

Growth Potential of *Salmonella* Typhi in Nigeria's "Swallow" Solid Foods and Sources of their Contamination by *Salmonella* and Coliform Bacteria in Eateries

Bernard Oyekweli Ejechi*, Joy Iyabo Okinedo

Department of Microbiology, Delta State University, Abraka, Nigeria

Abstract

The growth potential of *Salmonella* serovar Typhi was investigated in four popular Nigeria's cassava (*Manihot esculenta*)- and yam (*Dioscorea rotundata*)-based solid foods (amala, akpu/fufu, eba and pounded yam) commonly referred to as "swallow". Growth curves in the sterilised four "swallows" obtained from eateries tended to be identical while the growth rates marginally varied (0.25-0.37 log cfu/g/h), but was lower than in chicken meat (0.40 log cfu/g/h) used for comparison. Coliforms and *Salmonella* were isolated from contact surfaces of swallow food processing materials (mortars, pestles wooden spoon, electric pounder and nylon wrappers) using McConkey and Brilliant Green media with median counts lower in normal than makeshift eateries (coliform, 0.00-0.84 vs 1.50-1.70 log cfu/cm²; *Salmonella*, 0.00-0.30 vs 0.30-0.60 log cfu/cm²). Prevalence of eateries with coliform- and *Salmonella*-contaminated ready-to-eat swallow foods was 8.7-30.4% in normal eateries and 23.2-46.4% in makeshift eateries. Hygienic practices were generally low (<50% of maximum points) although the normal eateries were associated with good hygienic practice (OR, 1.64; 95% CL, 0.75-3.20; $P < 0.05$). It can be concluded that *S. Typhi* can grow in swallow foods, and that contact surfaces of processing materials are potential sources of bacterial contaminants during preparation of swallow foods especially in the commonly patronised makeshift eateries.

Keywords: *Salmonella* serovar Typhi; coliforms; growth rate; "swallow" food; eateries; hygienic practice.

Резюме

Потенциалът за растеж на *Salmonella* serovar Typhi е изследван в четири популярни твърди храни на базата на маниока (*Manihot esculenta*) в Нигерия (*Manihot esculenta*) и ям (*Dioscorea rotundata*) (amala, akpu/fufu, eba и стрит ям), които обикновено се наричат „лястовичка“. Кривите на растеж в стерилизираните четири „лястовички“, получени от заведения за хранене са идентични, докато темповете на растеж незначително варират (0.25-0.37 log cfu/g/h), но са по-ниски, от тези при пилешко месо (0.40 log cfu/g/h), използвани за сравнение. Изолираните колиформи и салмонела от контактни повърхности на материали за преработка на храна (хаванчета, пестици, дървени лъжици, електрически бъркалки и найлонови опаковки) върху среда на McConkey и Brilliant Green от нормални заведения показват по-нисък среден брой в сравнение с тези от импровизирани заведения за хранене (колиформи: 0.00-0.84 срещу 1.50-1.70 log cfu/cm²; *Salmonella*: 0.00-0.30 срещу 0.30-0.60 log cfu/cm²). Разпространението на заразени с колиформи и салмонела готови за консумация храни в нормалните заведения е от 8.7 до 30.4%, докато в импровизираните е от 23.2 до 46.4%. Хигиенните практики като цяло са слабо застъпени (<50% от максималните точки), въпреки че нормалните заведения за хранене са свързани с добра хигиенна практика (OR, 1.64; 95% CL, 0.75-3.20; $P < 0.05$). Може да се заключи, че *S. Typhi* може да развива в готови храни и че контактните повърхности на обработващите материали са потенциални източници на бактериални замърсители по време на приготвянето им, особено в обичайно покровителстваните импровизирани заведения за хранене.

Introduction

Salmonellosis is a major food-borne disease associated with morbidity and mortality world-wide (Crump *et al.*, 2004; CSFPH, 2013; WHO, 2015;

Ehuwa *et al.*, 2021) and it is widespread in sub-Saharan Africa (Clemens, 2009; Uche *et al.*, 2017). It arises from consumption of food and water contain-

* Corresponding author: ejechiben@gmail.com

ing *Salmonella* cells. It is known that 2500 serotypes exist in the genus *Salmonella* out of which 1600 belong to *Salmonella enterica* hence it accounts for most of the infections in man (Giaccone *et al.*, 2012; Eng *et al.*, 2015). Although *Salmonella* food borne disease has been largely associated with meat, poultry, dairy products, drinking water, vegetables and fruits (Gómez-Aldapa *et al.*, 2011), the organism can reach other types of food especially by cross-contamination and from the environment (Harris *et al.*, 2003; Giaccone *et al.*, 2012). Investigation of the growth kinetics of *Salmonella* has therefore been mainly in poultry products, beef, pork, fish, seafood, fruits and vegetables, and dairy products (Gómez-Aldapa *et al.*, 2011; Carrasco *et al.*, 2012; Smadi *et al.*, 2012; McAuley *et al.*, 2015; Sabike *et al.*, 2015; Fagbamila *et al.*, 2017) with little or no information on the growth in some African traditional foods.

The occurrence and growth of *Salmonella* has been investigated in Nigeria and sub-Saharan Africa (SSA) in street foods (Muleta *et al.*, 2001; Salamandane *et al.*, 2021), food animals and meat (Ebenso *et al.*, 2012; Tafida *et al.*, 2013; Bawa *et al.*, 2020; Thomas *et al.*, 2020), cereal based food (Okoronkwo *et al.*, 2016), fermented cereal beverage (Oduori *et al.*, 2021), poultry products (Fagbamila *et al.*, 2017; Agbaje *et al.*, 2021) and fish (Raudu *et al.*, 2014). However, there is paucity of information on the growth and survival of *Salmonella* in popular Nigerian traditional solid foods commonly referred to as “swallow” because it does not involve biting or chewing before swallowing. “Swallows” are mainly carbohydrate foods with high concentration of starch and are made from cassava (*Manihot esculenta*) and African yam (*Dioscorea rotundata*). The swallow foods are usually dense, elastic, dough-like and often moulded into ball-like shape after preparation. They are usually eaten with soup and they include “eba”, “amala”, “akpu/fufu” and “pounded yam”. Amala is prepared from yam or cassava flour or a combination of both. Sliced peeled tubers are grated and dried before grinding to fine powder-like flour. Thereafter they are mixed with boiling water and manually swirled or turned into a thick paste with wooden spoons before moulding into a ball and wrapped with transparent nylon if not served immediately. Pounded yam is made from peeled and boiled softened yam that is pounded to a thick paste in a mortar and moulded to a ball-like shape before wrapping like amala. Eba is prepared from garri which is a fried granular flour produced from fermented

cassava tuber (Halake and Chinthapall, 2020). The procedure for making the eba with garri is similar to that of amala. The fermented white paste from cassava is used to prepare akpu/fufu (Owolarafe *et al.*, 2018) by mixing with water and continuous stirring in a pot under heat till the desired smooth solid akpu structure is attained. Thereafter it is moulded and wrapped like othrt “swallows”. These “swallow” foods are commonly served in normal and makeshift eateries in Nigeria and some other SSA countries.

Available reports related to swallow foods in Nigeria tend to focus on the presence of microorganisms and safety of flours used for the preparation of swallow foods and not the prepared “swallow” food ready for consumption (Somorin *et al.*, 2011; Ossai, 2012; Adebayo-Oyetoro *et al.*, 2013; Elenwon *et al.*, 2019). The ready-to-eat “swallows” are prepared under varying hygienic conditions which, depending on the eatery, may expose them to microbial contamination. Thus given the popularity of swallow foods in Nigeria and indeed SSA, and the endemic nature of *Salmonella* infections in Nigeria (Akinyemi *et al.*, 2018), it is desirable to determine: 1, the extent to which *Salmonella* Typhi can grow in four Nigerian “swallow” foods; 2, prevalence of eateries with *Salmonella* sp. and coliform bacteria in ready-to-eat “swallow” foods; and 3, the potential sources of coliform and *Salmonella* contamination of the swallow foods in the eateries. The study outcome may provide useful information for public health authorities for the control of *Salmonella* infections in Nigeria and other SSA countries.

Materials and Methods

Source of *Salmonella* serovar Typhi

Salmonella serovar Typhi was obtained from the stock culture in the Microbiology laboratory of Delta State University, Abraka Nigeria. The identity was re-confirmed by biochemical profile tests using the “Abbreviated Panel of Tests” of Mikoleit (2014) which involves triple sugar iron agar (TSI), lysine iron agar (LIA), motility-indol-ornithine agar (MIO), Simmons citrate agar, and urea agar. These tests can differentiate *S. Typhi* and Paratyphi from other *Salmonella* serovars while production of H₂S (indicated by blackening of TSI) and absence of gas differentiates *S. Typhi* from *S. paratyphi* (Mikoleit, 2014).

Determination of growth of *S. Typhi* in the swallow foods

The isolate was first pre-enriched in buffered peptone water (Oxoid) and incubated at 37°C for 24

hours. Thereafter it was serially diluted with normal saline to obtain an inoculum size of 10^3 cells per 0.1 ml as determined by plate count on Nutrient agar. The four freshly prepared foods (eba, amala, pounded yam and akpu/fufu) were obtained from a restaurant and used for the growth study after sterilization by autoclave at 121°C for 15 minutes. They were manually macerated with sterile scalpel and 1g each was aseptically placed in 25 ml sterile flasks and inoculated with 0.1 ml normal saline suspension of 10^3 *S. Typhi* cells and plugged with cotton wool. A total of 27 flasks were prepared for each swallow food and incubated at room temperature ($30\pm 2^\circ\text{C}$) from 2 to 18h. Triplicate flasks were retrieved at intervals of 2h for determination of bacterial population by plate counts on Nutrient agar. This was carried out by introducing 9 ml of sterile normal saline into each flask and thoroughly shaken for 3 minutes before serial dilution and subsequent inoculation of Nutrient agar plates with 1 ml of the diluents. The above procedure was repeated with macerated boiled chicken meat in place of swallow food for the purpose of comparison. The average of the triplicate counts was calculated and recorded.

Microbial assessment of mortars, pestles, wooden spoons and nylon materials

Access to mortars, pestles and electric yam pounders used for preparation of akpu/fufu and pounded yam and the wooden spoons used for turning/swirling amala and eba was granted by only 22 eateries after agreeing on the confidentiality of the information which will not be linked to the eateries. They include 12 normal eateries, and 10 makeshift eateries that use mortars and pestles; all the eateries used wooden spoons for preparing eba and amala. The surfaces of the pestles and wooden spoons as well as the internal surfaces of the mortars and yam pounders were swabbed with sterile cotton wool moistened with 1 ml normal saline. The areas delineated for swabbing were 10 x 10 cm dimensions. The cotton swabs were subsequently transferred to tubes containing 9 ml saline and serially diluted before 1 ml was used to inoculate McConkey Agar (MA) and Brilliant Green Agar (BGA) plates. The plates were incubated at 37°C for 24-48 h and emerging pink-red colonies on MA (coliforms) and colonies surrounded by red halo on BGA (*Salmonella* spp.) were counted.

The nylon material (20 x 20 cm) used for wrapping the foods were obtained from eateries and shops and examined for coliform and *Salmonella* presence using MA and BGA. The nylon bags were aseptically opened and 10 ml of sterile normal

saline was poured in before shaking manually for 3 minutes in order to dislodge any bacteria from the internal surface. Thereafter, the saline was poured into sterile tubes and serially diluted before inoculation, incubation and enumeration of colonies as before.

Hygienic handling in the eateries

A three-section structured questionnaire was used to obtain information from eatery operators on the handling practices in the preparation of the swallow foods. The first section focused on questions related to the materials used in the swallow food preparation process with response options as "Yes" or "No". The second and third sections were on cleaning/disinfection and storage conditions of wrapping materials, respectively. A 4 point Likert-like scale was the measure used for both sections. The details of the measures are in Table 1. On this occasion it was less tasking to obtain informed consent of eatery operators hence the eatery operators/respondents that accepted to be interviewed were 100 (makeshift eateries, 54; normal eateries, 46). The interview was conducted face-to-face with the respondents by research assistants.

Detection of Salmonella and coliform bacteria in ready-to-eat swallow food

Ready-to-eat swallow foods (amala, eba, akpu/fufu, pounded yam) were purchased from the 100 eateries and assessed for hygienic handling, and tested for the presence of *Salmonella* and coliform bacteria using BGA and MA plates, respectively as before. Coliform presence was investigated for indication of sanitary and hygienic status of the eatery environment. Macerated swallow foods weighing 1 g each were introduced into tubes containing 9 ml of sterile normal saline and thoroughly manually shaken before 1 ml was taken out and used to inoculate MA and BGA plates. After incubation for 24-48 h, the plates were visually examined for the presence of coliforms and *Salmonella* as before.

Data analysis

The growth curves of *S. Typhi* in the four swallow foods and chicken meat were plotted (log cfu/g versus time) and the growth rate corresponding to the slope at the exponential phase was determined. The lag phase duration and the time of maximum growth was obtained from the curve. The maximum available points for hygienic practice involving cleaning/washing of the mortars, pestles, electric pounders and nylon stood at 20 while it was 8 for the storage conditions of the nylon wrapping material (Table 1). High scores indicated good hy-

Table 1. Measures of hygienic practice associated with preparation of swallow food

Questions	Scale			
	Yes	No	NA	NA
Section A (preparation process)				
Do you:				
1. Use mortar and pestle for preparing akpu/fufu and pounded yam?	“	“	“	“
2. Use electric yam pounder for pounding yam?	“	“	“	“
3. Use wooden spoon-like material to turn eba and amala into the desired paste?	“	“	“	“
4. Use wooden metallic spoon-like material to turn eba and amala into the desired paste?	“	“	“	“
5. Wrap the swallow foods with nylon before serving customers?	“	“	“	“
6. Mould the swallow foods before serving?	“	“	“	“
	1	2	3	4
Section B (Cleaning and washing)				
How often:				
1. Do you wash the nylon before use?	Not at all	Sometimes	Moist of the time	I always do
2. Do you wear hand gloves while moulding and wrapping the swallow foods?	“	“	“	“
3. Do you wash the mortar, pestle or the pounder after each round of pounding?	“	“	“	“
4. Do you wash the pots and the spoon/spoon-like material after each round of preparing amala or akpu/fufu	“	“	“	“
5. Do you use soap/detergent for the washings?	“	“	“	“
Section C (Storage of wrapping material)				
How long do the packs of nylon you usually purchase stay in your eatery before another purchase?	2-3 weeks	1 week	3-4 days	1-2 days
Will storage condition likely expose the nylon packs to contamination?	Most likely	Likely	Sometimes likely	Not likely

NA, Not applicable

gienic handling. Logistic regression was used to determine the association between types of eatery (independent variables) and hygienic practice using a dichotomy of poor/good hygienic practice as dependent variables. Score of $\leq 50\%$ and $>50\%$ of the maximum available points were adopted as poor and good, respectively.

Results

Growth of *S. Typhi* in swallow foods

The growth curves of *S. Typhi* in chicken meat and the swallow foods are presented in Fig. 1. Although with marginal variations, the sigmoid growth curves tended to be identical in all the swallow foods except in chicken which differed markedly.

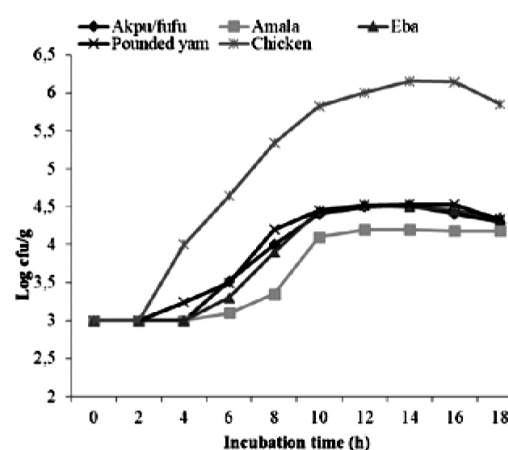


Fig. 1. Growth curve of *Salmonella* ser. Typhi in Nigeria's traditional "swallow foods" and chicken meat

Similarly, growth rates varied in the swallow foods with the lowest in akpu/fufu and the highest in pounded yam while it was comparatively higher in chicken than in all swallow foods (Fig. 2).

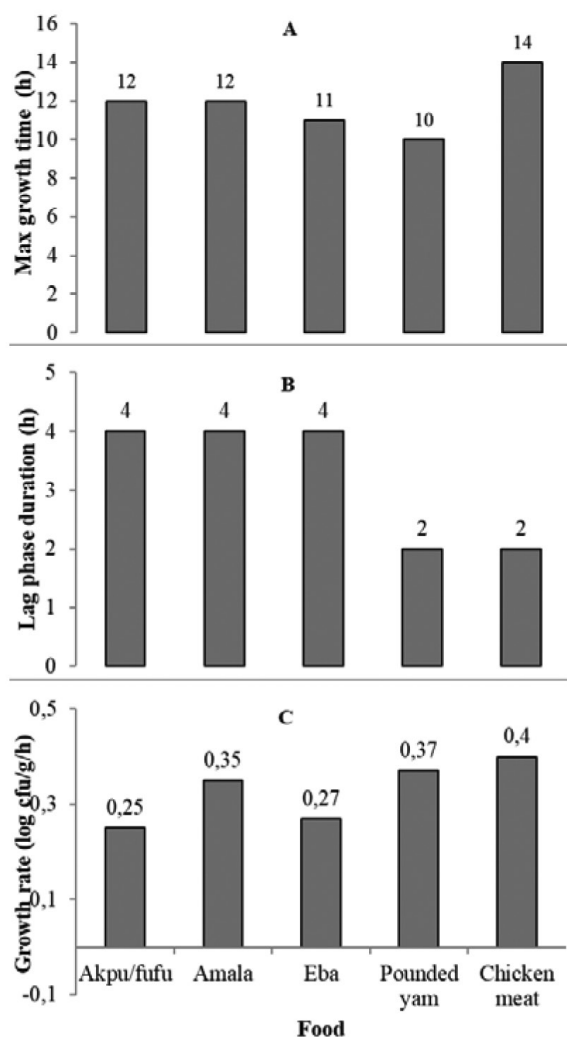


Fig. 2. Growth parameters of *Salmonella* ser. Typhi in Nigeria's traditional "swallow foods" and chicken meat (A, time maximum growth was attained; B, duration of lag phase; C, the growth rate).

The lag phases of *S. Typhi* in the swallow foods were similar except in pounded yam which was markedly shorter and similar to the lag phase in chicken meat. The time at which maximum growth was attained in the swallow foods marginally var-

ied with the lowest in pounded yam. Compared to swallow foods, maximum growth time was markedly greater in chicken meat.

Materials for preparation/processing of swallow food and the hygienic practice

All the makeshift eateries investigated used only mortar/pestle for pounding whereas the normal eateries use both mortar/pestle and electric pounders (Table 2). However, the prevalence of the use of electric pounders in normal eateries was markedly greater than the use of mortar/pestles. Use of wooden spoons was markedly more prevalent in makeshift eateries. All the eateries moulded the swallow foods into balls and wrapped them with nylon before serving customers with the exception of some makeshift eateries (<30%) that did not undertake wrapping (Table 2).

The practice of cleaning and washing of the swallow food preparation materials as well as the hygienic storage of the nylon wrapping material were above average (score >50%) in normal eateries, but below average (score <50%) in makeshift eateries (Table 3). However, by overall assessment as shown in Table 3, cleaning/washing and nylon storage conditions were generally poor (score <50%).

Logistic regression analysis showed that good hygienic practices were significantly more likely to be associated with normal eateries than makeshift eateries (Table 4), but none of the two types of eateries was associated with good hygienic nylon wrapping material storage practice.

Salmonella and coliforms on processing materials' contact surfaces and ready-to-eat swallow foods

Coliform bacteria were found on the surfaces of materials used for the preparation/processing of the swallow foods in both normal and makeshift eateries with median counts that did not exceed $1.70 \log_{10} \text{ cfu/cm}^2$ (Table 5).

The median counts showed that more coliform bacteria were isolated from the nylon food

Table 2. Prevalence of the use of swallow food preparation materials

Variables	Eatery operators/respondents			
	Normal eatery (N=46)		Makeshift eatery (N=54)	
	n	%	n	%
Use of mortar/pestle	21	45.6	54	100.0
Use of electric pounder	39	84.8	0	0.0
Use of wooden spoon turner	03	6.5	44	81.5
Moulding swallow food before sale/service	46	100.0	54	100.0
Wrapping with nylon	46	100.0	38	70.4

Table 3. Hygienic practice associated with swallow food preparation materials

Eatery	Hygienic practice	Hygienic practice score			
		Median		Min	Max
		Score	% of Max pts		
Normal	^a Cleaning/washing	12.5	62.5	10	15
	^b Storage of nylon	4.5	56.3	3.0	8
Makeshift	^a Cleaning/washing	8.5	42.5	6	12
	^b Storage of nylon	2.5	31.3	2	4
All eateries	^a Cleaning/washing	9.5	47.5	6	15
	^b Storage of nylon	3.5	43.8	2	8

Maximum available points: a, 20; b, 8

Table 4. Logistic regression analysis of the relationship between type of eatery and hygienic practice

Type of eatery	Hygienic practice	Odds Ratio		95% CL
Normal eatery	Cleaning/washing	Poor	1	
		Good	1.64*	0.75-3.20
	Nylon wrap storage	Poor	1	
		Good	1.15	0.62-2.80
Makeshift eatery	Cleaning/washing	Poor	1	
		Good	0.54*	0.22-1.58
	Nylon wrap storage	Poor	1	
		Good	0.87	0.44-2.66

* $P < 0.05$

Table 5. Microbial contamination of contact surfaces of swallow food processing materials

Bacteria	Eatery	Statistics	Bacteria (log cfu/cm ²) on contact surface of :			
			Mortar	Pestle	Electric pounder	Nylon wrap
Coliform	Normal (n=12)	Median	0.54	0.60	0.00	0.84
		Min	0.00	0.00	0.00	0.69
		Max	1.23	2.20	0.30	1.17
	Makeshift (n=10)	Median	1.50	1.50	NA	1.70
		Min	0.00	0.52	NA	1.00
		Max	2.06	2.04	NA	1.87
<i>Salmonella</i> spp.	Normal (n=12)	Median	0.00	0.00	0.00	0.30
		Min	0.00	0.00	0.00	0.00
		Max	0.30	0.30	0.00	0.48
	Makeshift (n=10)	Median	0.60	0.30	NA	0.30
		Min	0.00	0.00	NA	0.00
		Max	0.90	0.90	NA	0.60

NA, not available (yam pounder)

Table 6. Prevalence of eateries with presence of coliform bacteria and *Salmonella* in ready-to-eat swallow foods

Eatery type	Bacteria	No of eateries	%
Normal eatery (N=46)	Coliform	14	30.4
	<i>Salmonella</i>	04	8.7
Makeshift eatery (N=56)	Coliform	26	46.4
All eateries (N=100)	<i>Salmonella</i>	13	23.2
	Coliforms	40	40.0
	<i>Salmonella</i>	17	17.0

wrapping materials when compared to the other preparation materials. Table 5 further showed that the coliform counts were higher in makeshift eateries. Also based on median counts, *Salmonella* was not detected on the contact surfaces of the swallow food preparation materials in normal eateries except on the nylon wrapping materials whereas it was detected in all in makeshift eateries. The prevalence of eateries with *Salmonella* and coliform bacterial presence in ready-to-eat swallow foods was generally lower than 45% for coliform and 20% for *Salmonella* (Table 6). However, prevalence was markedly higher in makeshift eateries when compared to normal eateries.

Discussion

The results of the study showed that *Salmonella* ser. Typhi can grow in the traditional Nigerian different forms of cassava- and yam-based solid foods popularly referred to as “swallow”. Although the moisture contents of these swallow foods is low, *Salmonella* can survive in low moisture foods for long periods (Finn *et al.*, 2013). Cassava and yam are high energy food sources because of the high starch content which could reach 80% of the dry weight in yam (Obidiegwu *et al.*, 2020) and 80-90% in cassava (Bayata, 2019). Thus there is abundant source of energy for microbial growth which can only be limited by deficiency of protein, minerals and vitamins. Cassava has low protein content and the substantial level of minerals and vitamins are usually reduced by the various processing methods (Bayata, 2019). The nutritional profile of cassava does not markedly differ from that of yam. These identical nutritional profiles can explain the similarity of the growth patterns in all the swallow foods.

Compared to chicken meat, growth of *S. Typhi* in the swallow foods was slower and this is attributable to the better nutritional status of chicken meat (Marangoni *et al.*, 2015). The influence of nutritional status on the growth of *Salmonella* sp. can also be seen in the report of McAuley *et al.* (2015) where the growth rate of *Salmonella* ser Typhimurium declined from 0.865 in egg yolk to 0.614 in whole egg and 0.076 log₁₀ cfu/ml/h in egg white at 37°C. The markedly higher concentrations of lipids, minerals and vitamins in egg yolk (Rehault-Godbert *et al.*, 2019) may have accounted for the differential growth rate. Low growth rate notwithstanding, the fact that *Salmonella* Typhi can remain active in swallow foods for up to 10-12 h should be a cause for concern because the food can be consumed within this period. Thus it is important that

the potential sources of bacterial contamination of swallow foods be known.

The presence of *Salmonella* on surfaces of mortars, pestles, electric pounders and nylon wrappers is generally unacceptable, the low numbers notwithstanding. Contact surfaces are associated with transmission of pathogenic bacteria to food and only stringent washing and cleaning with antimicrobial agents like detergents can dislodge or them (Sharma *et al.*, 2022). Unlike metallic surfaces, wooden mortars and pestles have crevices that bacteria can “hide” and develop biofilms which often contain pathogenic microorganisms, and biofilms are known to be resistant to antimicrobial agents (Galie *et al.*, 2018). Electric poulder surfaces are mostly metallic hence the marginal presence of coliform bacteria and the absence of *Salmonella* on their contact surfaces. However, the presence of *Salmonella* and coliforms reflected insufficient or lack of stringent washing and cleaning, and poor storage conditions which, was corroborated by the coliform and *Salmonella* contamination of the ready-to-eat swallow foods and the low hygienic practice scores of the eatery operators. The bacterial contaminants could come from the kitchen indoor and outdoor environment which have been associated with cross-contaminations (Ejechi and Ochei, 2017; Carrasco *et al.*, 2012).

Sanitation and location of eateries could make a difference in microbial contamination of food. Makeshift eateries are temporary poorly constructed structures commonly found in nooks and corners of urban areas in Nigeria. Their locations are often characterised by poor sanitary conditions which include indiscriminate dumping of wastes which is characteristic of urban areas in SSA (Boadi *et al.*, 2005). On the other hand, normal eateries are generally located in good buildings and sanitary environment with minimal use of wooden materials (mortar, pestle, and turning spoons) that are more susceptible to bacterial colonization. Thus the greater prevalence of makeshift eateries with the presence of *Salmonella* and coliform bacteria in the swallow foods was not unexpected.

The major objective of the study was to demonstrate the potential of *Salmonella* to grow in the traditional solid foods which hitherto has not been given attention as potential sources of salmonellosis despite the popularity. The popularity of the swallow foods especially in makeshift eateries makes the growth of *Salmonella* a safety concern especially in a country where *Salmonella* infections are endemic (Akinyemi *et al.*, 2018); and several

reports have shown that food in restaurants and streets in SSA get contaminated from the kitchen in- and out-door environment (e.g. Baluka *et al.*, 2015; Fowoyo and Baba-Ali, 2015; Yeleliere *et al.*, 2017; Mohammed *et al.*, 2018). Besides, *Salmonella* has been reported to survive for considerable length of time in low- and intermediate-moisture food like swallow foods (Finn *et al.*, 2013).

Conclusion

The study has demonstrated the potential of *S. Typhi* to grow in Nigeria's traditional cassava- and yam-based swallow foods the low concentration of protein, minerals and vitamins notwithstanding. The swallow foods are vulnerable to bacterial contamination in eateries because *Salmonella* and coliforms were detected on the contact surfaces of the processing materials and ready-to-eat swallow foods in the investigated eateries. Inadequate or improper cleaning and washing of the processing materials was therefore indicated. This was corroborated by the generally low hygienic practice score especially in makeshift eateries where prevalence of *Salmonella* and coliform presence in ready-to-eat swallows was greater. Consumption of swallow foods in eateries and particularly in the commonly patronized makeshift type is popular hence the presence of *Salmonella* in the swallow foods and the processing materials should be of safety concern.

References

- Adebayo-Oyetoro, A. O., M. O. Bankole, A. M. Omenu, M. A. Atandas (2013). Microbiological safety assessment of fermented cassava flour “*Lafun*” available in Ogun and Oyo States of Nigeria. *Int. J. Food Sci.* **2013**: Article ID 845324.
- Agbaje, M., P. Ayo-Ajayi, O. Kehinde, E. Omoshaba, M. Dipeolu, F. O. Fasina (2021). *Salmonella* characterization in poultry eggs sold in farms and markets in relation to handling and biosecurity practices in Ogun State, Nigeria. *Antibiotics* **10**: 773.
- Akinoyemi, K., A. O. B. Oyefolu, W. B. Mutiu, B. A. Iwalokun, E. S. Ayeni, S. O. Ajose, S. K. Obaro (2018). Typhoid fever: Tracking the trend in Nigeria. *Am. J. Trop. Med.* **99**: 41-47.
- Baluka, S. A., R. A. Miller, J. B. Kaneene (2015). Hygienic practices and food contamination in managed food service facilities in Uganda. *Afr. J. Food Sci.* **9**: 39-42.
- Bawa, S. S., J. K. P. Kwaga, M. K. Lawan, S. B. Bawa (2020). Isolation of *Salmonella* from raw beef and chicken used in fast food restaurants in Abuja, Nigeria. *PAMJ - One Health*. **3**: Article 13.
- Bayata, A. (2019). Review on nutritional value of cassava for use as a staple food. *Sci. J. Anal. Chem.* **7**: 83-91.
- Boadi, K., M. Kuitunen, K. Raheem, K. Hanninem (2005). Urbanization without development: Environmental and health implications in African cities. *Environ. Dev. Sus-tain.* **7**: 465-500.
- Carrasco, E., A. Morales-Rueda, R. M. García-Gimeno (2012). Cross-contamination and recontamination by *Salmonella* in foods: A review. *Food Res. Int.* **45**: 545–556.
- Centre for Food Security and Public Health (CFSPH). (2013). *Salmonellosis*. College of Veterinary Medicine. Iowa State University. www.cfsph.iastate.edu (accepted 12 October, 2021).
- Clemens, J. D. (2009). Meeting on establishment of consortium to study invasive salmonellosis in sub-Saharan Africa. *Emerg. Infect. Dis.* **15**: e2.
- Crump, J. A., S. P. Luby, E. D. Mintz (2004). The global burden of typhoid fever. *B. World Health Organ.* **82**: 346–353.
- Ebenso, I., A. Ekwere, B. Akpan, B. Okon, U. Inyang, G. Ebenso (2012). Occurrence of *Salmonella*, *Vibrio* and *E. coli* in edible land snail in Niger Delta, Nigeria. *J. Microbiol. Biotechnol. Food Sci.* **2**: 610-618.
- Ehuwa, O., A. K. Jaiswal, S. Jaiswal (2021). *Salmonella*, food safety and food handling practices. *Foods* **10**: 907.
- Ejechi, B. O., O. P. Ochei (2017). Bacteriological safety assessment, hygienic habits and cross-contamination risks in a Nigerian urban sample of household kitchen environment. *Environ. Monit. Assess.* **189**: 298-312.
- Elenwo, M., N. Maduka, N. N. Odu (2019). Antibigram testing of bacterial isolates from cassava, yam and plantain flours and shelf life studies of the products sold in some markets in Port Harcourt, Nigeria. *Int. J. Pathog. Res.* **2**: 1-11.
- Eng, S. K., P. Pusparajah, N. S. Ab Mutalib, H. L. Ser, K. G. Chan, L. H. Lee (2015). *Salmonella*: A review on pathogenesis, epidemiology and antibiotic resistance. *Front. Life Sci.* **8**: 284-293.
- Fagbamila, I. O., Barco, L., Mancin, M., Kwaga, J., Ngulukun, S. S., Zavagnin, P., Lettini, A. A., Lorenzetto, M., P. A. Abdu, L. Kabir, J. A. Umoh, M. Ricci, Muhammad (2017). *Salmonella* serovars and their distribution in Nigerian commercial chicken layer farms. *PLOS ONE*. **12**: e0173097.
- Fowoyo, P. T., R. Baba-Ali (2015). Microbiological assessment of fast foods sold in Lokoja Metropolis, Nigeria. *Open Acc. Lib. J.* **2**: e1541.
- Finn, S., O. Condell, P. McClure, A. Amézquita, S. Fanning (2013). Mechanisms of survival, responses, and sources of *Salmonella* in low-moisture environments. *Front. Microbiol.* **4**: Article 331
- Galie, S., C. García-Gutierrez, E. M. Miguelez, C. J. Villar, F. Lombo (2018). Biofilms in the food industry: health aspects and control methods. *Front. Microbiol.* **9**: Article 898.
- Giaccone, V., P. Catellani, L. Alberghini (2011). Food as cause of human salmonellosis. In: Mahmood, B. S. M. (Ed.), *Salmonella – a dangerous foodborne pathogen*. Intech Open: Croatia, pp. 47-72.
- Gómez-Aldapa, C.A., M. R. Torres-Vitela, A. Villarruel-López, L. Castro-Rosas (2011). The role of foods in *Salmonella* infections. In: Mahmood, B. S. M. (Ed.), *Salmonella – a dangerous foodborne pathogen*. Intech Open: Croatia, pp. 21-46.
- Halake, V. N. H., B. Chinthapalli (2020). Fermentation of traditional African cassava based foods: Microorganisms role in nutrition and safety. *J. Exp. Agric. Int.* **42**: 56-65.
- Harris, L. J., J. N. Farber, L. R. Beuchat, M. E. Parish, T. V.

- Suslow, E. H. Garrett, F. F. Busta (2003). Outbreaks associated with fresh produce: Incidence, growth, and survival of pathogens in fresh and fresh cut produce. *Compr. Rev. Food Sci. Food Saf.* **2**: 78-141.
- Marangoni, F., G. Corsello, C. Cricelli, N. Ferrara, A. Ghiselli, L. Lucchin, A. Poli (2015). Role of poultry meat in a balanced diet aimed at maintaining health and wellbeing: an Italian consensus document. *Food Nutr. Res.* **59**: 27606.
- McAuley, C. M., L. L. Duffy, M. Subasinghe, G. Hogg, J. Coventry, N. Fegan (2015). *Salmonella* typhimurium and *Salmonella* Sofia: growth in and persistence on eggs under production and retail conditions. *BioMed Res. Int.* **8**: 1-8.
- Mikoleit, M. L. (2014). Laboratory protocol: Biochemical identification of *Salmonella* and *Shigella* using an Abbreviated Panel of Tests. WHO Global Foodborne Infections Network, Technical Report. DOI: 10.13140/RG.2.1.1183.3443. <https://antimicrobialresistance.dk>pdf> (accessed 15 November, 2022).
- Mohammed, S. S. D., R. A. Miller, A. M. Kaneene (2018). Evaluation of food contact surfaces in selected restaurants of Kaduna State University for the presence of *Escherichia coli* and *Staphylococcus aureus*. *Sci. World J.* **13**: 45-49.
- Muleta, D., M. Ashenafi (2001). Salmonella, Shigella and growth potential of other food-borne pathogens in Ethiopian street vended food. *East Afr. Med. J.* **78**: 576-580.
- Obidiegwu, J. E., L. B. Lyons, C. A. Chilaka (2020). The Dioscorea genus (Yam) - an appraisal of nutritional and therapeutic potentials. *Foods* **9**: 1304.
- Oduori, D. O., E. Kwoba, L. Thomas, D. Grace, F. Mutua (2021). Assessment of foodborne disease hazards in beverages consumed in Nigeria: a systematic literature review. *Foodborne Pathog. Dis.* **20**: 1-18.
- Okoronkwo, C. U., H. C. Okereke, O. N. Nwachukwu (2016). Assessment of the growth and survival of *Salmonella typhi* and *Escherichia coli* on some cereal based complementary foods in Abia State, Nigeria. *Asian J. Microbiol. Biotechnol.* **1**: 1-6.
- Ossai, S. O. (2012). Bacteriological quality and safety of street vended foods in Delta State, Nigeria. *J. Biol. Agric. Healthcare* **25**: 114-118.
- Owolarafe, O. K., B. O. Adetifa, A. C. Oyekanmi, T. G. Lemikan, T. M. Samuel (2018). Assessment of fufu production technologies in Ogun State, Nigeria. *AZOJETE* **14**: 547-558.
- Raufu, I. A., F. A. Lawan, H. Bello, A. S. Musa, J. A. Amehm, A. G. Ambali (2014). Occurrence and antimicrobial susceptibility profiles of *Salmonella* serovars from fish in Maiduguri, sub-Saharan, Nigeria. *Egypt. J. Aquat. Res.* **4**: 59-63.
- Rehault-Godbert, S., N. Guyot, Y. Nys (2019). The golden egg: Nutritional value, bioactivities, and emerging benefits for human health. *Nutrients* **11**: 684.
- Sabike, I. I., H. Fujikawa, A. M. Edris (2015). The growth kinetics of *Salmonella enteritidis* in raw ground beef. *Biocontrol Sci.* **20**: 185-192.
- Salamandane, A., A. C. Silva, L. Brito, M. Malfeito-Ferreira (2021). Microbiological assessment of street foods at the point of sale in Maputo (Mozambique). *Food Qual. Saf.* **5**: 1-9.
- Sharma, S., S. Jaiswal, B. Duffy, A. K. Jaiswal (2022). Advances in emerging technologies for the decontamination of the food contact surfaces, *Food Res. Int.* **151**: Article 110865.
- Smadi, H., J. M. Sargeant, H. S. Shannon, P. Raina (2012). Growth and inactivation of *Salmonella* at low refrigerated storage temperatures and thermal inactivation on raw chicken meat and laboratory media: Mixed effect meta-analysis. *J. Epidemiol. Glob. Health.* **2**: 165-179.
- Somarin, Y. M., M. O. Bankole, A. M. Omenu, O. O. Atandas (2011). Impact of milling on microbiological quality of yam flower in South Western Nigeria. *Res. J. Microbiol.* **6**: 480-487.
- Tafida, S. Y., J. Kabir, J. K. P. Kwaga, M. Bello, V. J. Umoh, S. E. Yakubu, A. J. Nok, R. Hendriksen (2013). Occurrence of *Salmonella* in retail beef and related meat products in Zaria, Nigeria. *Food Control* **32**: 119-124.
- Thomas, K. M., W. A. de Glanville, G. C. Barker, J. Benschop, J. J. Buza, S. Cleaveland, M. A. Davis, N. P. French, B. T. Mmbaga, G. Prinsen, E. S. Swai, R. N. Zadoks, J. A. Crump, (2020). Prevalence of *Campylobacter* and *Salmonella* in African food animals and meat: A systematic review and meta-analysis. *Int. J. Food Microbiol.* **315**: Article 108382.
- Uche, I. V., C. A. MacLennan, A. Saul (2017). A systematic review of the incidence, risk factors, and case fatality rates of invasive non-typhoidal *Salmonella* (iNTS) disease in Africa (1966-2014). *PLOS Negl. Trop. Dis.* **11**: e0005118.
- WHO (2015). WHO Estimates of the Global Burden of Foodborne Diseases: Food-borne Disease Burden Epidemiology Reference Group 2007-2015; World Health Organization: Geneva, Switzerland; <https://apps.who.int/iris/handle/10665/199350>. (accessed 6 September 2021).
- Yeleliere, E., S. J. Cobbina, Z. I. Abubakari (2017). Review of microbial food contamination and food hygiene in selected capital cities of Ghana. *Cogent Food Agric.* **3**: Article 1395102.