Analysis of risk factors for microbial contamination of vegetables in market gardening environments in Niamey, Niger

ABSTRACT:

Market gardening is an income-generating activity that is developing more and more in large African cities due to the strong demand for consumption in households and hotels. Market gardening has become a new profession and plays an important role in the supply of fresh vegetables. The aim of the present study was to assess market gardening practices at risk of causing vegetable microbial contamination in the market gardening environment of the urban community of Niamey. A descriptive cross-sectional study was carried out from march to June 2022 on three market gardening sites (*Harobanda, Gamkalé*and *Gounti yéna*) in Niamey city with market gardeners.A total of 108 market gardeners were surveyed using a pre-established questionnaire.Market gardening is 100% practiced by men, most of them are over 40 years old (53.70%), of Niger nationality (62.96%) and unschooled (45.10%). River water (swimming pool) is used for 81.48% of watering, without any treatment (92.30%). Market gardeners are unaware of the danger of going down to the water source to draw water (61.11%). Some 87.04% of fields have no latrine, 37.04% are near garbage, 35.19% near drainage channels and 100% near a road. Two (2) types of fertilizer are used: chemical fertilizer (96.30%) and manure (98.15%), without any treatment (69.23%). Vegetables are stored on the ground (87.04%) after harvesting. The behavior of market gardeners on production sites gives no guarantee of healthy vegetables. In view of this behavior, sanitary education seems necessary for market gardeners.

Keywords: Vegetable, Contamination,Microbiological market garden

1. INTRODUCTION

Agriculture is one of the main sectors of activity contributing to the socio-economic development of populations. It employs more than 40% of the working population worldwide, including more than 52% in Africa[1, 2, 3]. Market gardening is marked by specific and varietal diversification and is an activity found in almost every region of the country, but its scale varies very considerably between producers and between regions[1, 3, 4]. In Niger, as in all other Sahelian countries, market gardening plays an important role in socio-economic activities. Market garden produce makes a quantitative and qualitative contribution to improve the food situation of rural and urban populations through its mineral and, above all, vitamin content [5]. Market garden crops represent an important and varied food source that complements well the dietary needs of populations whose staple diet is essentially made up of carbohydrates, the main energy elements of diet [6]. Today, this major agricultural activity faces enormous difficulties, including, among others, land insecurity, access to agricultural inputs and the lack of specialized technical supervision. Added to all this is the thorny problem of pollution, due to the use of wastewater for irrigation and the proximity of production sites to major urban traffic arteries and industries [5]. The health risks associated with production conditions are numerous: irrigation water comes from urban effluent receptacles, polluting or unhygienic practices by certain market gardeners, etc.[7, 8]. Indeed, persistent organic compounds, which result from anthropogenic activities, have significant toxic potential for plants, humans and animals exposed to them [5, 9, 10, 11]. The general aim of this study is to assess market gardening practices at risk of causing vegetable microbial contamination in Niamey market gardening environment.

2. MATERIALS AND METHODS

2.1. Study area

The study was carried out in the urban community of Niamey. The city of Niamey is located in the South-Western part of Niger between 13° 24' and 13°35'N latitude and, 2°00' and 2°15'E longitude with an altitude between 160 and 250 m. Its administrative boundaries extend over 552.27km², including around 297.46km² of urbanized area [12]. Niamey's population is estimated at around 1,407,635. The city of Niamey is subdivided into 5 communal divisions districts, the population distribution of which by communal divisions districts is as follows: Niamey I: 287,902 inhabitants; Niamey II: 338,455 inhabitants; Niamey III: 223,685 inhabitants; Niamey IV: 376,271 inhabitants; Niamey V: 181,321 inhabitants [13]. The climate is Sahelo-Sudanian, with a long dry season from October to May and a short rainy season from June to September. The cold dry season is the most favorable for vegetable production, during which most crops are grown. This study focused on three (3) major vegetable-growing sites in the urban community of Niamey.

- Site 1, located in commune V of Niamey, stretches along the river over a length of around 2km and a width varying from 200m to 700m depending on the extent of the riverbed.
- Site 2, located in the heart of the city, the *Gamkalé* cornice forms part of the left bank of the River Niger. It is bounded on one side by the Kennedy bridge and on the other by the Niamey slaughterhouses.
- Site 3: *Gounti yéna*, a valley of around 38.1 ha. The environment around this valley is complex: less than 2 km from the valley and often within it, there are roads with high traffic density; a wastewater treatment plant collecting urban water and open dumps [14].

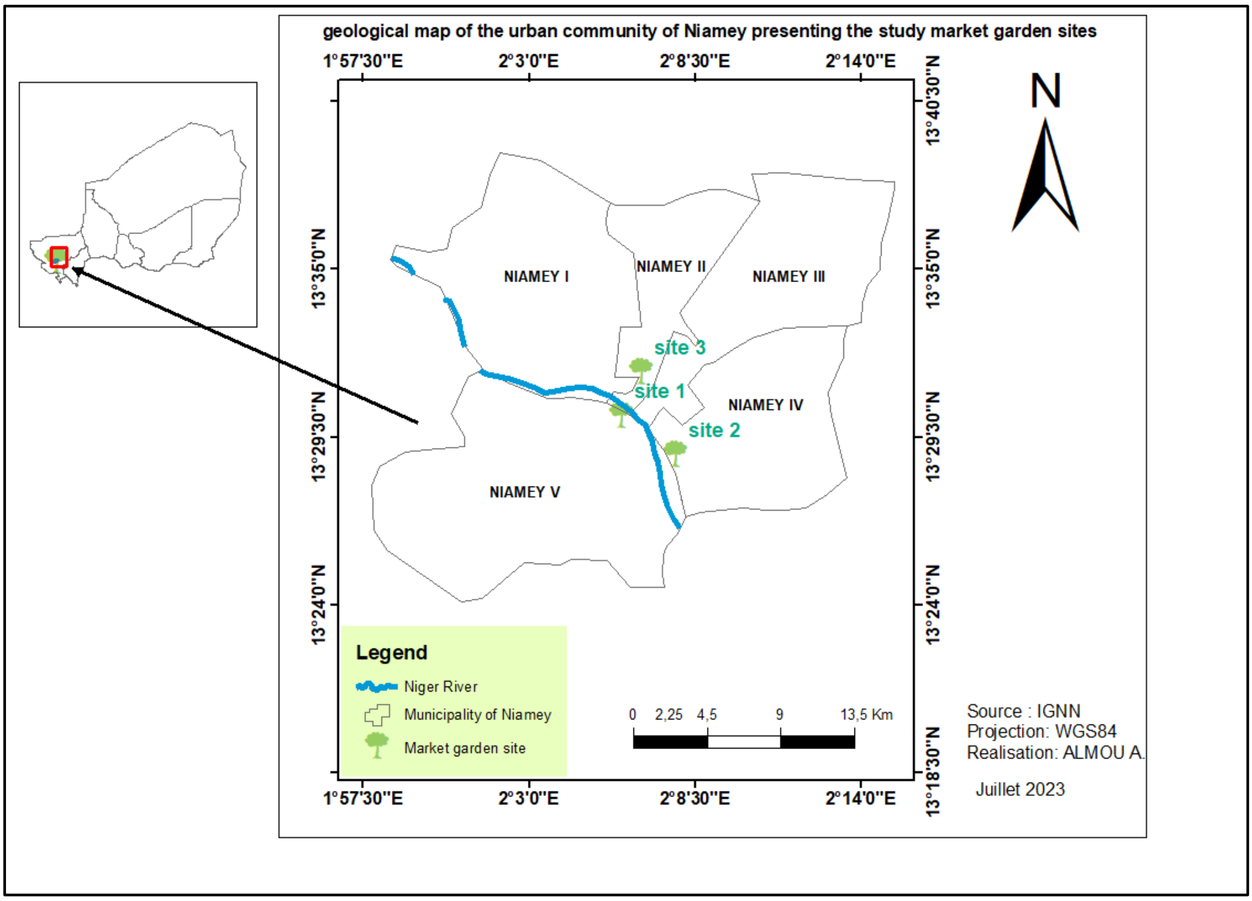

Figure 1 : Map of the city of Niamey, showing the market garden sites used in the study

2.2. Type of study

This was a descriptive cross-sectional study carried out with vegetable growers at three (3) market garden sites in the urbancommunity of Niamey.

2.3. Study population

To determine the characteristics of the production chain and the microbiological contamination risk profile of vegetables at the three (3) target market-growing sites in the city of Niamey, the study population consisted of vegetable growers.

2.4. Survey material

A survey sheet was drawn up to assess vegetable production conditions at three (3) targeted market garden sites in the urban community of Niamey.

2.5. Site selection criteria

The survey sites were selected on the basis of literature data and a field survey. Literature data from previous works[5, 14, 15, 16] was used to identify the main vegetable production areas, and the field visit enabled us to appreciate the reality first-hand.

2.6. Survey sample size

The population of this study consists of vegetable producers. The expected proportion of respondents is estimated from the study by [17] who assessed the contribution of the Federation of Vegetable Cooperatives of Niger (FCMN-niya) to capacity building of vegetable producers in the Niamey 5 communal district. For this study, the overall sample size was 108 respondents (producers). The overall sample is distributed as follows: 60 producers in site 1; 28 in site 2 and 20 in site 3.

2.7. Production site survey

The survey was carried out at three (3) market garden sites in the urban community of Niamey, for the identification of market garden practices likely to contribute to vegetable microbialcontamination. The five keys to grow safe fruit and vegetables, ensuring consumer health while reducing microbial contamination [17, 18]**,** were used as a basis for information. These were water used for watering, manure used as fertilizer, tools and their storage locations, grower's personal hygiene and accessibility of fields to animals. A questionnaire was drawn up for growers, providing information on their socio-demographic characteristics (age, gender, level of education, number of years' experience), practices likely to contribute to contamination (water used for irrigation, manure used as fertilizing agent, personal hygiene and accessibility of fields to animals) and the vegetable growing environment (types of vegetables grown, method of packaging and transporting vegetables).

2.8. Statistical analysis

The survey questionnaire was designed in Microsoft Word and then exported to **KOBO Toolbox**, an open source field data collection instrument developed in collaboration with Harvard Humanitarian Initiative, Brigham and Women's Hospital (www.koboToolbox.org). The ODK collect data version 21.2.4 application was used to collect data on smartphones. Collected data were exported from the server as a Microsoft Excel spreadsheet (.xlsx) and subjected to one-factor analysis of variance (ANOVA) on SPSS software version 23.0.0.0. Differences are considered significant for values of $P<.05$.

3. RESULTS AND DISCUSSION

3.1. Socio-demographic characteristics of growers

Table (1)shows the socio-demographic characteristics of vegetable growers at the market garderning sites in the city of Niamey (site 1: *Harobanda*; site 2: *Gamkalé*; site 3: *Gounti yéna*). Analysis of this table shows that 100% of market gardeners are men. The average age was 38.70±13.34, and 53.70% were over 40. There was no significant difference in the age of market gardeners between sites (P = .057). Nigeriens dominated sites 2 and 3 (100% and 60% respectively), while site 1 was dominated by Burkinabès (53.33%). The difference in nationality is statistically significant between sites (P = .000). Some 45% of market gardeners said they had never been to school, 27.45% had attended elementary school and only 01.96% had a higher level of education. Level of schooling was not significantly different between sites (*P* = .774). Market gardeners on sites 2 and 3 farm significantly larger plots of land (P = .000).

Table 1: Socio-demographic characteristics of market gardeners

Features		Market garden sites			Total
		Site 1	Site 2	Site 3	
Type	Male	60(100)[a]	28(100)[a]	20 (100)[a]	108(100)[a]
	Female	0(0.00)	0(0.00)	0(0.00)	0(0.00)[a,b]
Age	< 20 years	8(13.33)[a]	2(07.43)[a]	0(00.00)[a]	10(09.26)[b]
	20 to 39 years	22(36.67)[a]	10(35.57)[a]	8(40.00)[a]	40(37.04)[b]
	40	30(50.00)[a]	16(57.14)[a]	12(60.00)[a]	58(53.70)[b]
Nationality	Burkinabè	32(53.33)[b]	0(00.00)[a]	8(40.00)[b]	40(37.04)[c]
	Nigerien	28(46.67)[b]	28(100)[a]	12(60.00)[b]	68(62.96)[d]
Level of education	unschooled	26(46.43)[a]	10(38.46)[a]	10(50.00)[a]	46(45.10)[e]
	Primary	16(28.57)[a]	8(30.77)[a]	4(20.00)[a]	28(27.45)[e]
	Secondary	12(21.43)[a]	8(30.77)[a]	6(30.00)[a]	26(25.49)[e]
	Superior	2(03.57)[a]	0(00.00)[a]	0(00.00)[a]	2(01.96)[e]
Farm size	Important	2(03.33)[b]	14(50.00)[a]	8(40.00)[a]	24(22.22)[f]
	Average	32(53.33)[a]	8(28.57)[a]	8(40.00)[a]	48(44.44)[f]
	Small	26(43.33)[a]	6(21.43)[a]	4(20.00)[a]	36(33.33)[f]

3.2. Risk factors for microbial contamination linked to market gardening practices

Sources of irrigation water

The different sources of irrigation water and the factors likely to promote contamination of irrigation water sources are listed in Table (2). Three (3) sources of irrigation water were used at the various market garden sites surveyed: the river, wells and gutters. Market gardeners at sites 1 and 2 exclusively use river water, which was collected and stored in pools, while 90% of market gardeners at site 3 used gutter water, compared with 10.00% who use well water. There was a significant difference between sites in the source of water used (*P* = .000). All market gardeners in site 2 and 90% of market gardeners in sites 1 and 3 used water without any prior treatment. There is a significant relationship between water treatment and site (*P* = .006). In addition, the way in which some market gardeners managed their faecal waste could compromise the quality of water sources. In fact, 50% of market gardeners on site 3 and 43.33% on site 1 keep their faecal waste next to their water sources, while around 93% of market gardeners on site 2;90% on site 1 and 20% on site 3 washed vegetables with irrigation water before transporting them to market. A significant difference was observed between sites (*P* = .000). Depending on the site, 80 to 100% of market gardeners wont directly to the water source to draw water for irrigation, and most were unaware of the dangers associated with this practice. This practice is so widespread that no significant difference was observed between sites (*P* = .067). Several market gardeners declared that "*this water is harmless, we've been using it for years, if it represents a danger, you'll have seen it on our bodies*". The market gardeners at sites 1 and 2 said that "it'*s water that flows, so we can work with it without danger*", despite the fact that the water was pumped and collected in a swimming pool.

Table 1 : Different types of irrigation water sources and practices on the lathe

Parameters		**Market garden sites**			**Total**
		Site 1 n(%)	**Site2 n(%)**	**Site 3 n(%)**	
Source of irrigation water	Well	0(0.00)[a]	0(0.00)[a,b]	2(10.00)[b]	2(01.85)[a]
	Channel	0(0.00)[a]	0(0.00)[a]	18(90.00)[b]	18(16.67)[b]
	River (pool)	60((100)[a]	28(100)[a]	0(0.00)[b]	88(81.48)[c]
Water treatment watering	Yes	6(10.00)[a]	2(07.14)[a]	2(10.00)[a]	10(09.59)[ab]
	No	54(90.00)[a]	26(92.57)[a]	18(90.00)[a]	98(90.74)[ac]
Wash vegetables with irrigation water	Yes	56(90.00)[a]	26(92.86)[a]	4(20.00)[b]	84(77.78)[d]
	No	4(06.67)[a]	2(07.14)[a]	16(80.00)[b]	24(22.22)[e]
Keep fecal waste away from water sources	Yes	34(56.67)[b]	26(92.86)[a]	10(50.00)[b]	70(64.81)[f]
	No	26(43.33)[b]	2(07.14)[a]	10(50.00)[b]	38(35.19)[f]
Descending to the water source to draw water	Yes	52(86.67)[a,b]	28(100)[a]	16(80.00)[b]	96(88.89)[a]
	No	8(13.33)[a,b]	0(0.00)[a]	4(20.00)[b]	12(11.11)[a]
Assessing the danger of descending into the water source to draw water	Yes	2(03.33)[b]	10(35.71)[a]	0(0.00)[b]	12(11.11)[ae]
	No	46(76.67)[b]	4(14.29)[a]	16(80.00)[b]	66(61.11)[g]
	Don't know	12(20.00)[b]	14(50.00)[a]	4(20.00))[a,b]	30(27.78)[ag]

Values with the same letter in the same column are not significantly different (*P*>.05).

Environment of the market garden production site

The characteristics of the market garden environment at the various vegetable production sites surveyed are shown in table (3**)**. Around 13% of farmers have latrines in their fields, 15% near their fields and 37% near their site. This low availability of latrines was fairly consistent between sites (p = .688). At sites 2 and 3; 42.86% and 100% of fields respectively are close to a garbage dump, compared with 13.33% at site 1, the difference between sites is significant (P = .000). Secondly, all fields (100%) surveyed at site 3 are crossed by a sewage canal, compared with 57.14% at site 2 and 3% at site 1. The difference is also significant between sites (P = .000). All fields visited are either close to a road or a path, ranging from less than 100 m (56.70% of fields on site 1 and 10% on site 2) to 1 km (90.00% on site 3 and 43.30% on site 1). Around 70% of fields on site 1 and 100% on sites 2 and 3 are close to a dwelling. There was a significant difference between the different sites in terms of their proximity to dwellings (P = .000). Only on site 1 was the presence of animals close to fields observed, affecting 33.30% of fields.

Table 2 : Distribution (%) of the environment of the different market garden sites

Market garden environment		**Distribution n(%)**			**Total**
		Site 1	**Site2**	**Site 3**	
Latrine near the field	Yes	10(16.67)[a]	4(14.29)[a]	2(10.00)[a]	16(14.81)[a]
	No	48(80.00)[a]	24(85.71)[a]	18(90.00)[a]	90(83.33)[a]
	Don't know	2(03.33)[a]	0(0.00)[a]	0(0.00)[a]	2(01.85)[a]
Latrine in the field	No	54(90.00)[a]	22(78.57)[a]	18(90.00)[a]	94(87.04)[b]
	Yes	6(10.00)[a]	6(21.43)[a]	2(10.00)[a]	14(12.96)[b]
Garbage near the site	No	52(86.67)[c]	16(57.14)[a]	0(0.00)[a]	68(62.96)[a]
	Yes	8(13.33)[c]	12(42.86)[a]	20(100)[b]	40(37.04)[b]
Nearby drainage channels	No	58(96.67)[c]	12(42.86)[a]	0(0.00)[b]	70(64.84)[a]
	Yes	2(03.33)[c]	16(57.14)[a]	20(100)[b]	38(35.19)[b]
Presence of a road or path near the site	Yes	60(100)[a]	28(100)[a]	20(100)[a]	108(100)[a]
	No	0(0.00)[a]	0(0.00)[a]	0(0.00)[a]	0(0.00)[a]
Distance road site	<100 m	34(56.70)[b]	8(28.60)[a]	2(10.00)[a]	44(40.70)[a]
	100 to 1 km	26(43.30)[b]	20(71.40)[a]	18(90.00)[a]	64(59.30)[a]
Home near the site	Yes	42(70.00))[b]	28(100)[a]	20(100)[a]	90(83.33)[a]
	No	18(30.00)[b]	0(0.00)[a]	0(0.00)[a]	18(16.67)[b]
Distance between home and site	<100 m	24(57.14)[a]	14(50.00)[a]	8(40.00)[a]	46(51.11)[a]
	100 to 1 km	18(42.86)[a]	12(42.9)[a,b]	12(60.00)[b]	42(46.67)[b]
	>1 Km	0(0.00)[a]	2(07.10)[a]	0(0.00)[a]	2(02.22)[c]
Animals near fields	Yes	20(33.30)[b]	0(0.00)[a]	0(0.00)[a]	20(18.50)[b]
	No	40(66.70)[a]	28(100)[a]	20(100)[a]	88(81.50)[a]

Values with the same letter in the same column are not significantly different (P>.05).

Phytosanitary treatment

Table (4)distribution of market gardeners according to use of fertilizers and phytosanitary products. All market gardeners in sites 1 and 2 used chemical fertilizers and manure for field fertilization. A significant difference was recorded between the different sites (*P* = .011). At site 3, chemical fertilizers and manure were used by 80% and 90% of market gardeners respectively. Around 69% of market gardeners used manure without any treatment. Antimicrobials are also used by almost all market gardeners. Only17.24% of market gardeners in site 3 reported not using antimicrobials. A statistically different relationship was observed between sites (*P* = .029).

Table 3 : Distribution of market gardeners by use of fertilizers and phytosanitary products

Terms and conditions		**Distribution n(%)**			**Total**
		Site 1	**Site 2**	**Site 3**	
Use of chemical fertilizers	Yes	60(100.00)[a]	28(100.00)[a]	16(80.00)[b]	104(96.30)[a]
	No	0(0.00)[a]	0(0.00)[a]	4(20.00)[b]	4(03.70)[b]
Use of manure as fertilizer	Yes	60(100.00)[a]	28(100.00)[a,b]	18(90.00)[b]	106(98.15)[a]
	No	0(0.00)[a]	0(0.00)[a,b]	2(10.00)[b]	2(01.85)[b]
Manure processing	Yes	30(51.72)[b]	2(07.43)[a]	0(0.00)[a]	32(30.77)[a]
	No	28(48.28)[b]	26(92.86)[a]	18(100.00)[a]	72(69.23)[a]
Antimicrobial use	Yes	50(83.33)[b]	28(100.00)[a]	20(100.00)[a,b]	98(90.74)[ab]
	No	10(17.24)[a]	0(0.00)[a]	0(0.00)[a]	10(09.26)[c]

Values with the same letter in the same column are not significantly different (P>.05).

Packaging and transport of vegetables

Table (5) shows the packaging and transport of vegetables after harvesting. The results showed that harvesting was carried out by retail buyers at 100% on site 3, compared with 93.33% and 78.57% on sites 1 and 2, respectively. The difference was significant between the different sites (*P* = 0.024). At harvest time, 100% of vegetables were placed on the ground on site 2; 96.67% on site 1, but only 40% on site 3. They were mainly packed in wire bags (over 92.86%), and secondarily in cardboard boxes. There was no significant difference between sites (*P* =0.484). Vegetables were transported to sales outlets mainly in public transport vehicles (from 83.33% to 100%). The difference is not significant between the sites surveyed (*P* = .067).

Table 4 : Post-harvest packaging and transportation of vegetables

Packaging and transport after Harvesting		Distribution n(%) Site 1	Site 2	Site 3	Total
Harvest	Buyer	56(93.33)[a]	22(78.57)[a]	20(100.00)[a]	98(90.74)[a]
	Producer	4(06.67)[a]	6(21.43)[a]	0(0.00)[a]	10(09.26)[b]
Storing vegetables on the ground	Yes	57(95.00)[a]	28(100.00)[a]	8(40.00)[b]	93(86.11)[a]
	No	3(05.00)[a]	0(0.00)[a]	12(60.00)[b]	15(13.89)[a]
Washing harvesting equipment	Yes	42(70.00)[b]	28(100.00)[a]	20(100.00)[a]	90(83.33)[b]
	No	18(30.00)[b]	0(0.00)[a]	0(0.00)[a]	18(16.67)[b]
Post-harvest vegetable conditioning	Cardboard	4(06.67)[a]	2(07.14)[a]	0(0.00)[a]	6(05.56)[ab]
	Bag	56(93.33)[a]	26(92.86)[a]	20(100)[a]	102(94.44)[ab]
Vegetable transport	Walking	10(16.67)[a]	0(0.00)[a]	2(10.00)[a]	12(11.11)[c]
	Shared vehicle	50(83.33)[a]	28(100)[a]	18(90.00)[a]	96(88.89)[c]

Values with the same letter in the same column are not significantly different (P>0.05).

Behavior of market gardeners during market gardening activities

On the market garden sites, growers adopt certain behaviors during market gardening activities, which are reported in Figure 2. A good number of market gardeners work with torn clothes (23.33% on site 1 and 12.96% on site 3), dirty clothes (78.57% on site 2 and 50.00% on site 3), and bare feet (30.00% on sites 1 and 3 and 07.14% on site 2). In some cases, all three behaviors were present (20% on site 3 and 14.29% on site 2).

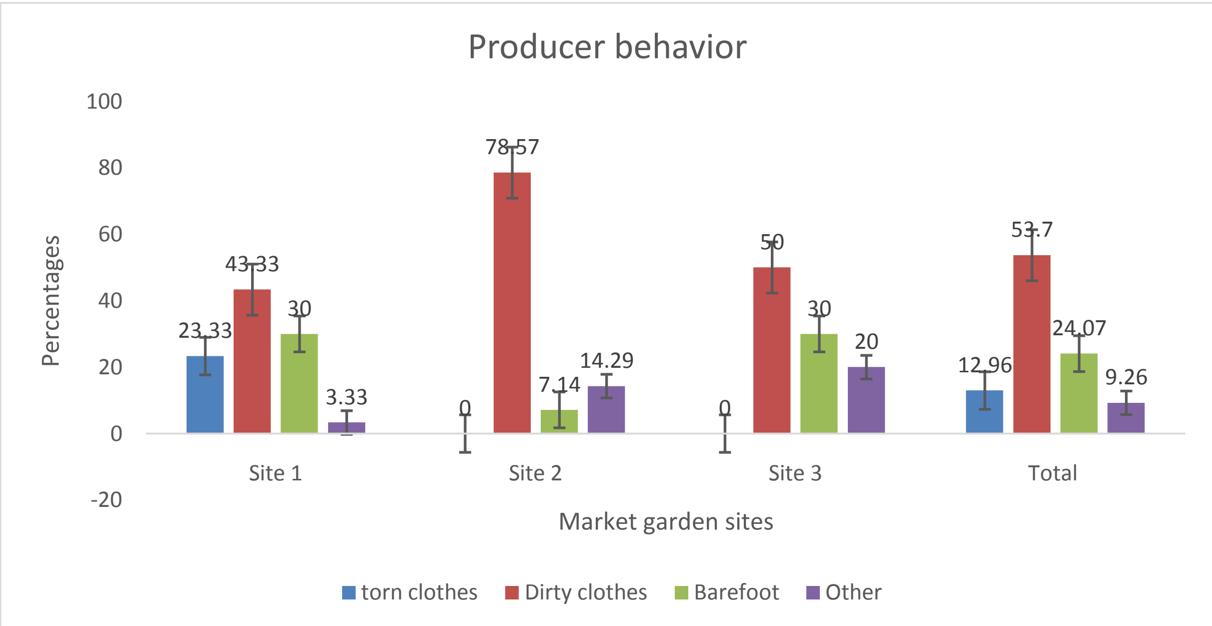

Figure 2 behavior of market gardeners at the time of market gardening activities

Protection against cuts or injuries during work

When growing vegetables, market gardeners run the risk of being injured by the tools they use. Figure 3shows the distribution of market gardeners who protect their injuries before working. The proportion of market gardeners who said they protected their injuries before working was 7% on site 1; 20% on site 2 and 40% on site 3. Respectively, 60%, 35.71% and 30% of market gardeners said they did not protect their wounds, while the rest said nothing on this question.

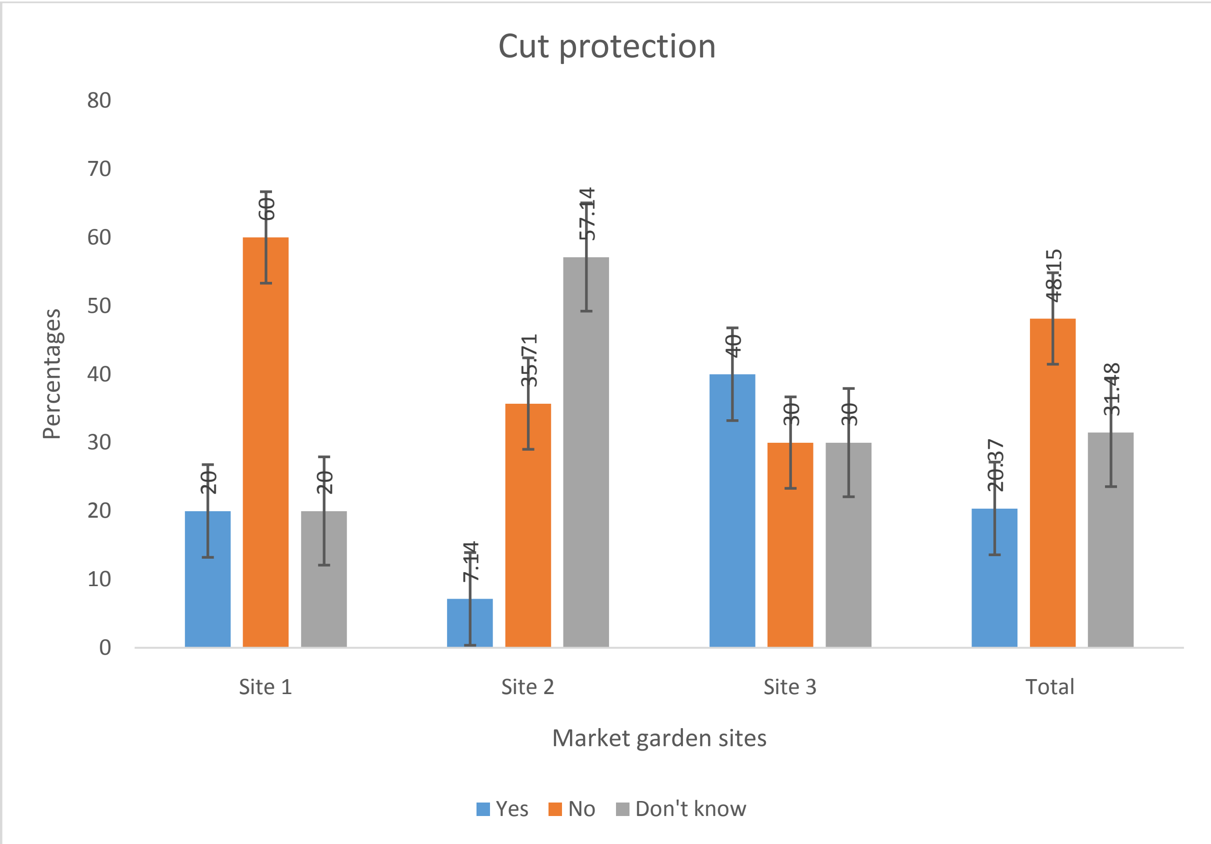

Figure 3 : Distribution of market gardeners according to wound protection

3.3. DISCUSSION

Socio-demographic characteristics of market gardeners

The study showed that market gardening is practiced by men (100%), regardless of the market gardening site considered in the Niamey urban community. According to a study by [20], market gardening is an exclusively male activity. Similar results were reported according to which men represented 71.74% of market gardeners on the *Harobanda* market garden site by [17]. The lack of female representation could be linked to the country's cultural and religious practices, but also to the arduous nature of irrigation practices [20]. However, male predominance in market gardening activities seems to be the rule in Africa, as reported by various studies [21, 22, 23, 24, 25, 26]. According to these authors, this distribution of activities can be explained by the fact that in society, tasks such as selling vegetables, which are less laborious and require less physical effort than production, are dedicated to women. Conversely, production, which requires preparation and irrigation of the land in all seasons and takes up between 40% and 70% of farmers' time, falls to men [24, 27]. Indeed, the drudgery and constant availability required by maintenance activities on a market garden site are not compatible with the availability of women, who must also carry out household activities and look after children [26]. This study also found that half (50%) of the market gardeners surveyed were aged 40 or over. Thus, market gardening is more common among older people. A similar finding was previously reported [20]. According to [17] the 40-50 age bracket is much more interested in market gardening activities among other age brackets without any level of education (47.10%). In Benin, 94% of cotton growers in northern Benin are men aged between 30 and 40, and 73% have received no schooling [25]**.** Farm size also varies from one site to another. On site 1, farm size is predominantly medium (53.33%), on site 2 predominantly large (50.00%) and onsite 3, farm sizes were medium (40.00%) and large (40.00%). This confirms the observations that large farms are concentrated on the *Gamkalé* cornice (which corresponds to our site 2) and the *Gounti yéna* lands (our site 3), which are threatened by urban sprawl, medium-sized farms [14].

Risk factors for microbial contamination linked to market gardening practices

This study enabled us to observe a number of market gardening practices likely to lead to contamination of vegetables on the production sites. Three sources of irrigation water were identified at the various market garden sites surveyed: The River Niger, gutters and wells. This corroborates previous observations [14]. Water from the river is used in the majority of cases (81.5%), followed by water from gutters (16.5%) and wells (2%). Market gardeners on the *Gamkalé* cornice (site 2) and Harobanda (site 1) use river water exclusively. Those at Gounti yéna (site 3), a non-permanent tributary, use 90% toilet wastewater and 10% well water. It is thanks to this gutter water that market gardening is practicable here throughout the 12 months of the year [14]. The study also revealed that some market gardeners (35%) store faecal waste, manure or other products near watering sources. Secondly, a significant number of market gardeners (77.78%) wash vegetables with irrigation water after harvesting, before transporting them to market. Sprinkling polluted water over the lettuces with a watering can is thought to be the source of *Salmonella* contamination[28]. Stagnant pond water and water from gutters used for watering have significantly higher *Salmonella* prevalence than river or borehole water, as in Tahoua, where borehole water is used [20]. These stagnant waters and gutters are exposed to contamination by manure (animal feces used as fertilizer)[21, 29, 30]. They are also subject to the effects of human anthropogenic activities [20]. A large number of market gardeners (88.89%) go down to the water source to draw water with watering cans. Around 89% of market gardeners do not use any watering water treatment and 90% of market gardeners on site 3 use water from gutters. From a health point of view, the biggest threat from wastewater reuse is the presence of pathogenic microorganisms. Viruses, bacteria and parasites can be present in wastewater in high concentrations and survive for long periods. Spreading this water on crops, especially those eaten raw, can lead to microbiological contamination of these products and encourage the introduction of pathogenic microorganisms into the food chain [31]. The reuse of wastewater and the use of manure as a soil fertilizer also leads to heavy contamination of vegetables by microorganisms, some of which may be harmful to consumers [7]. In Nigeria, [32] and Côte d'Ivoire, [24] it has been reported that the use of wastewater in irrigation, particularly water from ceanes, is one of the main causes of the spread of human pathogens in fields. A single application of irrigation water inoculated with Salmonella *was* enough to contaminate carrots and radishes at harvest, with *Salmonella spp.* surviving for 203 days in the soil [33].

In addition to the contamination caused by contaminated water, the use of manure as a soil fertilizer also results in heavy contamination of vegetables by microorganisms, some of which may prove harmful to consumers [7]. For example, strains of *E. coli* have been found on lettuces grown under greenhouse and field conditions after direct contact with manure-based fertilizers and contaminated irrigation water [34]. Similarly, *E. coli* and other enteric pathogens were able to survive in soils for long periods after these were modified by treatment with manure or manure-based fertilizer [35].

It is important to note that some market gardeners do not perceive the risk associated with the use of wastewater in market gardening. This same observation has been made in Côte d'Ivoire, [7]. In Accra, Ghana, nearly 80% of farmers surveyed did not perceive the health risks associated with using wastewater to water vegetables [36]. This lack of awareness of the risks is linked to the ideas and beliefs of market gardeners. This could explain, at least in part, the refusal of these market gardeners to accept a possible link between the quality of water used for watering and disease, the denial of water pollution, the possibility of risks for the family, and a responsibility in the chain of health risks [7]. Moreover, market gardening is practiced in an unsanitary environment in the city of Niamey. The survey results showed a lack of sanitary facilities both in the fields and near the fields. Some 85% to 90% of fields have no latrines, and 80% to 90% have none in their immediate vicinity. The lack of latrines in or near fields leads market gardeners to defecate in the open air in or near fields. This defecation in the vicinity of fields, constitutes an additional source of contamination for vegetables[24]. In addition, some fields are close to garbage dumps (13% of fields on site 1 to 100% on site 2), others are close to housing (70% on site 1 and 100% on sites 2 and 3) and all the fields surveyed are crossed by a road or path. Some fields on site 1 (33.33%) are also occupied by animals. It is well known that animals, whether domestic or wild, are vectors of enteric pathogens through their droppings [24,37].

Market gardening requires the use of fertilizers to boost the crop. It has been observed that 90% to 100% of market gardeners in the urban community of Niamey use manure as a fertilizer in the first or second week after transplanting. A few weeks later, market gardeners use chemical fertilizers. To protect the crop from certain insect attacks, all market gardeners in sites 2 and 3 and 82.76% of market gardeners in site 1 use phytosanitary products which they called (poisons), without any protective equipment. The same observation was made in Côte d'Ivoire[38] and Benin [3,25]. The use of untreated manure is recognized as one of the main risky practices, contributing significantly to the spread of man-made pathogens in fields [24, 32]. The major constraints hindering vegetable production are primarily insects, nematodes and pathogens including fungi. To cope with these demands and improve the productivity and yield of their crops, market gardeners resort to the use of chemical pesticides [3]. The abusive use of phytosanitary products is another source of intoxication and contamination of the environment and the trophic chain, with harmful consequences for human life [3]. The risk of intoxication is increased when doses are high and protection is non-existent [25]. Some authors assert that the abusive use of phytosanitary products is linked to the low level of education of market gardeners[7, 25, 36, 39, 40, 41, 42, 43, 44]. Personal protective equipment plays a very important role in reducing operators' exposure to phytosanitary products. Given their low level of education and supervision, growers are unfamiliar with the toxicity of the pesticides used and have little mastery of their use. The consequences of this situation are acute and chronic intoxication of farmers, but also consumer exposure to pesticide residues, which is underestimated[25, 45,46, 47].

At harvest time, 87.04% of market gardeners place the vegetables on the ground, 94.44% pack them in wire bags and 88.11% transport them to market in public transport vehicles. Vegetable contact with the ground could be a factor in contamination by microorganisms. According to [24], at harvest time, more than half of farmer's place vegetables on the ground. This allows, in the case of lettuce, to reduce weight during transport thanks to the release of cellular fluids. This practice does not comply with Canadian standards for fruit and vegetable production. In fact, the contact of vegetables with the soil could promote the transfer of microorganisms present on the soil to the vegetables[48]. Some growers store market garden produce in fiber bags that are often poorly maintained before storage [23]. This represents another factor in bacterial contamination during transportation of vegetables to the point of sale, especially as transport vehicles are poorly maintained [49, 50]. This method of packaging and transport poses a risk of cross-contamination, as vegetables can be contaminated by the ambient air and also by people in the vehicle transporting these bags of vegetables [24]. In addition, a significant number of the market gardeners surveyed work in dirty (53.70%) or torn (12.96%) clothes. Others work without protecting cuts (wounds or sores), yet to draw water for watering, they go down into the water source. This practice can also be a risk factor for the contamination of vegetables by germs on the bodies of market gardeners or on their wounds. Indeed, the absence of bandaging exposes vegetables to contact with wounds and therefore to contamination [24]. According to the US Food and Drug Administration, employees or growers suffering from gastroenteritis distress or open wounds can easily contaminate fresh produce with pathogens through handling, if they don't put on adequate protection [51].

4. CONCLUSION

This study identified market gardening practices likely to cause vegetable bio-contamination on market gardening sites. Several risk factors for microbiological contamination were identified, including the use of wastewater, washing vegetables with irrigation water, the use of untreated manure, open defecation, lack of personal hygiene, depositing vegetables on the ground and packaging conditions. To ensure healthy vegetable production, market gardeners need to be made aware of these issues and trained to deal with them.

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