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HYGIENE PRACTICES AND AIRBORNE MICROBIAL CONCENTRATIONS IN RESTAURANTS

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Abstract

This study was carried out to evaluate bioaerosol concentrations in the indoor air and the hygiene practices of restaurants to highlight the exposure risks and improve food safety in restaurants. Using depositional sampling techniques, air samples were collected from each restaurant kitchen and dining room and aerobically cultured. Hygiene/sanitary conditions were assessed using observation schedules and questionnaires. Meteorological parameters were also monitored during air sampling. The results revealed that bacterial and fungal concentrations (CFU m^{-3}) ranged from 1.07×10^{3}–1.36×10^{4} and 8.2×10^{1}–5.76×10^{2}, respectively. Regarding the sanitary conditions of the restaurants, 3.5% of the kitchens were in good sanitary condition, and the food was adequately protected from flies in only 14% of the kitchens. Only 3.5% of the food handlers had attended food hygiene basic training, up to 33% of the food handlers had no education at all, and only 0.10% had medical certifications. High microbial counts and the poor sanitary conditions and personal hygiene practices observed in this study not only indicate a strong need for improved hygiene but also constitute a serious potential health hazards.

Keywords: Indoor air; Bio-aerosols; Hygiene; Restaurants; Open plate technique

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Introduction

Indoor air quality is one of the most significant factors affecting the health and well-being of people (Dacarro *et al.*, 2007) as exposure to bioaerosols, containing airborne microorganisms and their by-products, can result in diseases including respiratory disorders and other adverse health effects (Gorny *et al.*, 2002; Fracchia *et al.*, 2006). In fact, possible associations between non-communicable diseases such as cancer and exposure to bioaerosols have been reported in past studies (Hayleeyesus *et al*., 2015; Johnson and Choi, 2012). Many human and animal pathogens are airborne (Brown and Hovmøller, 2002; Fisher *et al*., 2012). Poor air quality is responsible for an estimated seven million deaths globally (Anna, 2016). The air inhaled by people in their residential and occupational environment, both indoor and outdoor, is mostly populated with microorganisms (viruses, fungal spores and conidia, and bacterial endospores) trapped in colloidal suspensions through association with liquid droplets and particles of solid matter in the air such as plant pollen and fragments of plant tissues (Kalwasińska *et al.*, 2012; Karwowska, 2005). Possible sources of biological contamination of indoor air include people, organic dust, various materials stored in the buildings, and the air inflowing from the ventilation and air conditioning systems (Kalwasińska *et al.*, 2012). According to the EPA (US Environmental Protection Agency), the indoor environment is two to five times more toxic than the outdoor environment, and in some cases, the indoor air has been found to be 100 times more polluted (Rana, 2014). The air quality around and within the food industry could be affected by several factors. Improper environmental sanitary conditions during food processing could lead to the formation of suspended bioaerosols (Sutton, 2004). These bioaerosols, because of their small size and light weight, are easily dispersed (Van Leuken *et al*., 2016). Within the restaurant environment, environmental factors such as temperature, humidity, light and nutrient availability have been reported to further increase the chances of air pollution (Udochukwu *et al.*, 2015; Jyotshna and Helmut, 2011; Jones and Harrison, 2004). Due to lack of efficient monitoring systems, this is only noticed when infections set in and disease symptoms become apparent (Marius *et al*., 2012).

Due to the high risk of microbial contamination, the food industry like pharmaceutical and medical industries, recognizes that monitoring the microbial quality of air within these food processing environments is of paramount importance in standard quality-control practices. Many food producers now include bioaerosol monitoring as part of their Hazard Analysis Critical Control Point. In many cases, simply monitoring the overall population of airborne microbes may provide sufficient information (Richard, 2009). Although researchers have repeatedly stressed the importance of effective hygiene procedures in the prevention of cross-contamination within the food industry, hygiene practices have frequently been shown to be inefficient in controlling microbial growth and survival in the kitchen and dining room (Fur-Chi *et al.*, 2011). Literature suggests that several studies have been documented on the microbiological contamination of both kitchen utensils and kitchen surfaces. Occurrences of large populations of heterotrophic and enteric bacteria in kitchen sponges and dishcloths, for example, have been reported (Gerba *et al*., 2014). Gerba *et al*. (2014) found bacterial concentrations in large numbers in kitchen and hand towels, with heterotrophic plate count and *E coli* count as high as 10^9 and 10^4 CFU ml^{-1} respectively.

Globally, about 2.6 billion people, most of whom living in Africa and Asia, do not have access to proper sanitation facilities (Hoang and Nguyen, 2011). Due to the lack of access to safe water, poor sanitation and improper hygiene are responsible for about 60% of disease burden in the developing countries **(**O'Neill, 2016; Nhepi, 2015). In sub-Saharan Africa, only 15% of the population have basic hand hygiene facilities with soap and water as of 2015 (Kumar *et al*., 2017). This trend has not yet improved. In the last two-and-a-half decade, both air pollution and its debilitating health consequences have considerably increased around the globe. In the developing countries, in particular, air pollution is one of the significant causes of morbidity and mortality, posing a huge public problem (Cohen *et al*., 2017). Studies have shown that more than 80 %of people living in urban cities in these countries are exposed to unacceptable levels of air pollutants (Fagan, 2017). Additionally, access to reliable data has been one of the major problems in understanding the relationship between air quality and public health in these poor countries (Fagan, 2017). To avoid poisoning, illness and even death, good hygiene practices such as hand washing, maintaining general cleanliness and being aware of the dangers of cross-contamination between raw and cooked foods are essential for food preparation, not only in the food industry but also the domestic setting (Johnson, 2016). In the food industry, bioaerosols are a problem to production surfaces, raw products, ready-to-eat food and health of the workers (Bonetta *et al.,* 2010; Mullane *et al.,* 2008). In Nigeria, despite this threat, not adequate attention has been given to the monitoring of airborne microorganisms, whether outdoor or indoor (Makut *et al.,* 2014). This study was carried out to determine the bio-aerosols concentrations in the indoor air of restaurants, highlight the exposure risks, and assess the hygiene practices in restaurants.

Materials and methods

Study Area

The study was carried out in Kebbi State, located in the north-western part of Nigeria (Figure 1). Kebbi State is situated between latitudes 10° 8′ N – 13° 15′ N, and longitudes 3° 30′ E – 6° 02′ E. With the population of 3,238,628 in 2006, the State occupies an area of about 36 229 square kilometers (Jirgi *et al.,* 2016). The study was carried out in Birnin Kebbi, Jega and Aliero Local Government Areas of the State. Birnin Kebbi being the capital of the state whereas Aliero and Jega, being the commercial nerve centres of the state, were selected based on their strategic importance.

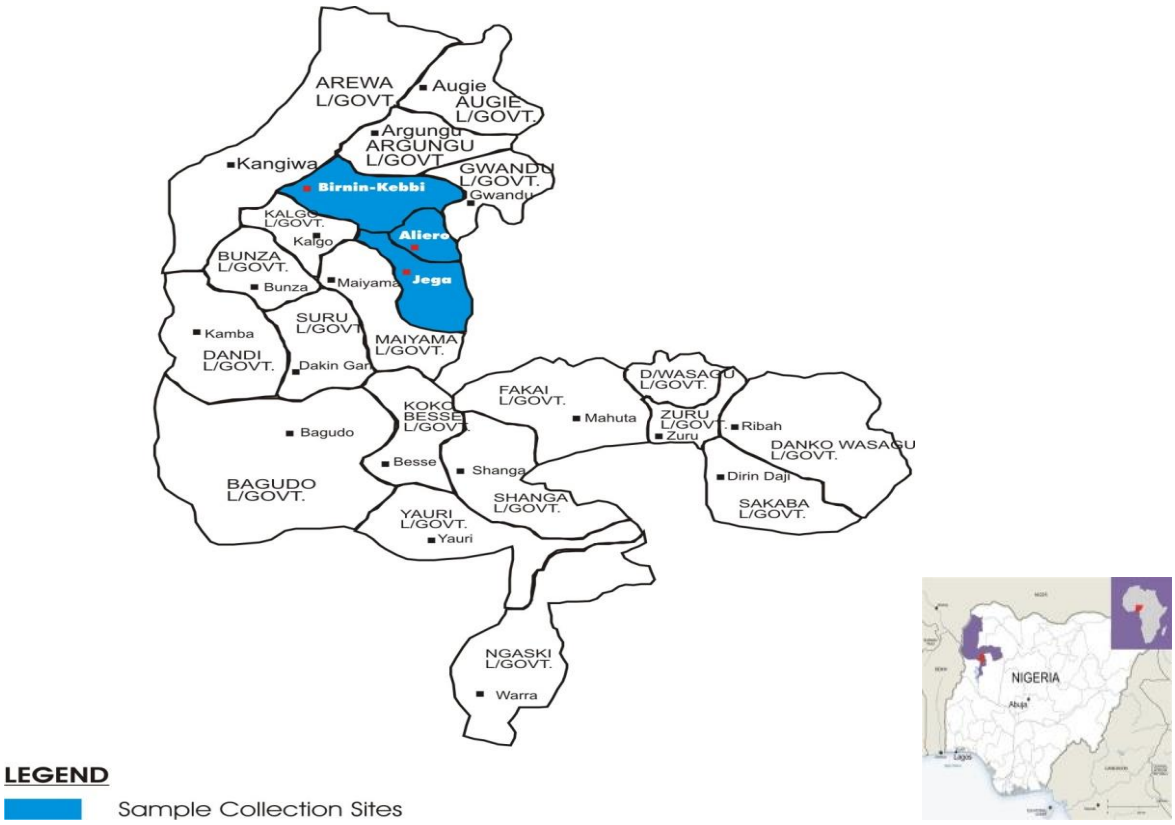

Figure 1: Map of Kebbi State Showing the Study Areas (LGAs)

Measurement of Meteorological Parameters (Temperature, Air flow velocity and Humidity)

During the bioaerosol sampling, meteorological parameters including temperature (°C), air flow velocity (m s^{-1}) and humidity (H, %) were also measured and recorded using digital thermometer (model HTC-1), anemometer (model CR2032) and hygrometer (model HTC-1), respectively, using protocols described by Cheryn (2014).

Assessment of Personal Hygiene and Sanitary Conditions of Kitchens and Dining Rooms

The personal hygiene practices of food handlers (such as access to hand washing soap and water, nature of finger nails, whether or not hair was covered, presence or absence of open wound), sanitary condition of kitchens and dining rooms (such as presence and nature of preparation tables, access to adequate supply of water, presence or absence of offensive odour, availability of hand washing soap and water) were assessed using observation schedules and questionnaire (Hess-Kosa, 2002; Baş *et al*., 2006 and Giritlioglu *et al*., 2011). Before initiating the study, an institutional ethical approval was obtained for this research from the Department of Environmental Health, Kebbi State Ministry of Environment. An informed oral consent was also sought and obtained from the restaurant owners and/or their employees before sample collection and administration of the questionnaires. The sample size in this study was determined using proportionate stratified random sampling technique as described by Nickolas (2017), where a total of 19 restaurants were selected for the study; with 8, 10 and 20 expected number of restaurants (with indoor kitchens only) in Aliero, Jega and Birnin Kebbi respectively, taking ½ fraction from each study location (i.e. 4+5+10), hence the 19 restaurants.

Sample Collection and Handling

Malt extract Agar (MEA) medium were incubated for 5 days at 27°C (Aboul-Nasr *et al.*, 2014). During each sampling, triplicate air samples were collected from dining rooms and kitchens of each restaurant. There were three days of sample collection at each restaurant (with interval of three days).

Enumeration of Bacteria and Fungi

After incubation, bacterial and fungal colonies were counted separately and expressed in colony forming unit per cubic meter (CFU m-^{3}) of air using the equation CFU m^{-3} = a × $10000(bt)^{-1}$, where a is the number of colonies on the Petri plate, b is the surface of the Petri plate and t is the time of Petri plate exposure (Stryjakowska-Sekulska *et al*. 2007).

Statistical Analysis

Using SPSS (Statistical package for the Social Sciences) Version 20, Pearson's correlation analysis was carried out to estimate the relationship between the meteorological parameter (temperature and humidity and air flow velocity) and the airborne bacterial and fungal concentrations (Aegerter *et al.,* 2003). The statistical significant difference in the concentration of airborne bacteria and fungi among morning and afternoon samples and among sampling sites were determined by one-way ANOVA (Kalwasińska *et al,* 2012). *p*-value of <0.05, was considered statistically significant.

Results

Socio-Demographic and Hygiene Characteristics of Food Handlers

A total of 201 food handlers participated in the study majority of whom were female (61%) and were mostly between the ages of 18 to 45 (95%) (Table 1). Only 3.5% of the food handlers had attended food hygiene basic training, and up to 33% of the food handlers had no any form of formal education at all. Also, 47.76% of food handlers wore clean attire and over 50% of them had cleaned, trimmed, and unpolished finger nails (Figure 2). Although 100% of the food handlers indicated that they were in good health, only (0.10%) had evidence of medical certification.

Table 1: Socio-Demographic Characteristics of Food Handlers.

SN	Variables	n=201	%
1	**Age (years):**		
	Below 18	007	03.48
	18-45	191	95.03
	>45	003	01.49
2	**Gender**:		
	Male	078	39.40
	Female	123	61.19
3	**Role**:		
	Cooks	094	46.77

	Waiters	107	53.23
4	**Level of Education**		
	No formal education	068	33.83
	Primary	017	08.46
	Secondary	090	44.78
	Tertiary	026	12.94
5	**Food handlers who attended basic training**	007	03.48

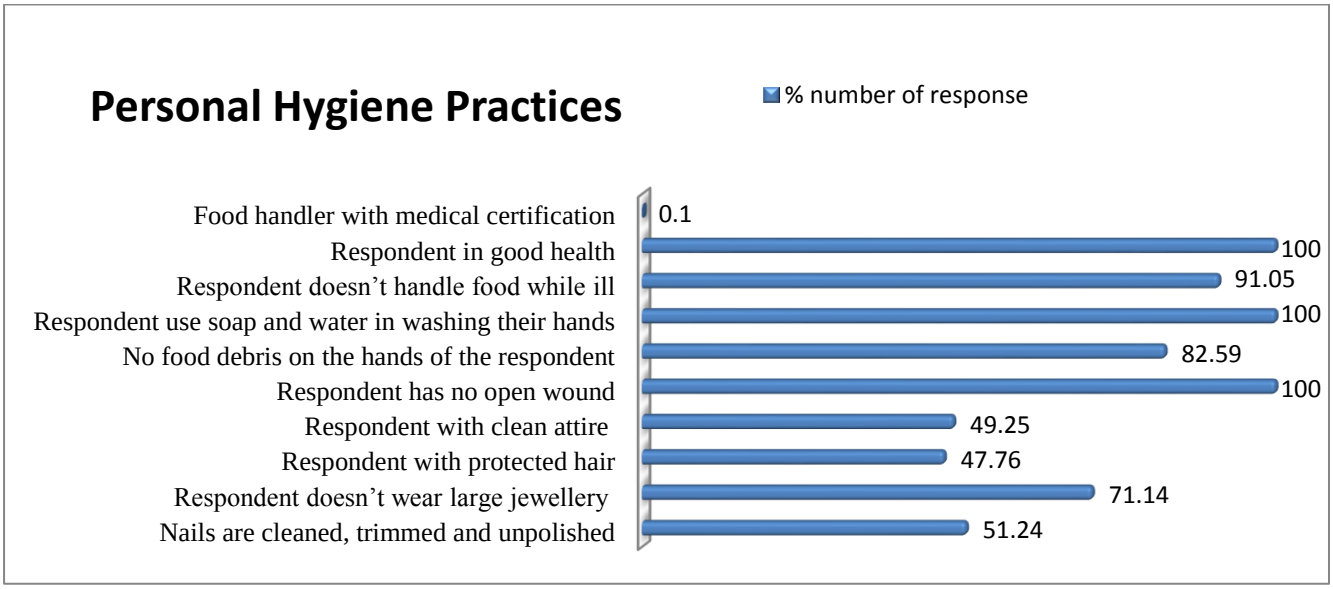

Figure 2: Hygiene Practices of the Food Handlers

Sanitary Conditions of Restaurants

Results for sanitary conditions of the restaurants are presented in Figures 3 and 4. Most of the respondents (87.7%) indicated that they cleaned their kitchens and dining rooms at least twice a day. Only 3.5% of the kitchens were physically clean (no signs of food debribs/spills on surfaces, sinks were rinsed out,utencils washed and kept orderly, counter tops and tables were wiped and no gabbages seen). In 14% of the kitchens, food was adequately protected from flies

and 22.8% had an adequate supply of water. Also, 49% of the dining rooms had a deciated hand washing area where soap was provided.

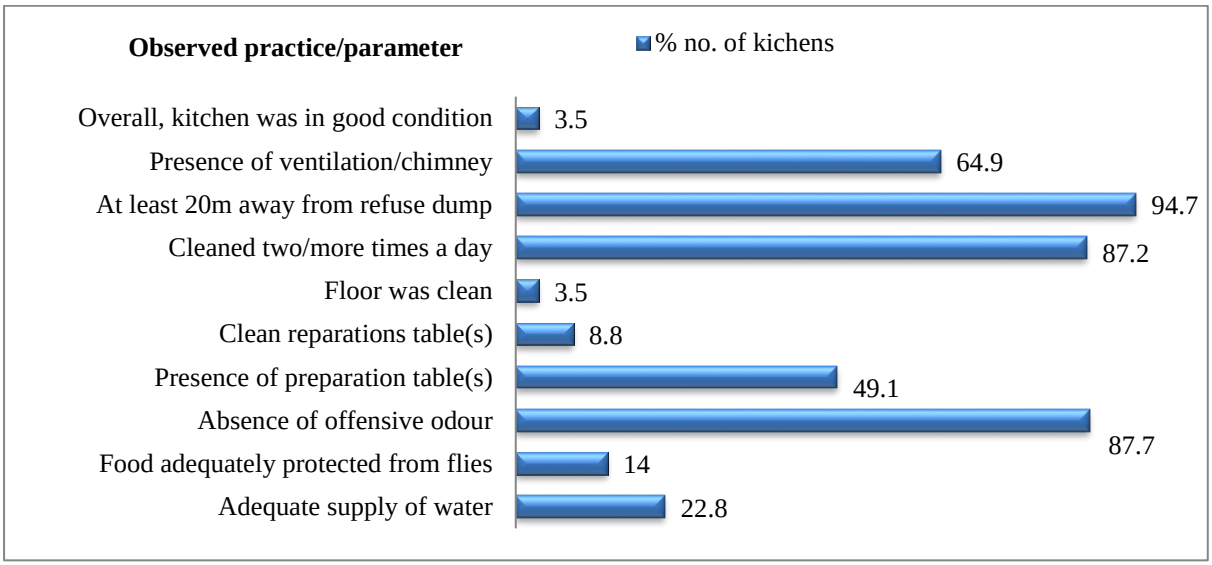

Figure 3: Sanitary Characteristics of the Kitchens

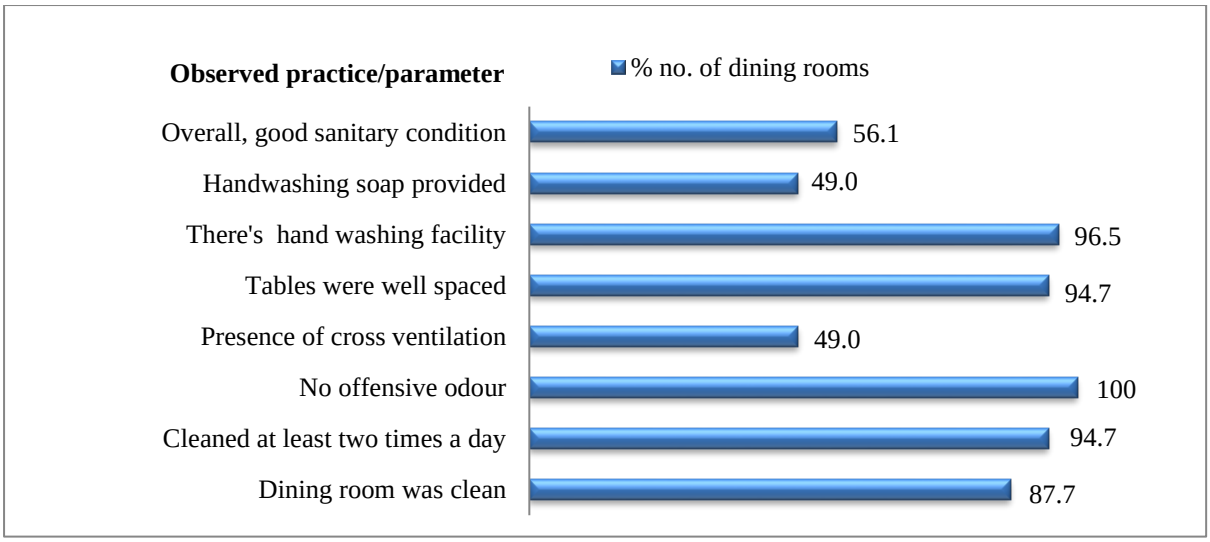

Figure 4: Sanitary Characteristics of the Dining Rooms

Meteorological Parameters Monitored

Results for meteorological parameters of restaurants' kitchens and dining rooms in Aliero, Jega and Birnin Kebbi are presented in Table 2. The temperature measured during monitoring ranged from 29°C to 43°C while the average humidity levels ranged from 29% to 53%. Airflow velocity ranged from 0 m s^{-1} to 1.2 m s^{-1}.

Table 2: Meteorological Parameters Monitored in the Kitchens and Dining Rooms of the Restaurants

SN	Sampling site	Sampling time	Temperature (^{0}C)		Humidity (%)		Air flow velocity (m s^{-1})	
			Dining	Kitchen	Dining	Kitchen	Dining	Kitchen
1	ARA	Morning	38	37	39	44	1	0.2
		Afternoon	42	41	38	44	1	0.2
2	ARB	Morning	36	39	44	44	0	0
		Afternoon	38	42	39	41	0	0
3	ARC	Morning	36	38	53	47	1	0.5
		Afternoon	38	42	49	36	1	0.5
4	ARD	Morning	37	35	42	49	0	0.8
		Afternoon	39	42	40	48	1	0.8
5	JRA	Morning	37	38	41	36	0.1	0.2
		Afternoon	37	43	36	34	0.1	0.1
6	JRB	Morning	33	39	37	37	0.2	0.6
		Afternoon	38	41	34	35	0.1	0.5
7	JRC	Morning	35	36	38	41	0.4	0.6
		Afternoon	39	41	37	36	0.4	0.6
8	JRD	Morning	30	39	39	40	0.1	0.4
		Afternoon	37	42	29	33	0.1	0.3
9	JRE	Morning	33	39	37	40	0	0.1
		Afternoon	37	42	33	36	0.1	0.1
10	BRA	Morning	34	37	41	42	0.9	0.5
		Afternoon	36	42	39	38	1.0	0.4
11	BRB	Morning	31	38	35	35	0.4	0.2
		Afternoon	34	42	33	34	0.3	0.2
12	BRC	Morning	35	38	34	34	0.6	0.5
		Afternoon	38	41	33	32	0.7	0.5
13	BRD	Morning	31	38	40	36	1.1	0.3
		Afternoon	34	41	37	35	1.2	0.4
14	BRE	Morning	30	39	35	42	0.6	0.9
		Afternoon	36	42	32	38	0.6	0.8

15	BRF	Morning	31	38	46	36	0.6	0.1
		Afternoon	38	42	36	36	0.7	0.1
16	BRG	Morning	33	37	37	39	0.2	0.1
		Afternoon	38	41	35	35	0.2	0.1
17	BRH	Morning	34	39	40	37	0.4	0.1
		Afternoon	37	42	35	34	0.5	0
18	BRI	Morning	29	40	38	40	0.4	0.2
		Afternoon	37	42	35	36	0.5	0.2
19	BRJ	Morning	33	39	39	37	0.4	0.2
		Afternoon	37	42	34	35	0.4	0.3

Key: ARA to ARD = Aliero Restaurant A to D; JRA to JRE = Jega Restaurant A to E and BRA to BRJ = Birnin Kebbi Restaurant A to J.

Aerobic Bacterial Count and Fungal Counts

Bacterial concentrations ranged from 1.07×10^{3}–1.36×10^{4}CFU m^{-3} while the fungal concentration ranged between 8.2×10^{1}–5.76×10^{2} CFU m^{-3} (Table 3). One-way ANOVA showed a statistically significant difference between the three sampling sites (p=0.032) regarding the bacterial concentrations. A statistically significant difference was also observed between the morning and afternoon bacterial counts in Aliero (p=0.017) and Birnin Kebbi (p=0.003). Regarding the fugal concentrations, there was no statistically significant difference between the three locations (p=0.156). However, there was a statistically significant difference between morning and afternoon fungal counts in Jega (p= 0.003), and Birnin Kebbi (p=0.000)

Table 3: Aerobic Bacterial and Fungal Counts from Kitchens and Dining Rooms of the Restaurants

SN	Sampling Site	Sampling Time	Aerobic Bacterial Count (CFU m^{-3}) (mean ±SD)				Fungal Count (CFU m^{-3}) (mean ±SD)			
			Dining room		Kitchen		Dining room		Kitchen	
1	ARA	Morning	1.77×10^3	±33.07	2.12×10^3	±27.02	2.47×10^2	±2.739	5.35×10^2	±8.388
		Afternoon	4.07×10^3	75.9	2.51×10^3	±30.75	2.05×10^2	±5.175	2.06×10^2	±4.353
2	ARB	Morning	2.88×10^3	±56.39	3.79×10^3	±60.37	2.47×10^2	±5.003	4.11×10^2	±9.381
		Afternoon	5.35×10^3	±94.43	5.35×10^3	±91.3	2.88×10^2	±4.243	1.64×10^2	±3.969
3	ARC	Morning	2.76×10^3	±49.95	2.84×10^3	±56.03	2.47×10^2	±6.247	2.47×10^2	±7.322
		Afternoon	3.83×10^3	±67.97	3.42×10^3	±34.65	1.23×10^2	±2.789	1.23×10^2	±3.346
4	ARD	Morning	1.07×10^3	±21.67	2.55×10^3	±30.47	8.2×10^1	±1.936	2.06×10^2	±3.279
		Afternoon	3.37×10^3	±103.9	2.43×10^3	±66.11	8.2×10^1	±2.522	1.23×10^2	±3.245
5	JRA	Morning	2.22×10^3	±29.48	8.89×10^3	±166.6	1.64×10^2	±2.587	4.11×10^2	±6.566
		Afternoon	4.32×10^3	±68.77	7.57×10^3	±137.8	1.23×10^2	±2.744	1.64×10^2	±3.712
6	JRB	Morning	2.02×10^3	±30.1	3.33×10^3	±41.37	2.88×10^2	±3.428	3.70×10^2	±5.472
		Afternoon	3.91×10^3	±46.69	4.73×10^3	±72.08	1.23×10^2	±3.609	1.23×10^2	±2.55
7	JRC	Morning	3.91×10^3	±54.94	5.35×10^3	±118.7	2.47×10^2	±6.058	2.47×10^2	±6.405
		Afternoon	4.98×10^3	±90.38	5.56×10^3	±74.54	1.64×10^2	±4.086	2.06×10^2	±6.14
8	JRD	Morning	5.10×10^3	±87.8	6.87×10^3	±115.8	1.65×10^2	±3.383	2.88×10^2	±6.521
		Afternoon	9.05×10^3	±102.7	6.42×10^3	±65.03	1.65×10^2	±2.619	1.23×10^2	±3.082
9	JRE	Morning	4.77×10^3	±71.45	3.46×10^3	±63.01	1.23×10^2	±3.046	2.88×10^2	±4.755
		Afternoon	5.56×10^3	±74.54	5.76×10^3	±113.8	2.06×10^2	±6.14	1.65×10^2	±4.324

10	BRA	Morning	1.98×10^{3}	±32.62	4.12×10^{3}	±80.99	1.65×10^{2}	±2.789	4.53×10^{2}	±8.136
		Afternoon	3.13×10^{3}	±36.04	5.93×10^{3}	±89.54	8.2×10^{1}	±2.186	2.47×10^{2}	±4.106
11	BRB	Morning	1.98×10^{3}	±16.46	2.06×10^{3}	±23.02	2.06×10^{2}	±3.563	3.29×10^{2}	±6.972
		Afternoon	2.26×10^{3}	±23.49	2.18×10^{3}	±31.8	1.65×10^{2}	±3.456	1.65×10^{2}	±4.868
12	BRC	Morning	3.13×10^{3}	±55.52	4.98×10^{3}	±92.87	3.29×10^{2}	±3.00	5.35×10^{2}	±8.599
		Afternoon	4.36×10^{3}	±94.48	3.95×10^{3}	±35.77	1.65×10^{2}	±3.563	1.23×10^{2}	±2.048
13	BRD	Morning	1.11×10^{3}	±31.94	2.43×10^{3}	±39.27	1.23×10^{2}	±2.774	3.29×10^{2}	±5.59
		Afternoon	1.65×10^{3}	±34	2.22×10^{3}	±64.3	1.23×10^{2}	±2.977	2.47×10^{2}	±4.822
14	BRE	Morning	1.11×10^{3}	±24.38	6.67×10^{3}	±88.58	2.06×10^{2}	±3.745	5.76×10^{2}	±8.638
		Afternoon	2.63×10^{3}	±20.89	8.23×10^{3}	±119.1	1.23×10^{2}	±2.774	4.53×10^{2}	±6.002
15	BRF	Morning	3.29×10^{3}	±28.2	5.60×10^{3}	±55.88	2.88×10^{2}	±5.657	4.12×10^{2}	±5.426
		Afternoon	5.76×10^{3}	±108.3	1.21×10^{4}	±130.3	2.06×10^{2}	±3.516	2.47×10^{2}	±3.358
16	BRG	Morning	3.17×10^{3}	±28.55	4.07×10^{3}	±48.73	2.47×10^{2}	±4.444	4.16×10^{2}	±7.681
		Afternoon	5.97×10^{3}	±87.92	9.10×10^{3}	±88.27	2.06×10^{2}	±2.667	2.06×10^{2}	±2.00
17	BRH	Morning	2.26×10^{3}	±25.02	7.08×10^{3}	±93.35	2.88×10^{2}	±5.191	4.12×10^{2}	±7.785
		Afternoon	2.80×10^{3}	±26.31	1.36×10^{4}	±100.4	1.65×10^{2}	±3.504	2.47×10^{2}	±3.391
18	BRI	Morning	3.33×10^{3}	±32.4	2.76×10^{3}	±29.39	3.29×10^{2}	±4.045	5.76×10^{2}	±10.16
		Afternoon	4.82×10^{3}	±53.63	4.12×10^{3}	±48.79	1.23×10^{2}	±2.108	2.06×10^{2}	±3.321
19	BRJ	Morning	3.05×10^{3}	±28.12	5.80×10^{3}	±54.73	2.88×10^{2}	±5.916	3.29×10^{2}	±9.124
		Afternoon	4.61×10^{3}	±54.27	6.63×10^{3}	±106.5	1.65×10^{2}	±3.464	1.23×10^{2}	±2.693

Key: ARA to ARD = Aliero Restaurant A to D; JRA to JRE = Jega Restaurant A to E and BRA to BRJ = Birnin Kebbi Restaurant A to J.

Correlation between Meteorological Parameters and Microbial Counts

Pearson correlation analysis showed varying degree of relationships between the microbial concentration and meteorological parameters (Table 4).

Table 4: Pearson Correlation Analysis

		Bacterial Count	Fungal Count	Temperature	Humidity	Air flow Velocity
Bacterial count	Pearson Correlation	1.000	0.123	0.458**	-0.317**	-0.347**
	Sig. (2-tailed)		0.290	0.000	.005	0.002
	N	76	76	76	76	76
Fungal count	Pearson Correlation	0.123	1.000	0.003	0.159	-0.136
	Sig. (2-tailed)	0.290		0.983	0.169	0.242
	N	76	76	76	76	76

.**Correlation is significant at 0.01 level of probability (2-tailed)

Discussion

The findings of the current study indicated that bacterial concentrations ranged from 1.07×10^3 CFU m^{-3}–1.36×10^4CFU m^{-3} and fungal concentration ranged from 8.2×10^1 CFU m^{-3}–5.76×10^2CFU m^{-3}. Bacterial concentrations in all the locations exceeded the recommended limit of 1.03×10^2CFU m^{-3} suggested by the National Institute of Occupational Safety and Health (USA), and 5×10^2CFU m^{-3} for culturable bacteria suggested by the American Conference of Governmental Industrial Hygienists (Kalogerakis *et al.*, 2005).The mean bacterial concentrations also exceeded the proposed Residential Limit Values of 2.50×10^2 CFU m^{-3} that Górny and Dutkiewiez (2002) earlier presented to the World Health Organisation (WHO) expert meeting in Berlin.Taking into account the available threshold limits for bacterial concentrations in the air environments, it is obvious that the indoor air of the studied restaurants was highly contaminated with bacteria. Microbial air contamination in restaurants may result in both product deterioration and infections (Kisembi, 2010). Exposure to bacteria in the air may result in various types of infections ranging from anthrax, tuberculosis, Legionnaire's disease, influenza, gastrointestinal illness, measles and a number of respiratory diseases or symptoms, bacteremia, to meningitis (Srikanth *et al*., 2008; Fisher and Phillips, 2009; Arzt *et al*., 2011; Langer et *al*., 2012; Rohr *et al*., 2015). *B. cereus*, an airborne bacterium, is known to cause food borne illnesses, causing severe nausea, vomiting, and diarrhea (Daliborca *et al*., 2013). Various airborne Gram-negative bacteria produce lipopolysaccharides (LPS) with hyper pro-inflammatory and toxic properties (Tirsoaga *et al*., 2007; Armstrong *et al*., 2013). These lipopolysaccharides (endotoxins) have been regarded to be one of main cause of both occupational lung diseases and organic dust toxic syndrome (Park *et al*., 2015). Mitchell *et al*. (2015) reported changes in pulmonary function due to endotoxin exposure in dairy workers. Apart from endotoxin, some airborne bacterial pathogens such as *Corynebacterium diphtheria* and *Bordetella pertussis*,

can also secret secondary metabolites called exotoxins (Hadfield *et al.*, 2000; Mattoo and Cherry, 2005; Warfel et al., 2012).

Interestingly, in this study, none of the locations exceeded the threshold concentrations of 1.00×10^{3}CFU m^{-3} for the fungi recommended by Górny and Dutkiewiez, (2002). Nevertheless, the fungal concentrations recorded in the current study exceeded in many cases, the limit of 2.50×10^{2}CFU m^{-3} proposed by the American Industrial Hygiene Association (Post-Remediation Guidelines, 2001). The Canadian Health and Welfare Department has equally recommended that, for any one fungal specie, a concentration of as low as 50 CFU m^{-3} should immediately be investigated; and that concentration of certain fungal pathogens of up to 100 CFU m^{-3} is not acceptable (Kim *et al.*, 2017). This might be due to their potential health risks. (Jyotshna and Helmut, 2011) have cited a scholarly article that indicated fungal concentration as low as 150 CFU m^{-3} of indoor air, be of concern. They concluded that high fungal concentrations in the indoor environments of various structures portend a public health danger. Exposure to fungi may cause skin and breathing problems, allergic, inflammatory, and toxic reactions (Daliborca *et al*., 2013; Lou *et al*., 2012; Fracchia *et al*., 2006). Respiratory symptoms may occur from the inflammation of airway as negative results of exposure to aerosols (Kim et al., 2017). Aerosols containing spores of pathogenic fungi such as Aspergillus, Cryptococcus, and Pneumocystis spp., when inhaled into the lungs, particularly in persons with suppressed immune system, could cause fatal invasive infections (Yu *et al*., 2010; Brown *et al*., 2012). Mycotoxins are associated various health effects on humans and animals, ranging from allergies, diseases, and sometimes death (Kim et al., 2017). Single mold specie may produce different types of these toxins (Andretta *et al*., 2011).

The high concentrations of bacteria and fungi observed in the present study cannot be disconnected from a number of microbiological contamination sources such as restaurants workers, customers, clothing materials, poor ventilation systems, poor hygienic and sanitary conditions, and foodstuff among many other sources. The human body, as well as clothing, harbour the growth of microorganisms. A strong relationship between occupant density, sanitation, ventilation system, human activity and microorganisms' concentration in the indoor air has been reported in past studies (Toivola *et al.* 2002; Arwowska 2003; Loftness *et al.*, 2007; Yoon *et al*., 2011; Hospodsky*et al.*, 2012; Udochukwu *et al*., 2016). Human activities like breathing, sneezing, coughing, talking, and movement, have been linked to the high concentration of indoor air bioaerosols (Chen and Hildemann, 2009; Castillo *et al*., 2012; Bhangar *et al*., 2014, 2015; Adams *et al*., 2015; Meadow *et al*., 2015; Nazaroff, 2015). When they studied microbiological quality of indoor air in university rooms in Poznan, Poland, Stryjakowska-Sekulska *et al.* (2007) reported high number of bacteria and fungi.

Our study indicated that bacterial counts from almost all the kitchens and dining rooms studied were higher in the afternoon than in the morning. In some cases, bacterial counts in the afternoon were more than double

the counts in the morning. This can be traced to a number of factors, which include but not limited to the absence of the customers and lower temperatures in the morning hours compared to the afternoon hours. This agrees with the findings of Udochukwu *et al.* (2016) who linked lower airborne microbial concentrations in morning samples as a direct result of the absence of customers and lack of conducive temperatures to facilitate much movement of microbes in the air. On the other hand, lower fungal counts were observed in the afternoon than in the morning. This maybe so because most moulds grow best at a temperature of about 30°C and are affected by light. Stryjakowska-Sekulska *et al.* (2007) asserted that indoor air is very much influenced by environment, season, and even daytime and that unusually high concentration of mould in a university canteen, in Poland came from fruits and vegetables used for the preparation of meals.

A statistically significant positive correlation was observed between the airborne mesophilic bacterial and fungal concentrations. This suggests a common source of contamination, which was likely related to poor hygiene practices. This is in line with the findings of Daliborca *et al*. (2013) who found a positive relationship between the airborne mesophilic bacteria and mould levels in public buildings, in Timisoara, Romania and suggested a common source of contamination. It was also observed, from the results of the present study that bacteria had a statistically significant positive relationship with temperature and negative relationships with both humidity and airflow velocity. On the other hand, fungi had a non-significant positive relationship with both temperature and humidity but negative relationship with airflow velocity. Different studies have documented different degrees of association between bioaerosol concentrations and environmental factors such as temperature and humidity (Gorny and Dutkiewicz, 2002; Zhu *et al*., 2003; Nikaeen*et al*., 2009; Dedesko et al., 2015). The positive relationship observed between humidity and fungal concentration is justifiable because humidity is still considered a critical factor affecting fungal growth since dampness facilitates the growth of fungal spores (Douwes *et al.*, 1999; Nielsen *et al.*, 1999; Niazi *et al*., 2015).

Like the results of the present study, Kavita and Jyoti (2014), also did find a strong positive relationship between temperature and airborne bacterial counts. Equally, Frankel *et al*. (2012) found that indoor temperature and humidity were positively correlated with levels of airborne fungi in homes in the northeast US. The negative correlation observed between both bacterial and fungal concentrations with indoor air velocity is conceivable in that as wind speed increases, settlement of microorganisms decreases, dilution increase and cell viability reduces. The influence of wind velocity as a dilution and survival factor of airborne bacteria has been largely demonstrated in dispersion models and environmental reports (Van Leuken *et al*., 2016).

The socio-demographic data of food handlers in the present study indicate that the majority of the respondents were female (61%) and were mostly between the ages of 18 to 45 (95%). This is similar to the findings of

Priyanka *et al.* (2014) whose study indicated that 85.7% of food handlers studied were females and majority of them were within the age range of 15 and 30 years. Gender and age in addition to other factors, are integral hygiene parameters in food handling. Studies by Çakiroğlu and Uçar (2008) as well as Kibret and Abera (2012) reported that female workers had better hygiene scores and practices than males. Olumankaiye and Bakare (2013) reported that environmental hygiene of food service outlets was significantly associated with age. As people age, their mobility deteriorates, so the cleanliness of their kitchen environment worsens; therefore, needing special assistance. On the contrary, however, studies have found that older workers had better hygiene scores than younger workers (Çakiroğlu and Uçar, 2008; Olumakaiye and Bakare, 2013). This could be because younger food handlers tend to be less experienced. Food hygiene basic training for food handlers was almost absent in this study. Only3.5% of the food handlers had attended food hygiene basic training, and up to 33% had no education at all. A number of researchers have documented that the level of education of the workers (Zeru and Kumie, 2007; Kibret and Abera, 2012) and basic training in food safety are associated with better food safety knowledge (Baş et al., 2006; Kibret and Abera, 2012; Olumankaiye and Bakare, 2013; Onyeheho and Hedberg, 2013). Additionally, a study by Isaac *et al.* (2013) on hygienic practices among food vendors in educational institutions in Konongo, Ghana indicated that the training of food vendors on food hygiene, had a significant association with important food hygiene parameter like hand hygiene and protection of food from flies and dust, and medical certification. On medical certification, as indicated in the findings of the current study, although up to 100% of the food handlers indicated that they were in good health, only 0.10% had evidence of medical certification. This could be linked to both lack of supervision and nonchalant attitudes from authorities. Otu (2014) linked lack of medical certification among food handlers in Ahmadu Bello University Zaria, Nigeria to the lack of enforcement from the authorities. Due to the importance of medical certification, stakeholders should therefore do more in the area of sensitization and ensure strict compliance. In order to reduce restaurant-related food borne infections, food handlers need medical certification (Brown et al. 2017).

Environmental hygiene is not only important for food safety but necessary to support safe food handling and hygiene by employees (Baluka*et al*., 2015). Our results indicated that only 3.5% of the kitchens were apparently clean (no signs of food debribs/spills on surfaces, sinks were rinsed out,utencils washed and kept orderly, counter tops and tables were wiped and no gabbages seen); in14% of the kitchens, food was adequately protected from flies and 22.8% had an adequate supply of water. Less than half of the restaurants had hand washing soap, indicating poor hygiene practices. In the current study, personal hygiene results revealed that 51.4% had their nails trimmed, cleaned and unpolished, 47.8% had protected hair and 49.3% wore clean attire. This is grossly inadequate and could be one of the major contributors of higher microbial counts observed. People who are employed directly in the preparation and distribution of food are crucial in

reducing food safety risks (Chapman, 2009; De Sousa, 2008). Poor hygiene practices during handling, processing and distribution of food are some of the important ways of product contamination (Kisembi, 2010). Taulo et al. (2009) reported that improper personal hygiene practices among food handlers was the most commonly reported practices that contribute to foodborne illness. Transmission of the pathogens to food by the food workers' hands has been reported as a major cause of food-borne outbreaks (Çakiroğlu and Uçar, 2008). Therefore, ensuring proper personal hygiene practices, particularly hand washing, has been cited as the most effective tool in preventing the spread of food-borne infections (NHS Plus, 2008).

Conclusions

The indoor air quality was found to be poor with the levels of airborne bacteria and fungi exhibiting levels higher than the prescribed limits. This is of particular concern because of their potential public health threat. The results were likely driven by poor sanitary conditions and personal hygiene practices. Since meteorological parameters have a significant influence on the distribution of microbes in the air, controlling such factors through for example, enhancing ventilation systems, could contribute to reducing indoor air microbial load. There is a strong need for improved hygiene practices, improved food hygiene basic training and education. It is necessary that educational, environmental hygiene and outreach programmes direct efforts toward improving the effectiveness of microbiological control measures in restaurants and other food outlets. Government and leaders in the food service industry should strive to institute a thorough assessment of the food processing chain to identify and address areas that are responsible for food and/or indoor air contamination. Here, developing the standards of air quality related to bioaerosol contamination in restaurant environments will be crucial as such guidelines for maintenance and/or monitoring of indoor air are lacking in Nigeria and most developing countries.

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