i.e., flamed, braised, cooked, fried, roasted, or other), and if the vendor ever participated in a formal food safety training (yes/no).

At endline we evaluated trained vendors' perceived ease of use and usefulness of the training and tool package, intent to implement lessons, and trust in training materials and trainers, scored on a five-point Likert scale 'Strongly Disagree' ('1') to 'Strongly Agree' ('5'). We also assessed tool use (yes/no) and perceived training benefits expressed as average daily customer and profit changes.

2.5. Data analysis

Data were downloaded from the KoboToolbox server, cleaned, and checked for missing data. Only outlets interviewed and observed at both times were included. Baseline descriptive statistics outlined socio-demographic, economic, and outlet traits for both groups, assessing differences as part of a randomization check. We also summarized means on perceived usefulness, ease of use, intentions to implement lessons, trust in training, and benefits gained from training. Self-reported behavior, knowledge, attitudes, and cognition items were compared between control and treatment groups, pre-training (Supplementary Table A3) and post-training, using chi-square and t-tests.

Due to some missing observational data, advanced statistical models were limited and we used univariate methods to compare treatment and control groups on observed practices at endline (pre-training results provided as Supplementary Table A4). To assess the treatment effect of the vendor training on self-reported behavior scores, and the secondary outcomes total knowledge, attitude and cognition scores (i.e., mean risk perception, attitude scores, self-efficacy scores), we utilized Analysis of Covariance (ANCOVA) with an interaction term between treatment and time added to account for the individual variation and pre-existing baseline differences (Twisk et al., 2018). Robust standard errors were estimated to account for potential heteroscedasticity in the data. As the randomization check showed no significant differences in characteristics between treatment and control groups, we did not control for these variables. Given inconclusive literature linking educational attainment and experience to vendor food safety knowledge/practices (Huynh-Van et al., 2022; Siddiky et al., 2022), we included baseline measures of education and years in business in our models. Where applicable, effect sizes (Cohen's d, eta squared η^2 and Cramer's' V) were estimated to indicate differences in group means. To check alignment between self-reported and observed behavior, chi-square tests (data not shown), were run to compare self-reported and observed items. For this, 16 observed practices were dichotomized into incorrect/insufficient ('0') or correct/sufficient ('1'). Statistical differences were only found in four domains with vendors overreporting mask wearing and underreporting separating viscera from feathers at the slaughter site, handling prepared chicken with a fork, and exclusively using good quality vegetables, indicating minimal discrepancy between self-reported and observed data. Data were analyzed using STATA/SE 16.1 (StataCorp, 2019) and statistical significance was set at $p < 0.05$.

Ethical approval

Ethical approval was obtained from the ILRI Institutional Research Ethics Committee (IREC, no. ILRI-IREC2021-63) and Comité d'éthique, Burkina Faso (CERS, 2022-11-232). All participants provided written consent to participate in this study. No incentives were provided as all outlets, including control ones, were invited to the cost-free training inclusive of a tool package.

3. Results

3.1. Baseline sample descriptives

Table 1 provides an overview of sample descriptives of the total survey sample (n = 162). No significant differences were found between the treatment (n = 72) and control (n = 90) arms. With the exception of one female vendor in the treatment arm, all participants were male. Mean age was 36.9 years, and over half of vendors (51.2%) obtained no (formal) education. The remainder completed primary education (29.0%) or at least secondary education (19.8%). Mean years of working as vendor was 9.1 years (range 1–30). For most vendors (72.2%), their chicken outlet was the only source of income. Secondary reported sources of income were non-food (44.4%) or other food-outlets (33.3%). Half of the outlets had an in-house slaughter space. The average number of employees was 3.3 (max. 15). On average, outlets with a slaughter space slaughtered 28.5 chickens, sold 29.1 carcasses, and served 26.1 customers (range: 4–130) daily. Sold dishes were flamed (50.6%), braised (45.1%), cooked (42%), roasted (14.8%), and fried (10.5%) chicken. Only 17 vendors had ever participated in another food safety training.

3.2. Changes in observed and self-reported behavior

Table 2 highlights improved observed food safety behaviors at treatment outlets versus controls at endline. Specifically, treatment outlets showed marginally significant better chicken management, particularly in securing an adequate elevated evisceration platform ($t(79) = -1.96$, $p = 0.054$, $d = 0.44$). In the domain of chicken carcass management, 61.8% of treatment outlets adhered to regular carcass wash water renewal compared to 36.4% of controls ($\chi^2(1) = 4.323$, $p = 0.038$), with a moderate training effect ($v = 0.25$). Handwashing during carcass management significantly improved ($t(161) = -2.68$, $p = 0.008$, $d = 0.42$). In domains of chicken preparation, 58.6% of treatment outlets used a fork instead of bare hands when handling prepared chicken, contrasting with 41.8% of control outlets ($\chi^2(1) = 4.76$, $p = 0.029$), with a small treatment effect ($v = 0.17$). Moreover, 38.4% of trained outlets had appropriate employee handwashing facilities compared to only 20.9% of control outlets ($\chi^2(1) = 6.05$, $p = 0.014$, $v = 0.19$). In terms of adequate handwashing during handling of prepared chicken, treatment outlets outperformed controls with a mean score of 1.1 ± 0.4 versus 0.9 ± 0.3 ($t(152) = -1.97 = 0.051$). Finally, 64.4% of treatment outlets used an adequate garbage bin versus 37.8% of controls ($\chi^2(1) = 11.41$, $p = 0.001$, $v = 0.26$).

Among vendors with a slaughter space, control outlets differed significantly with regards to self-reported safe slaughter behavior by cleaning chicken cages more frequently compared to treatment outlets ($t(79) = 2.12$, $p = 0.037$, $d = 0.48$), see Table 3. For self-reported behaviors relevant to all outlets, statistically significant better behavior was reported in the treatment group compared to the control group in relation to mask-wearing while cutting chicken (1.8 vs. 2.5, $t(160) = -3.86$, $p < 0.002$, $d = 0.36$), and inspecting nail hygiene (4.3 vs. 4.7, $t(160) = -3.49$, $p < 0.001$, $d = 0.19$). Interestingly, control outlets reported a higher frequency of using intact vegetables than treatment outlets (3.5 vs. 2.9, $t(160) = 2.18$, $p = 0.030$, $d = 0.20$)ANCOVA models in Table 4 show that self-reported food safety behavior (Model 2) was higher in both arms after training ($F(3, 317), 4.54$, $p = 0.026$), but lower among trained vendors compared to the control vendors (-1.889, $p = 0.031$). Further regression models (Supplementary Table A2) show that treatment outlets scored lower on safe food behavior at baseline compared to the control group ($F(4,157), 1.56$, $p = 0.025$), which resolved at endline.

3.3. Changes in knowledge, attitudes, and cognitions

Seven out of ten knowledge items showed significant differences between the treatment and control groups (Table 3). Treatment outlets had a significantly higher mean total knowledge score of 8.2 ± 1.6 compared to the control group 6.7 ± 2.2 ($t(160) = -4.77$, $p < 0.001$). Effect size for the difference between the groups (Cohen's $d = 0.75$) implied a large training effect. No significant differences were found between treatment and control groups regarding food safety attitudes and cognitions (i.e., risk perception, perceived control and responsibility, attitudes, subjective norm, or self-efficacy scores, Models 6–10).

ANCOVA analyses, adjusting for education and business experience, revealed a significant treatment-time interaction on knowledge scores (Table 4**,** Model 3**)**, confirming the positive effect of training on food safety knowledge score ($F(6, 317), 13.43 =$, $p < 0.001$). The effect size estimation ($\eta^2 = 0.05$) indicated a medium effect. Additional analyses (Table A2) regressing training on knowledge score post-training,

Table 2
Comparison between treatment and control group on observed practices, post-training.

Observed practices		Endline (post-training)		
		Control (n = 91)	**Treatment (n = 73)**	**p**
Live chicken management (modules 3 and 4)				
All chicken (alive) which are kept at the outlet premises look apparently healthy (only if chicken onsite = 78)	Yes	36 (87.8)	31 (94.9)	0.610
Ill-looking chicken are separated from the healthy-looking chicken (if ill-looking chicken)	Yes	0.0 (0.0)	5.0 (83.3)	0.338
Chicken cages are appropriate and well-maintained	Mean score[a]	1.2 (0.7)	1.3 (0.7)	0.355
Cages with chicken are placed within a reasonable distance from the food preparation and eating area	Mean score[a]	1.3 (0.7)	1.3 (0.8)	1.000
The slaughter site looks apparently clean and functional	Mean score[a]	0.8 (0.7)	0.9 (0.7)	0.684
The scalding water is sufficiently clean	Yes	15 (42.9)	15 (45.5)	0.829
The evisceration and plucking platform is elevated and easy to clean	Mean score[a]	1.0 (0.6)	1.3 (0.6)	**0.054**
Plucking and eviscerating practices are kept separate	Yes	32 (80.0)	28 (71.8)	0.394
At the slaughter site, viscera are kept separate from feathers	Yes	34 (85.0)	29 (76.3)	0.331
The scalding zone is separated from the grilling/cooking site	Yes	25 (59.5)	29 (78.4)	0.072
Chicken carcass management (module 5)				
Each batch of chicken carcasses is washed appropriately after plucking and eviscerating	Mean score[a]	1.2 (0.5)	1.3 (0.5)	0.309
Water used for washing a single batch of chicken carcasses is renewed after finishing each batch	Yes	12 (36.4)	21 (61.8)	**0.038**
Cutting materials used for plucking and eviscerating raw carcasses are sufficiently clean	Mean score[a]	1.1 (0.5)	1.0 (0.6)	0.430
Outlet has an adequate "cold chain" for transporting carcasses	Yes	14 (22.6)	5 (12.8)	0.222
Vendor washes hands with clean water and soap each time before handling raw chicken carcasses	Mean score[a]	0.9 (0.3)	1.1 (0.5)	**0.008**
Food preparation and cutting (module 6)				
Cutting boards/tables are cleaned adequately each time before cutting a batch of prepared chicken	Mean score[a]	0.9 (0.4)	0.78 (0.58)	0.160
Utensils are cleaned adequately each time before cutting a batch of prepared chicken	Mean score[a]	0.9 (0.5)	0.80 (0.55)	0.101
Vendor handles prepared chicken with a fork and knife	Yes	38 (41.8)	43 (58.9)	**0.029**
Vendor correctly wears a mask whilst cutting meat	Yes	0.0 (0.0)	2 (2.7)	0.112
Seasoning and service (module 7)				
Vendor exclusively uses good quality (intact) vegetables	Yes	43 (71.7)	35 (71.4)	0.978
Seasoning products are stored in sealed containers	Yes	83 (91.2)	61 (83.6)	0.137
Chicken orders are served out on clean plates or containers		1.5 (0.5)	1.6 (0.6)	0.494
Availability of a functioning handwashing facility for costumers to wash hands before eating	Yes	59 (75.6)	46 (74.2)	0.844
Personal hygiene and health (module 8)				
Availability of an adequate handwashing facility for employee(s)	Yes	19 (20.9)	28 (38.4)	**0.014**
Vendor washes hands with clean water and soap before and after each step of grilled chicken handling/preparation	Mean score[a]	0.9 (0.3)	1.1 (0.4)	**0.051**
The employee ('s) cloths are clean and presentable	Mean score[a]	1.4 (0.7)	1.3 (0.8)	0.420
All employee(s) working at the outlet during observation look apparently healthy	Yes	88 (96.7)	73 (100)	0.117
Nails of the employee(s) are clean and short	Mean score[a]	1.5 (0.5)	1.6 (0.6)	0.306
Environmental health and sanitation (module 9)				
Number of sources of contamination observed less than 10 m from the outlet location (max. 7)	Mean score	1.9 (1.1)	2.0 (1.0)	0.735
Number of sources of contamination observed on the outlet premises (max. 5)	Mean score	1.7 (0.8)	1.8 (0.9)	0.351
Availability of an adequate potable drinking water supply and storage system	Yes	69 (75.8)	49 (67.1)	0.218
Availability of a functional, raised dishwashing area with clean water and dishwashing soap	Yes	0.9 (0.6)	0.9 (0.7)	0.852
Trash cans are adequate, covered, and not overloaded	Yes	34 (37.8)	47 (64.4)	0.001
Availability of an adequate and functional waste water disposal system	Yes	11 (12.1)	9 (12.3)	0.963
Toilets on the outlet premises are sufficiently clean (if any)	Yes	58 (74.4)	49 (80.3)	0.407
Availability of an adequate handwashing facility available near the toilet	Yes	7 (8.8)	7 (11.1)	0.637

Notes: data from direct observations, n = 164 outlets observed, Blocks a and b only for outlets keeping chicken at the outlet premises (n = 151) and with a slaughter spot (n = 84).
[a] Mean score: 0 = Insufficient = 0, 1 = partly sufficient, 2 = sufficient.

confirmed the significant increase in knowledge in the treatment group ($F(4, 157)$, 8.36, $p < 0.001$, $\eta^2 = 0.13$), compared to the control arm. While all vendors showed higher perceived control and responsibility for safe food practices at endline compared to baseline ($F(6, 317)$, 4.91, $p = 0.046$), no significant effect of training was found (Model 5).

3.4. Training evaluation

Table 5 details trained vendors' evaluation of the training and tool package (n = 72). An average of 1.5 employees per outlet were trained (max. 3) over an average of 2.9 days. On a total score of five, trained vendors rated perceived usefulness and ease of use of the training as 4.8 and 4.9, respectively, reported high trust in the intervention (4.7), and reported high intentions to integrate lessons learnt in the future (4.8). Similarly, vendors highly valued the usefulness of and ease of use (4.8) of the tool package and reported high intentions to use the tools in the future (4.9). At endline, the most reported used tool was the plastic cutting board (87.5%), while the least used tool was protective clothing

Table 3
Comparison between treatment and control groups on knowledge, attitudes and cognitions, and self-reported practices post-training.

	Post-training		
	Control (n = 90)	**Treatment (n = 72)**	**p-value**
Self-reported behaviour for outlets with slaughter site (n = 84)			
Frequency of keeping ill and healthy chicken in the same cage	3.5 (1.3)	3.7 (1.4)	0.509
Frequency of cleaning the chicken cages	4.9 (0.4)	4.6 (0.8)	**0.037**
Frequency of removing waste from slaughter site	4.7 (0.6)	4.8 (0.4)	0.302
Frequency of water renewal after each batch of scalding chicken carcasses	3.1 (1.1)	3.5 (1.0)	0.165
Frequency of keeping plucking and evisceration practices separate	4.3 (1.0)	4.5 (0.8)	0.404
Frequency of keeping viscera and feather waste separate at slaughter site	3.9 (1.5)	3.5 (1.7)	0.311
Frequency of water renewal after each batch of eviscerating chicken carcasses	3.5 (1.1)	3.7 (1.0)	0.396
Frequency of cleaning cutting materials after handling each batch of carcasses	4.2 (1.0)	3.9 (1.0)	0.192
Total Behavior Score for outlets with slaughter site (n = 84, max *score 40)*	*32.1 (4.0)*	*32.2 (3.5)*	*0.908*
Self-reported behaviour (all outlets)			
Frequency of washing hands with water and soap before handling raw chicken	4.4 (0.9)	4.2 (0.8)	**0.053**
Frequency of storing carcasses in a different freezer than prepared chicken/other food	2.8 (1.5)	3.0 (1.6)	0.569
Frequency of cleaning cutting boards each time before cutting prepared chicken	3.9 (1.01)	3.7 (1.0)	0.221
Frequency of cleaning utensils each time before cutting prepared chicken	4.1 (1.1)	3.9 (1.0)	0.171
Frequency of handling prepared chicken with a fork and knife	3.5 (1.4)	3.7 (1.3)	0.321
Frequency of wearing a mask while cutting chicken	1.8 (0.8)	2.5 (1.2)	**<0.001**
Frequency of using good quality (intact) vegetables for cooking or as side-dish	3.5 (1.6)	2.9 (1.7)	**0.030**
Frequency of washing hands with clean water and soap before and after handling chicken	3.8 (0.9)	3.8 (0.7)	0.813
Frequency of inspecting nail hygiene of self/employees	4.3 (0.8)	4.7 (0.6)	**<0.001**
Frequency of emptying the garbage bin	4.6 (0.8)	4.7 (0.8)	0.234
Total Behavior Score (n = 162, max. score 50)	*36.8 (5.3)*	*37.0 (5.9)*	*0.797*
Knowledge	**Correct answer n(%)/mean (SD)**		
Microbes that can cause disease in consumers are not always visible on chicken meat	72 (80)	58 (80)	0.930
External surfaces (such as cutting boards, utensils, or money) provided they look clean, cannot contaminate grilled chicken	50 (56)	57 (80)	**0.002**
It is safe to slaughter and process sick chicken if the vendor ensures meat is cooked thoroughly	41 (46)	43 (60)	0.073
It is safe to pluck and eviscerate carcasses on the same surface	69 (77)	65 (90)	**0.023**
It is safe to keep raw chicken carcasses and prepared chicken in the same freezer provided they do not touch each other	46 (51)	58 (80)	**0.000**
It is safe to handle prepared chicken with bare hands provided they look clean	51 (57)	58 (80)	**0.001**
It is safe for customers to wash their hands without soap before eating the chicken	64 (71)	62 (90)	**0.022**
The koassa should wash hands with clean water and soap each time before each chicken handling activity	77 (86)	69 (96)	**0.029**
It is safe to place dishwashing containers on the ground provided the water looks clean	48 (53)	51 (70)	**0.023**
If the toilet is close to the eating area, meat could be contaminated with microbes	87 (97)	70 (97)	0.839
Total Knowledge Score (max. 10)	*6.7(2.2)*	*8.2 (1.6)*	***0.000***
Attitudes & cognitions			
Risk Perception (1 = never, 5 = always)			
Frequency of worrying about the safety of the ready-to-eat chicken sold	4.7 (0.6)	4.6 (0.8)	0.625
Perceived control & responsibility (1 = strongly disagree, 5 = strongly agree)			
"It can have severe health consequences if I sell contaminated chicken"	4.5 (0.8)	4.6 (0.8)	0.735
"It is likely that me selling contaminated chicken affects the health of customers"	4.5 (0.9)	4.6 (0.8)	0.468
"Avoiding contamination of chicken meat is part of my duty as a koassa"	4.8 (0.4)	4.8 (0.5)	0.831
Mean score perceived control & responsibility	*4.6 (0.6)*	*4.7 (0.6)*	*0.662*
Positive & Negative attitudes			
Food safety behaviors to avoid contamination of chicken during slaughtering are:			
necessary	4.5 (0.6)	4.4 (1.0)	0.522
a hassle	4.0 (1.0)	4.3 (0.9)	0.222
Food safety behaviors to avoid contamination of chicken during scalding, plucking and eviscerating are:			
necessary	4.4 (0.7)	4.5 (0.7)	0.602
a hassle	4.2 (1.2)	4.4 (0.8)	0.386
Mean score attitudes slaughtering and carcass management (n = 84)	*4.3 (0.6)*	*4.4 (0.6)*	*0.427*
Food safety behaviors to avoid contamination of chicken during grilling of chicken are:			
necessary	4.6 (0.5)	4.6 (0.5)	0.571
a hassle	4.3 (1.1)	4.4 (0.8)	0.783
Food safety behaviors to avoid contamination of chicken during serving to customers are			
necessary	4.6 (0.5)	4.5 (0.8)	0.781
a hassle	4.4 (0.9)	4.3 (0.8)	0.538
Mean score attitudes chicken preparation and serving (n = 162)	*4.5 (0.5)*	*4.5 (0.5)*	*0.924*
Subjective norm (1 = disagree, 5 = agree)			
"Other vendors selling ready-to-eat chicken at this market consistently pay attention to food safety behaviours when preparing chicken"	3.4 (1.0)	3.4 (1.0)	0.931
Self-efficacy (1 = not at all, 5 = a lot): Level of confidence in one's capabilities to …:			
avoid contamination when slaughtering chicken	4.6 (0.7)	4.5 (0.6)	0.602
avoid contamination when scalding, plucking, and eviscerating carcasses	4.7 (0.6)	4.4 (0.8)	0.145
Mean score self-efficacy slaughtering and carcass management (n = 84)	*4.6 (0.6)*	*4.5 (0.7)*	*0.280*

(*continued on next page*)

Table 3 (*continued*)

	Post-training		
	Control (n = 90)	**Treatment (n = 72)**	**p-value**
avoid contamination when flaming, grilling, or cooking chicken	4.6 (0.7)	4.6 (0.6)	0.956
avoid contamination when serving chicken to customers	4.7 (0.6)	4.7 (0.5)	0.974
Mean score self-efficacy chicken preparation and serving (n = 162)	*4.6 (0.6)*	*4.6 (0.5)*	*0.987*

Notes: vendor surveys, n = 162.

Table 4
Impact of training on knowledge, attitudes & cognitions, and self-reported practices.

	Coef.	SE	95% CI		p-value
BEHAVIOR					
Model 1. Behavior score (slaughter outlets)					
Treatment	−1.968	1.010	−3.961	−2.634	0.053
Post-training	−0.782	0.938	−2.634	1.079	0.406
Treatment*time	2.027	1.282	−0.504	4.558	0.116
Model 2. Behavior score (all outlets)					
Treatment	−1.889	0.872	−3.604	−0.172	**0.031**
Post-training	1.812	0.810	0.219	3.405	**0.026**
Treatment*time	2.184	1.249	−0.273	4.642	0.081
KNOWLEDGE					
Model 3. Knowledge score					
Treatment	−0.306	0.295	−0.886	0.273	0.299
Post-training/endline	0.269	0.310	−0.341	0.880	0.386
Treatment*time	1.805	0.420	0.978	2.631	**<0.001**
ATTITUDES & COGNITIONS					
Model 4. Risk perception					
Treatment	−0.117	0.121	−0.354	0.121	0.335
Post-training	0.019	0.098	−0.173	0.211	0.843
Treatment*time	0.076	0.164	−0.247	0.400	0.643
Model 5. Perceived control & responsibility (mean score)					
Treatment	−0.210	0.114	−0.434	0.015	0.067
Post-training	0.202	0.101	0.004	0.440	**0.046**
Treatment*time	0.263	0.148	−0.027	0.555	0.075
Model 6. Attitudes (mean score slaughter outlets)					
Treatment	−0.198	0.146	−0.486	0.090	0.177
Post-training	−0.136	0.131	−0.395	0.123	0.301
Treatment*time	0.297	0.199	−0.096	0.689	0.137
Model 7. Attitudes (mean score all outlets)					
Treatment	−0.004	0.086	−0.173	0.166	0.966
Post-training	0.073	0.081	−0.086	0.232	0.366
Treatment*time	−0.001	0.113	−0.223	0.222	0.996
Model 8. Subjective norm					
Treatment	−0.070	0.141	−0.347	0.209	0.621
Post-training	0.007	0.146	−0.280	0.294	0.962
Treatment*time	0.082	0.211	−0.280	0.294	0.697
Model 9. Self-efficacy (with slaughter site)					
Treatment	−0.162	0.170	−0.498	0.173	0.339
Post-training	0.143	0.144	−0.142	0.428	0.323
Treatment*time	0.012	0.219	−0.421	0.445	0.956
Model 10. Self-efficacy (all outlets)					
Treatment	−0.025	0.085	−0.192	0.143	0.770
Post-training	0.093	0.084	−0.072	0.258	0.267
Treatment*time	0.032	0.118	−0.200	0.264	0.787

Notes: data from surveys (n = 162 for all outlets, n = 82 for slaughter outlets), control group and pre-training/baseline set as reference. Model adjusted for educational attainment and years in business. SE = standard error, CI = confidence interval.

(apron and cap) (24.5%). Only four vendors reported no use of the tools. Among 59 vendors who reported business gains as a result of participating in the training, 74.6% noticed a daily mean increase of 8.3 ± 6.3 in customers. Another 64.4% reported a daily mean increase in revenues of 21,242 CFA (equivalent to 34.2 USD).

Table 5
Evaluation of training attendance, perceived usefulness and ease of use training/tool package.

n (%) or mean (SD)	
No. of employees trained per outlet	1.5 (0.5)
No. of days ILRI food safety training attendance	2.9 (0.3)
Training (1 = disagree, 5 = agree)	
Perceived usefulness training: "Attending the training is an efficient way to manage the safety of chicken meat at my outlet"	4.8 (0.4)
Perceived ease-of-use training: "Because of the training, it is easy to manage the safety of ready-to-eat chicken in my daily work"	4.9 (0.3)
Trust: "I believe that the content of the training and the trainers were trustworthy"	4.7 (0.5)
Intentions: "I plan to integrate the lessons learnt during this training in my daily work in the future"	4.8 (0.4)
Extent to which vendor feels informed about preventing food contamination in daily work	3.9 (1.0)
Tool package	
Uses hand washing materials	59 (81.9)
Uses liquid soap	56 (77.8)
Uses apron and cap	13 (24.5)
Uses cleaning sponge	45 (62.5)
Uses plastic cutting board	63 (87.5)
Uses plastic tablecloth to cover cutting table	49 (68.1)
Uses plastic garbage bin	50 (69.4)
Uses none of these	4 (5.6)
Perceived usefulness tool package: "Using the ILRI tool package is an efficient way to improve food safety"	4.8 (0.5)
Perceived ease of use tool package: "It is easy to use the tool(s) in my daily work activities as koassa"	4.8 (0.6)
Intentions to use tool package: "I plan to use the tools I received during the training in the future in my work as koassa"	4.9 (0.3)
Business performance	
Vendor observed any benefits to his/her business after training	59 (95.2)
More customers	44 (74.6)
Higher revenu	38 (64.4)
Other	25 (42.4)
Mean more customers (per day)	8.3 (6.3)
Mean higher revenue (in CFA per day)[a]	21242.2 (21147.5)

Notes: n = 72 Treatment outlets only.
[a] 34.2USD, 1CFA = 0.00161 USD, March 2023.

4. Discussion

The aim of this study was to assess the impact of a participatory food safety training program including hygienic training, distribution of a behavior-enabling tool package, and a business management module on observed and self-reported vendor food safety behavior, as well as on key behavioral determinants knowledge, attitudes, and cognitions of ready-to-eat chicken meat vendors in urban informal markets of Ouagadougou, Burkina Faso. This study advances prior research using a strong RCT approach, combining vendor surveys with direct outlet observations to assess both self-reported and observed behaviors (Zanin, da Cunha, de Rosso, Capriles, & Stedefeldt, 2017). Unlike traditional vendor trainings, which primarily emphasize knowledge-sharing and creating awareness, this tailored participatory training paired with an affordable, renewable tool package was highly evaluated by participants as shown by high scores on perceived usefulness and ease of use. The training significantly boosted food several safety behaviors in domains of personal hygiene (i.e., mask wearing, nail hygiene), carcass management and slaughter practices (i.e., evisceration, carcass washing, handwashing), and safe food preparation practices (i.e., fork use, employee handwashing and facilities, waste management). Training moreover positively impacted knowledge scores (measured on a 10-point scale, effect size 0.75).

For food safety trainings to effectively prevent foodborne illnesses, key behaviors that are clearly linked to disease outcomes must be targeted. The results of this study showed several self-reported food safety improvements linked to preventing FBD, including improved personal

hygiene (e.g., mask use and nail hygiene) after training. Due to nails' high permeability and vulnerability to microbial contamination, maintaining clean nails has been an effective strategy to prevent microbe transmission. For example, in Nigerian food markets, nail contamination correlated with bacteria including *Staphylococcus* spp. and *Salmonella* spp., responsible for FBD (Yandev, Iorliam, & Adebo, 2022), suggesting that more frequent nail hygiene inspections lowers contamination risks.

This study also noted several moderate intervention effects in observed behaviors: ensuring an elevated evisceration platform, adequate employee handwashing facilities, frequent carcass wash water renewal, proper handwashing during chicken handling, using a fork for prepared chicken, and correct use of a garbage bin. While we did not test vendor behaviors' effects on chicken microbial load, practices such as frequent renewal of wash water have been significantly linked to reducing pathogen levels in poultry meat. For instance, In Zambia's poultry abattoirs, unwashed chicken had lower *E. coli* contamination than washed ones (35% vs. 65%). This suggests that water transmission of bacteria, particularly in poor quality or reused water, common in informal settings, poses significant FBD risks (Mpundu, Mbewe, Muma, Zgambo, & Munyeme, 2019). A KAP study among street vendors in Kenya revealed that the most important predictors of *E. coli* contamination were unhygienic outlet circumstances, as well as poor handwashing practices, personal hygiene, and waste management (Birgen, Njue, Kaindi, Ogutu, & Owade, 2020). Findings also align with literature showing that handwashing demonstrations in particular, combined with lab experiments highlighting bacteria's rapid multiplication, can effectively improve behaviors and ultimately reduce food hazards (Nik Rosmawati et al., 2018; Shojaei, Shooshtaripoor, & Amiri, 2006).

Interestingly, several best practices were directly implemented after training, as they required no extra investments because of distributed resources, including handwashing materials and garbage bins. These tools took away barriers for vendors to directly implement lessons learnt and enabled appropriate handwashing and waste disposal practices. In the context of Sub-Saharan Africa, there is relatively limited evidence of comparable vendor training programs that distribute practical tools alongside training, which complicates a comparison of the relative impact of our intervention to similar interventions with or without tool supplementation. However, our findings are similar to studies that show a positive impact of combining training with the distribution of technology or tools. For instance, in Senegal, a RCT evaluating an intervention including the distribution of basic hygiene kits and food safety training, targeting vendors of roasted sheep meat, showed that the combination of training and tools was more effective (reflected in improved microbial quality of roasted meat samples) than training or receiving tools only. However, this approach proved not sustainable ten months post-training, possibly due to the depletion of tools received by the program (Traoré et al., 2021). This signifies the importance of economic viability: provided equipment should be easily replaceable, affordable, and available in local markets (Grace, 2023). In the Vietnamese pork value chain, the use of behavioral nudges such as posters in food safety interventions was perceived as positive and effective (Hennessey et al., 2020). Among pork vendors in Uganda, training alone proved not as successful as a training coupled with behavioral nudges including the distribution of equipment. The authors of this study conclude that training alone does not lead to behavior change, as changes require repetition, but nudges may re-enforce food safety messages (Roesel et al., 2023). Regarding technological interventions only (without training), a pilot study investigating the impact of insecticide-treated materials to keep flies off of meat at pork outlets in Kampala, Uganda, showed a reduction of 48% of flies in these outlets (Heilmann et al., 2017). While the impact of our intervention is substantial, further empirical research is warranted to investigate the effectiveness of incorporating hands-on, practical tools into vendor training programs on food safety outcomes, and compare their (longer-term) impact to interventions relying on traditional methods alone (Johnson, Mayne, Grace, & Wyatt, 2015). Additionally, subsequent studies could estimate the cost-effectiveness of such approaches for determining their scalability and broader implementation (Kwoba et al., 2023).

Hygienic practices only become habitual over time, implying a challenge in changing ingrained, undesirable automatic habits (Curtis, Danquah, & Aunger, 2009; Verplanken, 2006). Additionally, improvements related to environmental hygiene, such as furnishing, maintaining adequate sewage systems, and regularly removing sources of contaminants (e.g., roadside dust) were limited. Vendors often lack direct control over these practices, an observation that aligns with findings from a study in India where street vendor behavior changes needing financial investments showed minimal impact (Singh, Dudeja, Kaushal, & Mukherji, 2016). Hence, even if vendors are able to uphold hygiene measures at their outlets, disabling environments, including inadequate market infrastructure, poor environmental conditions such as crowding, garbage collection, and road maintenance, if unaddressed, render their efforts futile (Grace, 2023).

Surprisingly, control outlets reported a higher frequency of using intact vegetables than treatment outlets, while observations did not show any differences between groups with regards to the use of intact vegetables. The higher self-reported frequency of using intact vegetables might be explained by baseline differences in the types of dishes sold and could simply reflect a higher frequency of vegetable use in dishes by control outlets at baseline.

For behavior to change, vendors' motivations, including positive attitudes and beliefs towards food safety behaviors, risk perceptions, and beliefs about capabilities (self-efficacy) to make the necessary changes are vital (van Rijen, Mergelsberg, Hoor, & Mullan, 2021). For instance, in Kenya, culturally accepted and religious practices influenced informal market vendors' perceptions of food safety risks and disease transmission, and ultimately their willingness to adopt biosecurity measures (Nyokabi et al., 2018). Informal milk vendors in Mali refused efforts to wash their milk containers with soap, as their belief that soap taints the taste of milk trumped their concerns over pathogenic milk borne bacteria (Roesel & Grace, 2014). Our study did not show differences between the treatment and control group in terms of attitudes and cognitions. However, trained vendors scored high on risk perceptions and showed strong intentions to implement lessons learnt, which is key to adopting (new) behavior. Vendors moreover exhibited high trust in training/trainers and highly rated perceived usefulness and ease of use of training and materials. Importantly, both perceived usefulness and ease of use are critical antecedents shaping attitudes and intentions to implement behavior change and adopting technologies (Davis, 1989).

Most trained vendors (95%) reported increased daily customer visits (8.3 ± 6.3) and higher revenues (21,242 FCFA) associated with attending training. Observing that business improves after investing time and resources has been importantly mentioned as a key incentive for vendors to adopt food safety measures (Grace, 2023). Similar outcomes were seen in a qualitative study among Kenyan dairy traders who attended hygiene training within the 'MoreMilk' project. Participating in training boosted sales, reduced waste, and expanded businesses (Alonso et al., 2018). While our business profit indicators were subjective, future studies could explore the costs or profits attributed to improved practices amongst other business aspects. Perceived behavioral control over safe food handling practices was significantly higher post-training in both groups. Despite not associated with training, perceived control and responsibilities for food safety outcomes remain an important moderator of behavioral intentions, and a lack of capabilities to practice behavior will likely hinder positive change. Evidence has shown that increases in perceived behavioral control can be strengthened by the supply of tools to perform safe food behavior (Pilling, Brannon, Shanklin, Howells, & Roberts, 2008). Hence, enabling tools are key for vendors to translate intentions into behavior, through increases in perceived control and responsibilities for food safety outcomes.

Knowledge increases do not necessarily translate into action (Da

Cunha, Stedefeldt, & De Rosso, 2014), especially when trainings solely rely on educating. Trainings should thus be tailored to vendors' everyday life realities and tap into unmet needs by providing concrete solutions. The positive impact of this training on vendors' food safety knowledge is in line with previous studies from Brazil, India and Nigeria (Choudhury et al., 2011; Da Cunha et al., 2014; Okojie & Isah, 2019; Soon et al., 2012), where trained food handlers showed higher knowledge scores than non-trained food handlers. Learning, however, decays over time and so prior studies have recommend 'booster' trainings every six to twelve months for sustained knowledge (Da Cunha et al., 2014; Kwoba et al., 2023). Besides knowledge, this underscores the necessity of post-training follow-ups, such as on-site coaching, to improve hygiene practices.

Despite this RCT's strengths, there are some methodological considerations. While our study is unique in assessing a wide range of observed and self-reported food safety behaviors, knowledge, attitudes, and cognitions through combining direct observations with vendor surveys, future research could link these data to microbial counts on chicken meat at trained outlets to estimate behavior's impact on food safety or health. Challenges related to the dynamic roles of vendors during peak hours and potential behavior adjustments (e.g., social desirability bias) led to missing data across domains, restricting the feasibility of conducting more advanced statistical analyses on observational data. Addressing this, an increase in sample size might not only strengthen the reliability and relevance of our findings within the study's scope, but could also mitigate the impact of missing data and enhance the robustness of future analyses. Finally, although we assessed change a few months post-training, we lacked sustainability evaluation. Longer-term repetitive measures are essential to evaluate prolonged impact and cost-effectiveness of such training programs (Global Alliance for Improved Nutrition, 2022).

5. Conclusion

Understanding the effectiveness of food safety training interventions is necessary for sustainable effects and scaling up (Egan et al., 2007). To our knowledge, this study is amongst the first to assess the impact of a capacity-building food safety training intervention for street food vendors in Sub-Saharan Africa that included the distribution of practical tools. This impact assessment study has shown that vendors can effectively improve food safety in urban informal markets when equipped with the right skills and enabling tools. The vendor training program resulted in important behaviors to improve in domains of personal hygiene and several slaughtering and chicken preparation practices. Moreover, training significantly boosted food safety knowledge. In addition, it is encouraging that vendors noticed increased profits and number of customers because of their participation in training. Investment in tailored, contextual training and tools, combined with follow up support, for this 'missing middle' in the food chain is imperative to empower vendors to adhere to safe food behaviors. Ultimately, improving informal market food safety necessitates combining an enabling environment, providing training and technologies, and building motivation and incentives for behavior change (Grace, 2023).

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CRediT authorship contribution statement

Donya S. Madjdian: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Marcel van Asseldonk:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Guy Ilboudo:** Writing – review & editing, Project administration, Investigation. **Michel Dione:** Writing – review & editing, Project administration, Investigation. **Abdoul-Aziz Ouedraogo:** Writing – review & editing, Formal analysis, Data curation. **Kristina Roesel:** Writing – review & editing, Funding acquisition, Conceptualization. **Delia Grace:** Writing – review & editing, Funding acquisition, Conceptualization. **Elise F. Talsma:** Writing – review & editing, Methodology, Conceptualization. **Theodore J.D. Knight-Jones:** Writing – review & editing, Supervision, Methodology. **Emely de Vet:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data underlying this manuscript are available from https://hdl.handle.net/20.500.11766.1/FK2/BYIUM4

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodcont.2024.110510.

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