Bacterial contamination of Nigerian currency notes: A comparative analysis of different denominations recovered from local food vendors

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Microbial transmission, on the surface of any currency note, can either be through direct (hand-to-hand contact) or indirect (food or other inanimate objects) means. To ascertain the degree of bacterial load enumerated during the handling of money and food items, particularly on currency note by denominations, should be of public health importance. Despite the available literature regarding microbial contamination of Nigerian currency notes, there is still paucity of information about how microbial contamination/load differ across the denominations specific to different food vendors. In this context, therefore, the current study investigated bacterial contamination of Nigerian currency notes via a comparative study of different denominations (₦1000, ₦500, ₦200, ₦100, ₦50, ₦20, ₦10, and ₦5) recovered from local food vendors. Specifically, the different food handlers/vendors included fruit, meat, vegetable, fish, and grain/cereal sellers. All emergent data from 8×5 factorial design of experiment were of duplicate measurements. To consider the currency denominations and food vendor type, a one-factor-at-a-time analysis of variance (ANOVA) was conducted. Results showed that about 81.7% of currency notes were contaminated with either Escherichia coli, Klebsiella spp. or Staphylococcus spp. in varying degrees. The higher denominations of ₦500, ₦200, and ₦100 note, with the exception of ₦1000 note, recorded increased degree of contamination over the lower denominations ₦50, ₦20, ₦10, and ₦5 note. Specifically, the ₦100 currency note appeared the most contaminated (1.32 × 10^5 cfu/ml) whereas ₦5 note appeared the least contaminated (1.46 × 10^4 cfu/ml). The frequency of isolated bacteria on currency notes from vegetable, meat, and fish sellers were significantly higher (p<0.05) compared to other food vendors. The degree of bacterial contamination appears dependent on the food vendor type and currency denomination(s). An increased awareness and education
among food vendors and ready-to-eat food sellers is needed, to mitigate the possible cross-contamination between currency notes and foodstuff, as this would help consumers know more about the potential health risks such simultaneous activities do pose on food safety.
Bacterial Contamination of Nigerian Currency Notes: A Comparative Analysis of Different Denominations recovered from Local Food Vendors

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Abstract

Microbial transmission, on the surface of any currency note, can either be through direct (hand-to-hand contact) or indirect (food or other inanimate objects) means. To ascertain the degree of bacterial load enumerated during the handling of money and food items, particularly on currency note by denominations, should be of public health importance. Despite the available literature regarding microbial contamination of Nigerian currency notes, there is still paucity of information about how microbial contamination/load differ across the denominations specific to different food vendors. In this context, therefore, the current study investigated bacterial contamination of Nigerian currency notes via a comparative study of different denominations (₦1000, ₦500, ₦200, ₦100, ₦50, ₦20, ₦10, and ₦5) recovered from local food vendors. Specifically, the different food handlers/vendors included fruit, meat, vegetable, fish, and grain/cereal sellers. All emergent data from 8×5 factorial design of experiment were of duplicate measurements. To consider the currency denominations and food vendor type, a one-factor-at-a-time analysis of variance (ANOVA) was conducted. Results showed that about 81.7% of currency notes were contaminated with either *Escherichia coli*, *Klebsiella* spp. or *Staphylococcus* spp. in varying degrees. The higher denominations of ₦500, ₦200, and ₦100 note, with the exception of ₦1000 note, recorded increased degree of contamination over the lower denominations ₦50, ₦20, ₦10, and ₦5 note. Specifically, the ₦100 currency note appeared the most contaminated (1.32 × 10^5 cfu/ml) whereas ₦5 note appeared the least contaminated (1.46 × 10^4 cfu/ml). The frequency of isolated bacteria on currency notes from vegetable, meat, and fish sellers were significantly higher (p<0.05) compared to other food vendors. The degree of bacterial contamination appears dependent on the food vendor type and currency denomination(s). An increased awareness and education among food vendors and ready-to-eat food sellers is needed, to mitigate the possible cross-contamination between currency notes and foodstuff, as this would help consumers know more about the potential health risks such simultaneous activities do pose on food safety.

Keywords: Bacterial contamination; currency notes; food vendors; *Escherichia coli*; *Staphylococcus* spp.; *Klebsiella* spp.
Introduction

Worldwide, currency notes and money in general serve as means of economic exchange of goods and services, to defer payments and settle debts (Awe et al., 2010; Ogunleye, 2005; Okon et al., 2003). Between the late 1800s and early 1900s, scientists postulated the association of handling money with disease transmission. Subsequently, by modern scientific techniques, these postulations confirmed that pathogenic organisms can be isolated from currency/money surfaces (Alemu, 2014; Awe et al., 2010). For example, *Citrobacter* spp., *Escherichia coli*, *Mycobacterium* spp., *Pseudomonas aeruginosa*, *Salmonella* spp., and *Staphylococcus aureus*, are among the examples of foodborne pathogenic microorganisms reported on currency notes (Awe et al., 2010). By adhering to various surfaces, food pathogens such as *E. coli*, *S. aureus* and *Salmonella* spp. could remain viable for hours or even days of post-contamination (Okpala and Ezeonu, 2019). However, whether it is between clean and dirty hands, the movement of currency notes especially within the agrofood supply chain would never stop. This inevitable situation potentially facilitates continued occurrence of microbial contamination and proliferation between currency notes and foodstuffs even more likely (Agarwal et al., 2015; Thiruvengadam et al, 2014). To reiterate, the process of microbial contamination and more importantly, its subsequent transmission, the latter with respect to the surface of any currency note, has been understood to be of either direct (hand-to-hand contact) or indirect (food or other inanimate objects) means (Cooper, 1991).

Even though consumers can help to prevent foodborne disease incidence, the different sources from which microorganisms are able transfer to food is not new. For instance, microbial contamination takes place during the various stages of food preparation. Another instance, fruits on trees and vegetables grown on the soil are naturally microbiologically contaminated. Some cells of such microbes could still remain even after washing (Okpala and Ezeonu, 2019). Besides foodstuffs as well as drinking water that could get contaminated, there remains a wide spectrum of microbial pathogens that can contaminate animals and food products, all of which are among the fundamental causes of foodborne disease incidence and spread (Okpala et al., in-
During the food handling processes within the agrofood supply chain, the contamination of currency notes can take place, particularly involving diverse flora and fauna, aerosols generated by coughing and sneezing, anal region, wounds, to the skin, water, and soil (Agarwal et al., 2015; Thiruvengadam et al., 2014). Currency notes, even before it would reach the bank and in the process of circulating and passing through hands during daily transactions, can equally transmit the pathogenic microbes (Awodi and Nock, 2001; Yakubu, Ehiowemwenguan and Inetianbor, 2014). Besides the large surface area of any given currency note, a number of pathogenic microorganisms, not only capable of surviving on these notes but also, can serve as useful candidates of foodborne pathogens (Michaels, 2002; Podhajny, 2004) and can increase the probability of foodborne disease incidence/spread. The latter can also serve as a useful indicator of poor environmental hygiene and sanitation levels, all of which remains of great public health importance (Cooper, 1991).

Relevant literature about microbial status and survival of pathogens on currency notes have been shown by many workers in Turkey, the United States, Australia, India, Egypt, and China (Xu et al., 2005; Goktas & Oktay, 1992; Pope et al., 2002; FSA, 2000; El-Dars & Hassan, 2005; Singh, Thakur & Kalpana, 2002). Other studies regarding contamination ascribed to microbial load specific to national currency notes have been reported in Bangladesh (Ahmed et al., 2010; Hosen et al., 2006), Ethiopia (Alemayehu and Ashenafi, 2019), India (Rote, Deogade and Kawale, 2010), Iran (Dehghani, Dehghani, and Estakhr, 2011), Nepal (Lamichhane et al., 2009; Prasai et al., 2008), Nigeria (Awe et al., 2010; Kawo et al., 2009; Oyero and Emikpe, 2007; Umeh et al., 2007), Saudi Arabia (Ghamdi et al., 2011; Rashed et al., 2006), South Africa (Igumbor et al., 2007), as well as Sudan (Saadabi et al., 2010). In Europe, Mändar et al. (2016) studied microbial contamination of euro money, whereas in the USA, Michaels (2002) reported on handling money and serving ready-to-eat food, which considered the same gloved hands or without hygiene intervention, and provided in food service establishments, would introduce the risk of cross-contamination to foods. In the global front, Vriesekoop et al. (2010) performed the hygiene status of some world’s currencies by capturing food outlets in 10 different countries (Australia, Burkina Faso, China, Ireland, Netherlands, New Zealand, Nigeria, Mexico, the United Kingdom, and the
By assessing the public health risks associated with the simultaneous handling of food and money, Brady and Kelly (2000) showed that coagulase-positive Staphylococci could be present on the currency note surfaces. The environment remains a critical player in the food-related microbial transmission process to humans. The environment would also compose materials that are viable candidates for the (microbial) pathogens (Anderson and May, 1991; Struthers and Westran, 2003).

Besides currency note contamination with bacteria that bring about wide range of diseases (Pope et al., 2002), how it is able exchange through hands especially within the food supply chain (Agarwal et al., 2015; Thiruvengadam et al., 2014), together with the poor sanitation practices that could arise in the market, restaurants and slaughterhouses is likely to reflect how multi-resistant microbial strains are able to cross-contaminate (Emikpe and Oyero, 2011; Oyero and Emikpe, 2007). Despite the available literature about microbial contamination of Nigerian currency note (Emikpe and Oyero, 2011; Enemour, Victor, and Oguntibeju, 2012; Oyero and Emikpe, 2007; Umeh, Juluku, and Ichor, 2007; Uneke and Ogbu, 2007), relevant information regarding how microbial contamination/load differ across the denominations is still insufficient. It is reasonable to say that food handlers in Nigeria, oftentimes, after handling currency notes, do fail to properly wash or sanitise their hands and other food/food-related facilities. To better understand how (pathogenic) microorganisms get enumerated, and subsequently circulated between foodstuffs and different currency denominations/notes, should be of consumer health concern. This should be considered particularly important with respect to food handlers in Nigeria who many a times have to perform financial duties alongside foodstuffs. For the reason that foodstuffs would most likely differ with microbial contaminants/load, however, such additional knowledge and understanding on microbial enumeration as well as circulation between foodstuffs and different currency denominations/notes could help, not only in identifying the actual sources of the foodborne diseases, but also, in enlightening the food handlers, food traders, health workers, and the general public as a whole, about the inherent (public) health risks potentially associated with the currency notes, specifically when not handled in a hygienic safe manner. In this context, therefore, the current study investigated the bacterial contamination of Nigerian currency notes via a comparative study of different
denomination notes recovered from local food vendors.

Materials & Methods

Schematic overview of experimental programme

The schematic overview of the experimental programme, from the collection of currency note samples, preparation of currency note samples for microbial determinations, inoculation, incubation, to identification of different bacterial isolates, is shown in Figure 1. To reiterate, this current study was directed to investigate the bacterial contamination of Nigerian currency notes via a comparative study of different denomination notes recovered from local food vendors. Specifically, the different food handlers/vendors included fruit, meat, vegetable, fish and grain/cereal sellers. The different denominations included ₦1000, ₦500, ₦200, ₦100, ₦50, ₦20, and ₦5 currency notes. For the reason that there were 5 different food handler/vendor types, and 8 different currency note denominations, a factorial design of experiment was deemed appropriate for this study, specifically 8 x 5 factorial type.

Collection currency notes

A total of 80 samples of Nigerian currency notes consisting of 10 pieces of eight (8) different denominations (₦1000, ₦500, ₦200, ₦100, ₦50, ₦20, ₦10, and ₦5) were randomly collected from different food vendor types at Relief Market in Owerri, Imo State, Nigeria. This Relief Market is among major markets that provide the food demands of the ever increasing Owerri population, projected excess of 800,000 as of 2019 (Macrotrends, Accessed 27 Sept., 2020). Each currency denomination was aseptically collected from food vendors and placed in an ultra violet (UV) sterilized polyethylene bag and shortly after, transported to Food Microbiology laboratory of the Department of Food Science and Technology, Federal University of Technology, Owerri for bacteriological analysis. At all instances, the time period from point of collection of currency note, to arrival of laboratory did not exceed 2 h.

Preparation of materials/samples

Ringer’s solution (quarter-strength) was prepared, by dissolving one ringer’s solution tablet (Merck, Darmstadt, Germany) with a composition of 2.25 g/L sodium chloride, 0.015 g/L potassium chloride, 0.12 g/L calcium chloride, and 0.05 g/L sodium...
bicarbonate, in 500 mL of distilled water. All media, diluents, glasswares, and forceps used were sterilised by autoclaving at 121 °C for 15 min at 15 psi, while the wire loops were sterilised by flaming. Materials were allowed to cool, wrapped in an aluminum foil, and stored until needed for microbiological analysis.

Upon arrival at laboratory after sample collection, each Naira note was aseptically inserted into a beaker containing 100 mL of sterile ringer’s solution, and allowed to stand for 30 min at ambient temperature (25 - 28 °C). During this 30 min period, the beaker was gently and repeatedly shaken as it is widely believed to facilitate the detachment of the adhered microbes (bacteria) from the Naira currency surface as much as possible into the solution. Subsequently, the Naira note was aseptically removed from the beaker using sterile forceps. Thus, the beaker content (washed liquor of soaked notes) served as the resultant test sample for bacterial inoculation, so as to determine the (bacterial) load as well as enumerate the type. The prepared suspensions for test inoculation were used within 2 h to avoid the risk of cross contamination from the environment.

Serial dilution, incubation and counting of bacterial colonies

Serial dilution (10^{-2} and 10^{-3}) of the washed liquor of soaked notes was performed. Subsequently, aliquot sample (0.1 ml) of each was inoculated on nutrient agar plates using spread plate method, and incubated at 37 °C for 24 h. This was performed in duplicates for each currency denomination note per food vendor type. To verify testing conditions, a negative control (with no test material included) was performed using the chosen diluent, inoculated on nutrient agar plates and incubated at 37 °C for 24 h. The control served strictly for the validity and verification of the testing conditions.

The colony counter (Astor 20 Colony Counter, Astori Tecnica, Italy) was used to determine the colony numbers on different plates. The arithmetic mean of the counts per medium were recorded, and resultant colony forming units per millilitre (cfu/ml) in the original inoculum, was determined consistent with methods described previously (Cheesbrough, 2000).

Bacterial characterisation and identification

The characteristic identification (and not quantification) of bacterial colonies were
based on its morphology and Gram reaction, catalase and coagulase tests; biochemical tests for indole production, citrate utilization, and urase activity; triple sugar iron (TSI) agar tests (for glucose, lactose and sucrose fermentation); as well as hydrogen sulfide/gas production tests, and oxidase tests, following the methods described previously (Buller, 2014; Cheesbrough, 2000).

**Statistical analysis**

All emergent data from 8×5 factorial design of experiment as shown in Table 1 were of duplicate measurements. In order to determine the degree of bacterial load that had proliferated on currency note by food vendor type, a one-factor-at-a-time ANOVA was applied. The Fisher’s least significant difference (LSD) was used to resolve mean differences. The statistical significant difference was set at the 95% (p<0.05) confidence level. The IBM SPSS software version 20 (IBM Corporation, New York, USA) was used to do the data analysis.

(Please place Table 1 here)

**Results**

Table 2 shows the total viable count (TVC) of Naira denominations isolated from different food vendors. The TVC on Naira denominations handled by fruit, meat, vegetable, fish and grain sellers respectively ranged from 3.0 × 10^3 to 2.2 × 10^5 cfu/ml, from 3.0 × 10^3 to 1.9 × 10^5 cfu/ml, from 3.0 × 10^2 to 1.3 × 10^5 cfu/ml, from 1.3 × 10^4 to 2.9 × 10^5 cfu/ml, and from 5.0 × 10^2 to 5.1 × 10^4 cfu/ml. Additionally, the TVC significantly differed (p<0.05) across different currency notes, which ranged from 1.46 × 10^4 to 1.33 × 10^5 cfu/ml, and across different food vendors, which ranged from 8.91 × 10^3 to 1.18 × 10^5 cfu/ml. Additionally, the TVC trend across the different currency denominations followed: ₦100 (132.72 × 10^3 cfu/ml) > ₦200 (75.40 × 10^3 cfu/ml) > ₦500 (66.80 × 10^3 cfu/ml) > ₦20 (50.90 × 10^3 cfu/ml) > ₦1000 (42.26 × 10^3 cfu/ml) > ₦10 (37.40 × 10^3 cfu/ml) > ₦5 (14.64 × 10^3 cfu/ml).

(Please place Table 2 here)

Tables 3, 4 and 5 respectively show the *Escherichia coli*, *Klebsiella* spp. and *Staphylococci* spp. of Naira denominations recovered from different food vendors. Specifically, the *E. coli* count isolated from Naira denominations recovered from fruit, meat, vegetable, fish, and grain sellers respectively ranged from 9.0 × 10^2 to 4.0 × 10^3
cfu/ml, from $7.0 \times 10^1$ to $6.5 \times 10^3$ cfu/ml, from $2.0 \times 10^2$ to $6.0 \times 10^2$ cfu/ml, from $1.0 \times 10^2$ to $1.0 \times 10^4$ cfu/ml, and from $2.0 \times 10^1$ to $8.2 \times 10^2$ cfu/ml. Specifically also, the *Klebsiella* spp. count isolated from Naira denominations recovered from fruit, meat, vegetable, fish, and grain sellers respectively ranged from $2.0 \times 10^2$ to $8.5 \times 10^2$ cfu/ml, from $4.0 \times 10^1$ to $5.2 \times 10^3$ cfu/ml, from $1.0 \times 10^2$ to $1.8 \times 10^3$ cfu/ml, from $1.9 \times 10^2$ to $5.0 \times 10^3$ cfu/ml, and from $4.0 \times 10^1$ to $1.1 \times 10^2$ cfu/ml. Specifically also, the *Staphylococcus* spp. count isolated from Naira denominations recovered from fruit, meat, vegetable, fish and grain sellers respectively ranged from $3.0 \times 10^2$ to $3.7 \times 10^3$ cfu/ml, from $1.1 \times 10^2$ to $3.7 \times 10^3$ cfu/ml, from $7.0 \times 10^1$ to $6.0 \times 10^3$ cfu/ml, from $1.5 \times 10^2$ to $6.0 \times 10^3$ cfu/ml, and from $4.0 \times 10^1$ to $1.6 \times 10^3$ cfu/ml.

(Please place Tables 3, 4, and 5 here)

The mean values of *E. coli*, *Klebsiella* spp., and *Staphylococci* spp. counts isolated from Naira denominations, with emphasis on the different food vendors, is shown in Figure 2. The results indicate that, specific to *E. coli*, *Klebsiella* spp., and *Staphylococci* spp., the Naira denominations recovered from grain sellers obtained less bacterial contaminants, whereas those recovered from meat and fish sellers obtained more bacterial contaminants. Mean values of *E. coli*, *Klebsiella* spp. and *Staphylococci* spp. counts isolated, with emphasis on the Naira denominations recovered from different food vendors, is shown in Figure 3. The results indicate that the ₦100 and ₦200 specifically obtained higher *E. coli* and *Staphylococci* spp. respectively, whereas ₦500 obtained higher *Klebsiella* spp. and *Staphylococci* spp., although not significantly different (P>0.05). However, the Naira denominations with the least isolated bacterial contaminants appears to be ₦10 and ₦5 (specific to specific to *Klebsiella* spp.), ₦5 (specific to *Staphylococci* spp.), and ₦1000 (specific to *E. coli*).

(Please place Figures 2 and 3 here)

The prevalence of *E. coli*, *Klebsiella* spp. and *Staphylococci* spp. on Naira denominations recovered from different food vendors is shown in Table 6. Regardless of food vendors, 81.7% of Naira denominations recovered had been contaminated by at least one of the determined bacteria, and in the following prevalence trend: *E. coli* (87.5%) > *Staphylococci* spp. (85%) > *Klebsiella* spp. (72.5%). Besides, the total prevalence of bacterial load of Naira denominations, specific to how it was recovered...
from food vendors, followed this trend: vegetable sellers (91.7%) > meat sellers (87.5%) > fish sellers (87.5%) > fruit sellers (75%) > grain sellers (66.7%).

(Please place Table 6 here)

Discussion

The TVC on Naira denominations clearly obtained varying ranges across food vendors. The ₦100 currency denomination obtained the highest TVC (1.32 × 10^5 cfu/ml), which is consistent with the report of Kawo et al. (2009), attributable to its frequent as well as high usage in today’s Nigeria and across her society's daily transactions (Adamu et al., 2012; Umeh et al., 2007). On the other hand, the ₦5 currency denomination obtained the least TVC (1.46 × 10^4 cfu/ml), probably attributable to its limited use, considering that in recent times, it is hard to find any commodities sold for ₦5 in Nigeria. Overall, about 95% of higher denominations (₦1000, ₦500, ₦200, and ₦100) appeared more contaminated compared to 85% of lower denominations (₦50, ₦20, ₦10 and ₦5), resembling the observation of previous workers (Adamu et al., 2012).

The fact that *E. coli* could be isolated, as shown in Table 3, from low level of 2.0 × 10^1 cfu/ml as found in ₦500, ₦100, and ₦5 denominations of grain sellers, to as high level of 1.0 × 10^4 cfu/ml as found in ₦100 denomination of fish sellers, might be suggestive of the poor hygienic practices and sanitary condition exercised by these different food vendors, particularly in the handling of the Nigerian currency notes. It is possible that bacterial coliforms could find its way to the surface of the currency notes through other means apart from the food stuffs. For the currency notes to pass through the diverse environments could make it emerge a reservoir, capturing various bacteria including pathogenic *E. coli*, considered capable of surviving several days on inert surfaces (Pomperayer and Gaylarde, 2000). In addition, the currency notes if poorly handled may result in contamination of foodstuffs (and ready-to-eat foods), unless good hygienic practices (GHPs) are exercised (Barro, *et al.*, 2006). Nonetheless, the *E. coli* remains an important member of *Enterobacteriaceae* known to bring about food infections and poisoning (Awe *et al.*, 2010). Some *E. coli* strains can be associated with
heat stable enterotoxin production (WHO, 1984; Jensen et al., 1997).

As shown in Table 4, the fact that Klebsiella spp. could also be isolated from Naira denominations from food vendors, from low level of $4.0 \times 10^1$ cfu/ml as found in ₦500 and ₦20 denominations of the grain sellers, to as high level of $5.2 \times 10^3$ cfu/ml as found in ₦200 denomination of the meat sellers, should not be too surprising, given that this specific bacteria is also an Enterobacteriaceae member. Just like E. coli, Klebsiella spp. can contaminate the water used in moistening the fingers while counting money or cross-contamination from offals. As a rod shaped Gram-negative bacteria, Klebsiella spp. could be found on the skin, mouth, intestinal lining, and could associate with urinary tract infections (Prescott et al., 2008). High rates of Klebsiella spp. on some currency notes is not new, as it has been reported in the United States coins and dollar bills (Gadsby, 1998). However, the degree to which currency notes get contaminated with Klebsiella spp. should not be underestimated. Thus, the bacterial contamination of currency notes are not only confined to developing nations.

Staphylococcus spp., a gram-positive bacteria of spherical shape is among common contaminants isolated from currency notes (Xu et al., 2005). In this current study, the rate at which Staphylococcus spp. would be found on the Naira denominations, could be attributed to such factors as contamination between normal skin (hands, fingers, faces) flora, nasal discharge, soil as well as ubiquitous distribution in the environment (Igumbor et al., 2007; Kumar et al., 2009; Larkin et al., 2009). Additionally, the rubbing off or maybe surfing from a skin flake could facilitate the occurrence of Staphylococcus spp. on the currency notes (Ahmed et al., 2010). Among Staphylococcus spp., for example, S. aureus has the capacity to secrete toxins such as pyrogenic toxin and super antigens, which can bring about health issues like food poisoning as well as toxic shock syndrome (Ayopo, 2010). Given that S. aureus could flourish in the human nose, throat, and skin, the recontamination of currency notes can occur especially during inadequate hygiene, adding cross-contamination from between currency notes and foodstuffs.

The association of E. coli, Klebsiella spp. and Staphylococci spp. of the current work would differ when emphasis is either given to different food vendors or Naira denominations, as respectively demonstrated in Figures 2 and 3. When emphasis is
given to the different food vendors (Refer to Figure 2), higher E. coli and Staphylococci spp. loads were respectively found on Naira denominations recovered from the meat and fish sellers. This occurrence might reflect the nature of foodstuffs dealt by these vendors. High moisture content, blood, and intestinal components in both fish and meat samples have the capacity to provide a sufficient reservoir for various degrees of bacterial proliferation. When emphasis is given to the Naira denominations recovered from different food vendors (Refer to Figure 3), the ₦100 and ₦200 obtained higher E. coli and Staphylococci spp. respectively, whereas ₦500 had higher Klebsiella spp. and Staphylococci spp., with the least isolated bacterial contaminants at ₦10 and ₦5 (Klebsiella spp.), ₦5 (Staphylococci spp.), and ₦1000 (E. coli). The increasing TVC trend across Naira denominations ₦100, ₦200 and ₦500 in Table 2, can be seen to corroborate the data presented in Figure 3, which are respectively loaded with E. coli, Klebsiella spp. and Staphylococci spp., attributable to the frequency of its usage in daily/ various food market transactions. In addition, the ₦1000 currency note appeared the least (bacterial) contaminated, probably because it is least used in Nigeria’s daily foodstuffs transactions. This same reason apply to ₦5, which also appeared the least (bacterial) contaminated, as shown in Table 2, which also corroborated the data presented in Figure 3, consistent with the least Klebsiella spp. and Staphylococci spp., and a low E. coli count, after ₦1000 note. Previous researchers have shown that the improper handling of currency money by food vendors can transfer bacteria from currency notes to humans (Michaels, 2002; Lamichhane et al., 2009). For the reason that the higher denomination notes obtained greater bacterial contaminants, with the exception of ₦1000, authors of current work opine that the Naira denominations might associate with the degree of (bacterial) contamination, resembling the argument Uneke and Ogbu (2007) has made on this matter.

The prevalence of E. coli, Klebsiella spp. and Staphylococci spp. on currency notes from different food vendors suggested the following trend: E. coli (87.5%) > Staphylococci spp. (85%) > Klebsiella spp. (72.5%). Different from the current study, the findings of Yazah et al. (2012) reported much less data frequency with different trend of S. aureus (22.5%) > E. coli (12.5%) > Klebsiella spp. (5%) on the Naira currency notes. Based on the different food vendors, the prevalence showed the following trend:
vegetable sellers (91.7%) > meat sellers (87.5%) > fish sellers (87.5%) > fruit sellers (75%) > grain sellers (66.7%). Similar bacterial contamination observations involving the Nigerian currency notes recovered from fish, meat and vegetable sellers have been shown in previous studies (Ahmed et al., 2010; Barua et al., 2019). Applicable to other countries, the Nigerian currency notes when handled in an unhygienic manner would most likely supplement the frequency of bacterial contamination. This situation can arise from various sources such as atmosphere (air), body of handlers (hand, skin, wounds, etc), counting machine, storage environment, soil, etc (Awodi and Nock, 2001; Prasai et al., 2008). Additionally, tongue-wetting of fingers appears a habit of many when counting money, which could serve as means of contaminating currency notes, fingers (Igumbor, et al., 2007) as well as foodstuffs. For emphasis, the simultaneous handling activity between foodstuffs/food items and currency notes continues to serve as strong candidates capable of promoting as well as progressing foodborne disease incidence and spread through contamination and cross-contamination.

Conclusions

The bacterial contamination of Nigerian currency notes via a comparative study of different denomination notes recovered from local food handlers/vendors has been successfully investigated. Results showed about 81.7% of currency notes were contaminated with either E. coli, Klebsiella spp. or Staphylococcus spp., and in varying degrees. With the exception of ₦1000 note, the (other) higher denominations of ₦500, ₦200, and ₦100 note recorded increased degree of contamination over the lower denominations of ₦50, ₦20, ₦10, and ₦5 note. Naira denominations note from meat, fish, and vegetable sellers obtained higher level of bacterial contaminants compared to those of the other food vendors.

Increased awareness and education among food vendors and ready-to-eat food sellers is warranted if possible cross-contamination between currency notes and foodstuff is to be mitigated. The Central Bank of Nigeria (applicable to central banks at other countries) would have to increase the robustness of the existing retrieval system, if the bacterial contamination and re-contamination of Naira denominations are to be reduced. This would specifically help to ensure that such highly used higher
denominations of ₦500, ₦200, and ₦100 note, as reported in this current study, do not
remain in the circulation process for too long. Additionally, this current study contributes
to the call for increased awareness at the local, state and federal government levels in
Nigeria, to place more emphasis on the potential public health risks that can potentially
arise from the simultaneous handling of money and foodstuffs.

There is the possibility that nutrient agar used in the current study could be
limiting the colony richness of some specific bacteria over others on the spread
plate. Hence, in order to enhance the richness of colony on the spread plate,
considering more bacterial specific agar for use is very needful in future studies
involving same and or other currency notes versus similar (to current study) or other
food vendors. Another direction of future studies could be the use of 16s rRNA
sequencing as well as matrix-assisted laser desorption and ionisation (MALDI), which
are among promising molecular level microbiological techniques. These techniques can
help increase the accuracy of bacterial identification when applied to studies
investigating same (as well as other) currency notes versus same (as well as other)
food vendors. It is also recommended that future studies could determine the
prevalence of other microorganisms like yeast, fungi, and virus on currency notes
across various food vendors, in and or by comparing different locations.

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Figure 1

The schematic overview of the experimental programme, from the collection of currency note/paper samples, preparation of currency note samples for microbial determinations, inoculation, incubation to identification of different bacterial isolate.
Figure 2

Mean values of E. coli, Klebsiella and Staphylococcus count isolated from Naira denominations, with emphasis on the different food vendors

(Blue colour) *E. coli*.

(Orange colour) *Klebsiella*.

(Grey colour) *Staphylococci*. 
Figure 3

Mean values of E. coli, Klebsiella and Staphylococcus count isolated, with emphasis on the Naira denominations recovered from different food vendors

(Blue colour) *E. coli*.

(Orange colour) *Klebsiella*.

(Grey colour) *Staphylococci*. 
Table 1: Factorial experimental design table
**Table 1: Factorial experimental design table**

| Name | Currency denomination | Food vendor type |
|------|------------------------|------------------|
| Type | Ordinal                | Nominal          |
| Levels |                      |                  |
| 1    | ₦1000                 | Fruit seller     |
| 2    | ₦500                  | Meat seller      |
| 3    | ₦200                  | Vegetable seller |
| 4    | ₦100                  | Fish seller      |
| 5    | ₦50                   | Grain seller     |
| 6    | ₦20                   | -                |
| 7    | ₦10                   | -                |
| 8    | ₦5                    | -                |
| Naira Denomination | Total Viable Count (cfu/ml) |
|--------------------|-----------------------------|
| 1 Naira            |                             |
| 5 Naira            |                             |
| 10 Naira           |                             |
| 50 Naira           |                             |
| 100 Naira          |                             |
| 500 Naira          |                             |
| 1000 Naira         |                             |
Table 2: Total viable count (cfu/ml) of Naira denominations recovered from different food vendors

| Currency denomination | Fruit sellers | Meat sellers | Vegetable sellers | Fish sellers | Grain sellers | Mean × 10^3 |
|------------------------|--------------|-------------|-------------------|--------------|--------------|-------------|
| ₦1000                  | 1.3 × 10^5   | 3.9 × 10^4  | 3.0 × 10^2        | 3.0 × 10^4   | 1.2 × 10^4   | 42.26       |
| ₦500                   | 9.0 × 10^3   | 7.5 × 10^4  | 1.3 × 10^5        | 1.2 × 10^5   | NGD          | 66.80       |
| ₦200                   | 3.0 × 10^4   | 3.0 × 10^3  | 3.0 × 10^3        | 2.9 × 10^5   | 5.1 × 10^4   | 75.40       |
| ₦100                   | 2.2 × 10^5   | 1.4 × 10^5  | 5.0 × 10^4        | 2.5 × 10^5   | 3.6 × 10^3   | 132.72      |
| ₦50                    | 8.0 × 10^3   | 1.6 × 10^5  | 7.0 × 10^3        | 1.4 × 10^5   | NGD          | 63.00       |
| ₦20                    | 1.4 × 10^4   | 1.9 × 10^5  | 2.0 × 10^4        | 3.0 × 10^4   | 5.0 × 10^2   | 50.90       |
| ₦10                    | 3.0 × 10^3   | 8.6 × 10^4  | 2.8 × 10^4        | 7.0 × 10^4   | NGD          | 37.40       |
| ₦5                     | NGD          | 2.9 × 10^4  | 2.7 × 10^4        | 1.3 × 10^4   | 4.2 × 10^3   | 14.64       |
| Mean × 10^3            | 51.75        | 90.25       | 33.16             | 117.88       | 8.91         |

Values are the means of duplicate determinations
NGD = No Growth Detected
Table 3 (on next page)

*Escherichia coli* count (cfu/ml) of Naira denominations recovered from different food vendors
Table 3: *Escherichia coli* count (cfu/ml) of Naira denominations recovered from different food vendors

| Currency denomination | Fruit sellers | Meat sellers | Vegetable sellers | Fish sellers | Grain sellers | Mean × 10³ |
|------------------------|--------------|-------------|-------------------|-------------|--------------|------------|
| ₦1000                  | NGD          | 1.2 × 10²   | 4.0 × 10²         | 2.5 × 10²   | NGD          | 0.15       |
| ₦500                   | 4.0 × 10³    | 7.0 × 10¹   | 2.0 × 10²         | 3.0 × 10³   | 2.0 × 10¹    | 1.46       |
| ₦200                   | 9.0 × 10²    | 6.1 × 10³   | 6.0 × 10²         | 5.2 × 10²   | 1.0 × 10²    | 1.64       |
| ₦100                   | NGD          | 6.5 × 10³   | 3.0 × 10²         | 1.0 × 10⁴   | 2.0 × 10¹    | 3.36       |
| ₦50                    | 1.2 × 10³    | 2.0 × 10³   | 4.0 × 10²         | 3.2 × 10³   | 8.0 × 10²    | 1.52       |
| ₦20                    | NGD          | 5.0 × 10³   | 2.0 × 10²         | 3.0 × 10²   | NGD          | 1.10       |
| ₦10                    | 1.3 × 10³    | 3.0 × 10²   | 2.0 × 10²         | 1.0 × 10²   | 4.0 × 10¹    | 0.39       |
| ₦5                     | 7.0 × 10²    | 2.0 × 10²   | 2.0 × 10²         | 1.6 × 10²   | 2.0 × 10¹    | 0.24       |
| Mean × 10³             | 1.01         | 2.54        | 0.31              | 2.18        | 0.12         |

Values are the means of duplicate determinations

NGD = No Growth Detected
**Table 4** (on next page)

*Klebsiella sp.* count (cfu/ml) of Naira denominations recovered from different food vendors
Table 4: *Klebsiella* sp. count (cfu/ml) of Naira denominations recovered from different food vendors

| Currency denomination | Fruit sellers | Meat sellers | Vegetable sellers | Fish sellers | Grain sellers | Mean × 10^3 |
|-----------------------|---------------|--------------|------------------|--------------|---------------|-------------|
| ₦1000                 | NGD           | NGD          | 7.0 × 10^2       | NGD          | NGD           | 0.14        |
| ₦500                  | 8.5 × 10^2    | 5.0 × 10^2   | 1.8 × 10^3       | 5.0 × 10^3   | 4.0 × 10^1    | 1.64        |
| ₦200                  | 6.0 × 10^2    | 5.2 × 10^3   | 4.0 × 10^2       | 8.5 × 10^2   | NGD           | 1.41        |
| ₦100                  | 2.7 × 10^3    | NGD          | 1.4 × 10^2       | NGD          | NGD           | 0.57        |
| ₦50                   | 3.5 × 10^2    | 8.0 × 10^2   | 1.2 × 10^3       | 2.0 × 10^2   | 1.1 × 10^2    | 0.53        |
| ₦20                   | 7.0 × 10^2    | 3.0 × 10^2   | 5.0 × 10^2       | 1.9 × 10^2   | 4.0 × 10^1    | 0.35        |
| ₦10                   | 2.0 × 10^2    | 4.0 × 10^1   | 1.0 × 10^2       | 2.0 × 10^2   | 6.0 × 10^1    | 0.12        |
| ₦5                    | 3.2 × 10^2    | NGD          | 3.0 × 10^2       | NGD          | NGD           | 0.12        |
| Mean × 10^3           | 0.72          | 0.86         | 0.64             | 0.81         | 0.03          |

Values are the means of duplicate determinations

NGD = No Growth Detected
Table 5 (on next page)

*Staphylococci sp.* count (cfu/ml) of Naira denominations recovered from different food vendors
Table 5: *Staphylococci sp.* count (cfu/ml) of Naira denominations recovered from different food vendors

| Currency denomination | Fruit sellers | Meat sellers | Vegetable sellers | Fish sellers | Grain sellers | Mean × 10^3 |
|------------------------|--------------|--------------|-------------------|--------------|---------------|-------------|
| ₦1000                  | 3.0 × 10^2   | 2.8 × 10^3   | NGD               | 1.5 × 10^2   | NGD           | 0.65        |
| ₦500                   | 3.7 × 10^3   | 1.6 × 10^2   | 7.0 × 10^1        | 4.3 × 10^3   | NGD           | 1.65        |
| ₦200                   | 4.2 × 10^2   | 3.7 × 10^3   | 6.0 × 10^3        | 1.5 × 10^2   | 9.2 × 10^2    | 2.24        |
| ₦100                   | 8.0 × 10^2   | 2.7 × 10^3   | 2.0 × 10^2        | 4.0 × 10^3   | 1.6 × 10^3    | 1.86        |
| ₦50                    | 1.9 × 10^3   | 1.8 × 10^2   | 1.2 × 10^2        | 3.5 × 10^3   | 5.0 × 10^1    | 1.15        |
| ₦20                    | NGD          | 4.0 × 10^2   | 1.2 × 10^2        | 6.0 × 10^3   | 4.0 × 10^1    | 1.24        |
| ₦10                    | 4.1 × 10^2   | 8.0 × 10^2   | 9.0 × 10^2        | 3.0 × 10^2   | 5.0 × 10^1    | 0.35        |
| ₦5                     | NGD          | 1.1 × 10^2   | NGD               | 4.0 × 10^2   | 1.4 × 10^2    | 0.13        |
| Mean × 10^3            | 0.94         | 1.22         | 0.93              | 2.35         | 0.35          |

*Values are the means of duplicate determinations*

NGD = No Growth Detected
Table 6 (on next page)

Prevalence of *E. coli*, *Klebsiella sp.*, *Staphylococci sp.* on currency notes from different food vendors
Table 6: Prevalence of *E. coli*, *Klebsiella sp.*, *Staphylococci sp.* on currency notes from different food vendors

| Isolated bacteria | Fruit sellers | Meat sellers | Vegetable sellers | Fish sellers | Grain sellers | Total |
|-------------------|---------------|--------------|-------------------|--------------|--------------|-------|
| *E. coli*         | 5 (62.5%)     | 8 (100%)     | 8 (100%)          | 8 (100%)     | 6 (75%)      | 35 (87.5%) |
| *Klebsiella sp.*  | 7 (87.5%)     | 5 (62.5%)    | 8 (100%)          | 5 (62.5%)    | 4 (50%)      | 29 (72.5%) |
| *Staphylococci sp.* | 6 (75%)   | 8 (100%)    | 6 (75%)          | 8 (100%)    | 6 (75%)      | 34 (85%)   |
| Total             | 18 (75%)      | 21 (87.5%)   | 22 (91.7%)        | 21 (87.5%)   | 16 (66.7%)   | 98 (81.7%) |