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Evaluation of the Effectiveness of Traditional *Rastrineobola argentea* Sundrying Process Practiced along the Shores of Lake Victoria, Kenya

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Abstract Quality of fish depends on its texture, odour and hinges on duration of harvesting and processing. Traditional sun-drying free-to air of *Rastrineobola argentia* who's effectiveness and efficiency to reduce moisture content that cut-off microbial ability to grow in this fish is unknown. Thus evaluation of effectiveness and quality of *R. argetea* processed by sun-drying along the shores of Lake Victoria, Kenya was done. Random and purposive study designs were adapted while convinient sampling upheld for beaches and markets. A total of 130 samples each comprising of 500g tin(s) of approximately 100 - l50g of *R. argentea* were purchased as wet (0h), semi-dry (3h) or dry(8-10h). Conventional microbiological methods were used to determine presence of *E. coli*, *Salmonella*, *Klebsiella*, *Clostridium*, *Staphylococcus*, mould and yeast and their antimicrobial profile. ANOVA was used to determine statistical significance. Mean Aerobic Plate Count of sun-dried *R. argentiae* in markets was statistically higher (p=0.003) while that of beaches varied with sampling time (wet, p=0.02); (dry, p=0.02); (semi-dry, p=0.03). Recovered microbes were, *E. coli* 44.7% (8-10h); 71.4% *Proteus* spp (3 h); 50% *Salmonella* spp (3h). 100% of *E.coli*, were resistant to ampiclox, 66% to tetracycline, 5% to cefuroxime, 2.4% to nalidixic acid. *Salmonella* spp were resistant to 20% tetracycline, ampicillin and sulfamethoxazole, 50% to chloramphenicol, 10% to streptomycin. Citrobactor was resistant to 14.3% nalidixic acid and sulfamethoxazole, 71.4% to ampicillin and chloramphenicol. Antimicrobial resistance was different for beaches and markets. *R. aregentea* from the beaches and markets were contaminated with microbes and sun-drying did not reduce their population.

Keywords Sund-drying, *Rastrineobola argentea*, Antimicrobial, Beaches, Market, Gulf

1. Introduction

Rastrineobola argentea [1] is a small, zooplanktivorous cyprinid fish from Lake Victoria and Lake Kyoga, East Africa [2-4]. It is a relatively cheap source of animal protein as nourishment for man and livestock as well as being the second most commercially important fishery of Lake Victoria. *R. argentea* fishing in Kenya is concentrated around known fishing grounds basically offshore and carried out at night with or without light attraction. The former method is practiced mostly towards the outer portion of the Gulf while the latter is found within the middle and inner area of the Gulf. *R. argentea* catching nets in Kenya may measure up to 100m long, with mostly 5mm stretched mesh size. The main processing method is by sun-drying where over 98% of the catch is processed locally by drying directly on the ground or spread on old fishing nets or papyrus reeds. This in turn compromises the end products quality and safety through microbial contamination [5, 6]. This type of exposure together with handling process coupled with lack of preservation and storage facilities puts the fish at risk of contamination with microbes due to its high concentration of lipids and moisture.

Fish microenvironment dictates the type and sum total of bacteria population found on its gills, skin and intestines that would eventually result to its spoilage. Occasionally bacteria that contribute to fish spoilage (determined by the levels of trimethylamine [$N(CH_3)_3$] are those within Gram negative *Enterobactereceae*, *Pseudomonaceae*, *Lactobacillus*, *Enterococcus* and *Staphylococcus* [7]. Together with other chemicals, microbial spoilage contributes 25% loss of gross primary agricultural and fishery products annually [8]. This translates to one-fourth of the world's food supply [9] and 30% of landed fish [10] hence threatening food security. The bacteria would lead to fish spoilage immediately after

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capture producing many proteolytic and hydrolytic enzymes [11, 12] leading to production of amines, biogenic amines such as putrescine, histamine and cadaverine, organic acids, sulphides, alcohols, aldehydes and ketones with unpleasant and unacceptable off-flavours [13-16]. Engvang and Nielsen, [17] reported the presence of proteolytic enzymes in muscle and viscera of the fish after catch that contribute to post harvest deterioration by proteolysis of proteins followed by a process of solubilization in fish muscle and fish products during storage and processing [18]. These proteolytic enzymes operates optimally at specific pH and temperature [19] which are intrinsic factors that influence microbial identities and growth besides other contamination from the environment (water activity, nutritional composition of the fish, and redox potential) [14]. One way to circumvent fish contamination is by ensuring proper fish processing and preservation methods are used. Among these is the use of 3% UV that reaches the ground level in form of sun rays (from 400nm to 10nm in wavelength) from sunlight that has been found to be effective in microbiological sanitization. Thus despite negligible advantage that sundrying may have on *R. argentea* its real effect on fish process has been less quantified. Quality of fish majorly depends on its texture and odour on or after catch. This is affected by myriad of factors that may be intrinsic or extrinsic. Among extrinsic factors are the presences of bacteria that contaminate the fish and are known to thrive in ubiquitous environments depending on moisture content. The duration of harvesting and processing of fish will determine the quality of the processed product. During this period fishes continue to deteriorate due to improper handling and further processing can never bring back its freshness. One of the processing methods is the use of traditional sun-drying free-to air of *R. argentia*. However, the effectiveness and efficiency of this method to drastically reduce moisture content to negligible concentrations that cut-off microbial ability to grow in this fish is unknown. In this regard, this study reports the effect of the traditional sundrying method on the levels of coliforms, fungal and pathogenic bacteria on *R. argentea*. Although the traditional sundrying method has been reported not be effective as fish preservation method no study has demonstrated this among the Lake Victoria fishery.

2. Material and Methods

2.1. Study Area

Lake Victoria is the world's second largest fresh water body. It has a surface area of about 68,800 Km^2 and a catchment area of 284,000 $Km.^2$ The shore line is approximately 3,500 Km long. It touches the equator on the North, lies between latitude 0.7° N- 3° S and longitude 31.80E-34.80E and in the South of Equator between 0° 6′ S-0° 32′ S and 34° 13′ E- 34° 52′ E at an altitude of 1134m above sea level [20]. The lake is shared by three riparian countries where Tanzania occupies 49%, Uganda 45% and Kenya 6% of the lake. The basin supports over 30 million people. The major portion of Kenya part of Lake Victoria is the Nyanza Gulf (also known as Winam Gulf or Kavirondo Gulf). It has a catchment area of 3,600 km^2 drained by five major rivers (Nzoia, Kuja, Nyando, Yala, Sondu) through which it contributes approximately 30% of total riverine inflow into L. Victoria [21]. It receives a mean annual rainfall of about 1,153 mm and experiences a mean annual temperature of 22°C and a mean annual potential evaporation of 1968 mm. Winam Gulf experiences long rains from March to May with peak in April and short rains in August and October. This inflows from various rivers and storms act as secondary pollutants to the lake with microbes that thrive in respective environemental conditions resulting to fish contamination. To verify this hypothesis, both fresh and dry fish samples from the lake and those transported to various local markets were conveniently sampled. The selected four markets were, Luanda market market (0° 0′ 0′′ North, 34° 35′ 0′′ East, Kibuye market (0° 5′ 34′′N, 34° 46′ 6′′ E), Busia market (0° 27′ 0′′ N, 0° 7′ 30′′ E), Yala market (0° 60′ 0′′ N, 34° 32′ 0′′ E); and three landing beach sites, viz:- Dunga beach (0° 10′ 00′′ S, 34° 47′ 0′′ E), Usenge beach (0° 4′ 23.23′′ N, 34° 3′ 37.12′′ E), Uhanya beach and Uyoma Naya beach.

2.2. Sampling Plan

A sum total of 130 dry *R. argentea* samples were purchased in regular consumer packages of 500g size tins (quantity approximately 100 - l50g of *R. argentea*). The *R. argentea* was then packaged and transported in sterilized polythene bag(s). Fish sampling from the fish markets was done randomly during market days only and in the morning when deliveries were made to the markets. At the landing sites fish samples were collected at around 7 00 a.m the time when fishing boats land their catch. In this regard, three samples (500g tins) were randomly collected from fish traders or fishermen each day of beaches and markets. *R. argentea* was collected at different intervals of processing at the beach, viz; 0, 3 and 8 h. However the collections were on different days for the landing sites. For markets, those that had been dried for as along as 10 h and above only were sampled. The samples were immediately transported aseptically in cooler box to the Maseno university Zoology laboratory for processing and analysis.

2.3. Determination of Aerobic Plate Count and Total Coliform Count

Microbial determinations were carried out using the standard methodologies described in the [22]. Briefly, 25 g of each sample was weighed aseptically and diluted in 225 ml of buffered peptone water (HiMedia Lab. Pvt. Mumbai, India) from which other experiments were conducted.

2.4. Determination of Aerobic Plate Count (APC)

1 ml of homogenate was added to 9 ml sterilized peptone water to make 10 ml of the mixture, followed by serial dilutions ranging from 10^{-2} to 10^{-6} by adding 1 ml of homogenate to about 9 ml sterilized peptone water. Using the

pour plate method 1 ml of each dilution was tranfered to sterile plates and about 15 ml of Plate count agar (PCA) added, mixed and allowed to solidify. Plates were then incubated at 37 ± 2°C for 48 h, and colonies were counted using colony counter (SC6PLUS colony counter – Bibby Scientific) and reported as cfu/g.

2.5. Determination of Total Coliforms

The 3 tube MPN method was used; 10 ml of the 10^{-1} dilution was inoculated into each three tubes containing 10 ml of double strength MacConkey broth purple (HiMedia Lab. Pvt. Mumbai, India). Then 1 ml of each 10^{-1} dilution was inoculated to each three tubes containing 10 ml of single strength MacConkey broth purple. The same procedure was repeated for 10^{-2} and 10^{-3} dilutions. Tubes were incubated at 36 ± 1°C to 24 and 48 h. Tubes showing changes from purple to yellow were identified as positive for faecal coliforms. Counts per 100 ml were calculated from Most Probable Number (MPN) tables. From the positive tubes using sterile inoculating wire loop, MacConkey Agar were plated and incubated at 37°C overnight for recovery and identification of respective coliforms and *E. coli* as described thereafter.

2.6. Isolation and Confirmation of Coliforms and *E. coli* in *R. argentea* Samples

From each MacConkey Agar plate 4 – 6 colonies of diverse characteristic were picked and inoculated on Nutrient agar (HiMedia Lab. Pvt. Mumbai, India) plates for further biochemical tests which included TSI, LIA, Indole, Methyl - Red, Voges – Proskauer and Citrate utilization (IMViC) reactions. Cultures were further confirmed using API- 20E (Biomérieux, France). The confirmed isolates were then stored on tryptic soy broth with 15% glycerol at 20°C for antimicrobial susceptibility testing.

2.7. Isolation and Confirmation of *Salmonella* Serovars

A portion of the remaining homogenates were incubated for 24±2 h at 35°C for pre-enrichment of the possible isolates. After incubation, 0.1 ml of the resulting homogenate was transferred to 10 ml of Selenite F broth (Himedia laboratory pvt Ltd Mumbai India) which were then incubated for 24 h at 37 ± 2°C for the inhancement of *Salmonella* spp growth.

From the overnight Selenite F culture broth, a loop full of broth was obtained and streaked onto Deoxycholate citrate Agar (DCA) (Himedia laboratory pvt Ltd Mumbai India), and Xylose Lysine Desoxycholate Agar (Himedia laboratory pvt Ltd Mumbai India) respectively. These plates were incubated for 24 h at 35±2°C. After 24 h incubation, two presumptive *Salmonella* colonies were picked from each selective agar and inoculated on Nutrient agar awaiting biochemical confirmation which included Urea broth (Himedia laboratory pvt Ltd Mumbai India), Triple Sugar Iron agar (TSI) (Himedia laboratory pvt Ltd Mumbai India) and Lysine Iron Agar (LIA) (Himedia laboratory pvt Ltd Mumbai India) all incubated at 35±2°C for 12 h and examined for the reactions characteristic for suspected *Salmonella*. Cultures were further confirmed using API- 20E (Biomérieux, France)

2.8. Isolation and Enumeration of *S. aureus*

Baird Parker agar medium (Himedia laboratory pvt Ltd Mumbai India) was used to isolate *Staphylococcus aureus*. Portions (0.1 ml) of appropriate dilution were spread plated in triplicate. Counts on Standard plate count agar, were obtained after incubation for 48 h at 25°C, while Baird Parker agar plates were inoculated aerobically at 37°C for 24 h. Results were calculated as mean of three different determinations.

2.9. Enumeration of Clostridium

Clostridum spp were determined using Cooked meat agar medium (Himedia laboratory pvt Ltd Mumbai India) that was incubated at 37°C for 24 h in anaerobic system using gas generation kit as described by Cravene *et al*., [23].

2.9.1. Enumeration of Yeasts and Moulds

Mould and fungi were isolated and enumerated by pour plate method and growth on Potato Dextrose Agar (PDA) (Himedia laboratory pvt Ltd Mumbai, India). Serial dilutions of 10^{-1} to 10^{-4} were prepared by diluting 1 g of the sample into 10ml of sterilized distilled water. One millimeter aliquots from each of the dilutions were inoculated on petri dishes with already prepared PDA. The plates were then inoculated at 25°C for 24 h. After incubation all white spots and spread were counted and recorded as moulds using the colony counter (SC6PLUS colony counter – Bibby Scientific) as descrite isolates.

2.9.2. Antimicrobial Susceptibility Testing

Antimicrobial susceptibility was done according to the guidelines of the Clinical and Laboratory Standards Institute (CLSI) [24] using the disk diffusion technique with commercially available discs (Himedia laboratories pvt Mumbai India). The eleven antimicrobials and concentrations in micrograms that were tested include; tetracycline (30µg), sulfamethoxazole (25µg), chloramphenicol (30µg), ampicillin (10µg), nalidixic acid (30µg), ciprofloxacin (5µg), streptomycin (10µg), ceftriaxone (30µg), cefuroxime (30µg), cefotaxime (30µg) and Augumentine (30µg) (all from HIMedia Laboratory Pvt. Ltd Mumbai India). The isolates were inoculated on nutrient agar plates for 16 h to establish a culture in the logarithmic growth phase then a small colony isolate was suspended in sterile normal saline (0.9% sodium chloride) solution to form turbidity. This was then applied evenly onto the surface of Muller Hinton agar (HI Media Laboratory Pvt. Ltd Mumbai India) in a Petri-plate using sterile cotton tipped swab to make a uniform lawn. Drug disks were then carefully placed onto the agar surface. The plate were inverted and incubated for 18 h. The inhibition zones, were measured in mm using a precision calipers. The scores were scored as sensitive, intermediate, susceptibility and resistant according to the

criteria described by the Clinical and Laboratory Standards Institute (CLSI) [24]. ATCC 25922 was used as a control.

3. Results

3.1. Aerobic Plate Count (APC) on *R. argentea* at Fish Landing Sites and Fish Markets

In order to determine heterotrophic (aerobic and facultatively anaerobic) bacteria density, Aerobic plate Count (APC) was determined as a measure of quality and effectiveness of traditional sun-drying processing. The mean APC of sun-dried *R. argentea* sold in commercial markets was significantly higher in three markets (Table 1). Kibuye market had the lowest mean $\log_{10}$ 5.43 cfu/g whereas Lunda market had the highest $\log_{10}$ 5.93 cfu/g followed by Yala $\log_{10}$ 5.87 cfu/g. Statistical analysis using ANOVA, indicated significant difference among the markets p = 0.003.

Table 1. Log_{10} mean colony forming units (CFU/gm) of sun-dried *R. argentea* contamination in respective commercial markets

Market	Min	Max	Mean	S. Deviation	p. Value
Lunda	5.45	6.3	5.93	0.24	0.13
Yala	4.48	6.22	5.87	0.43	0.24
Kibuye	4.6	6.3	5.43	0.49	0.27
Busia	4.85	6.15	5.64	0.38	0.21

Table 2. Showing the aerobic plate count (APC) values for respective fish landing sites

Landing site	min	max	mean	S.Devia	p value
Dunga					
Boat (0)	5.9	6.33	6.03	0.17	0.21
3 h	5.73	6.3	6.03	0.21	0.26
8 h	5.99	6.33	6.11	0.15	0.19
Usenge					
Boat	5.11	5.95	5.63	0.34	0.42
3 h	5.89	6.23	6	0.14	0.17
8 h	5.69	6.09	5.87	0.18	0.22
Uhanya					
Boat (0)	5.93	6.09	6.01	0.07	0.09
3 h	6.01	6.11	6.07	0.04	0.05
8 h	5.94	6.12	6.03	0.07	0.08
Port Victoria					
Boat	5.3	6.01	5.68	0.26	0.33
3 h	5.42	6.3	5.93	0.32	0.4
8 h	5.66	5.99	5.82	0.12	0.15

Among the landing sites sampled, Dunga beach registered relatively high levels of APC with the highest being after 8 h of the drying process, which showed a mean of $\log_{10}$ 6.11 cfu/gm, followed by Uhanya, whereas Port Victoria recorded the lowest at $\log_{10}$ 5.82cfu/g after 8 h of drying. Taken together, among the three beaches, Uhanya, Usenge and Port Victoria there was a general increase in the levels of APC by the third hour of drying, but by the eight hour the levels had decreased. However this senerio was not replicated for Dunga beach. When using ANOVA to compare between the beaches with respect to time of fish processing, there was statistically significant difference (p = 0.02) among the microbial levels of fish during receiving fish from the boat, and for fish sampled after 8 h (p = 0.02). There was no statistical significance difference (p = 0.73) among APC when fish was sampled just after 3 h of drying (Table 2).

Boat (0 hours) at landing and sample collection; 3 hours after spreading and drying the sample; 8 hours after spreading and drying the sample.

3.2. Total Coliform Counts (MPN/g)

Most Probable Number (MPN) was used to determine the level of coliform contamination of fish at the markets and landing sites. The results show that among markets, Kibuye market had the lowest mean of 0.14 MPN/g whereas Lunda market had the highest 0.71 MPN/g followed by Yala 0.22 MPN/gm. Results of ANOVA, shows that there was no statistical significant difference among the markets (p = 0.5) (Table 3).

Table 3. Showing total coliform counts (MPN/g) of the respective markets in the study areas

Market	Min	Max	Mean	std	p. Value
Kibuye	0.03	0.61	0.14	0.16	0.08
Luanda	0.03	11	0.71	2.5	1.2
Yala	0.03	0.62	0.22	0.19	0.1
Busia	0.03	0.61	0.18	0.16	0.09

Table 4. Showing total coliform counts (MPN/g) of the respective beaches in the study areas

Landing site	min	max	mean	std	p value
Uhanya					
Boat	0.03	1.5	0.42	0.61	0.76
3 h	0.092	2.9	0.72	1.22	1.5
8 h	0.03	4.6	1.41	1.98	2.46
Port Victoria					
Boat	0.061	0.93	0.27	0.37	0.46
3 h	0.062	0.95	0.29	0.38	0.47
8 h	0.2	4.6	2.1	1.8	2.38
Dunga					
Boat	0.15	2.1	1.2	0.76	0.94
3 h	0.15	4.6	2.47	2.02	2.5
8 h	0.36	11	4.92	5.56	6.91
Usenge					-----
Boat	0.03	3.6	1.5	1.87	2.32
3 h	0.094	3.8	1.98	1.81	2.25
8 h	0.21	3.8	1.85	1.58	1.97

In the case of landing sites Dunga beach registered the highest mean at 4.92 MPN/g after 8 hours of processing. Simillarly as in the case of APC, there was an increase of total coliform (TC) by the third hour of drying followed by a

decrease by the eight hour of processing. When comparing among the beaches and time of sampling no statistical signicant difference was observed P > 0.05 (Table 4).

Boat (0 hours) at landing and sample collection; 3 hours after spreading and drying the sample; 8 hours after spreading and drying the sample.

3.3. Coliform Recovered from *R. argentea* Processed in Different Conditions from the Landing Sites

Out of all the *R. argentea* samples collected from the four beaches (Port Victoria, Usenge, Uhanya and Dunga), sun-dried (8-10 h) samples at the beach had a higher recovery of *E. coli* (44.7%) followed by wet (31.6%) and then semi-dry (23.7%) respective. *Proteus* spp contamination was high in semi-dried *R. argentea* samples (71.4%) followed by wet (28.6%). Dry samples did not have any *Proteus* spp contamination. In regard to *Salmonella* Spp, semi-dried samples (50%) had a higher contamination followed by sun-dry (37.5%) and wet (12.5%) samples. *Citrobater* Spp contamination of the samples was the same for all the beaches (Table. 5). Only in one occasion was *Klebsiella* spp isolated from semi-wet samples (data not shown). Samples from Uhanya beach were only contaminated with *E.coli*.

Table 5. Percentage coliform recovered from *R. argentea* in different processing conditions from the beaches

Bacterial isolate	boat (0 h)	3 h	8 h
E. coli	31.6%	23.7%	44.7%
Proteus spp	28.6%	71.4%	0%
Salmonella spp	12.5%	50%	37.5%
Citrobacter spp	33.3%	33%	33%

R. argentea samples from the selected markets were found to be contaminated with *E.coli*, *Citrobacter* spp, *Salmonella* spp, and *Proteus* respectively with *E.coli* and *Citrobacter* having the same magnitude of contamination. In addition, *Staphylococus* spp, yeast, moulds and *Clostridium perfringens* were also isolated from the market samples while from the beach samples, *E.coli*, *Salmonella* spp, *Citrobacter* spp, *Proteus* spp and *Klebsiella* spp were predominantly isolated in that order.

3.4. Antimicrobial Screening Pattern of Coliform in the Respective Beaches and Markets

The isolated bacteria were screened for various antimicrobials sensitivity patterns. Of the isolated 41 *E.coli*, (100%) were resistant to ampicillin/cloxacillin 66% to tetracycline, 5% to cefuroxime, 2.4% to nalidixic acid. Intermediate drug resistance was also observed; 76% to cefuroxime, 10% to chloramphenicol, 10% to nalidixic acid and 27% to tetracycline. Susceptibility to gentamicin and co-trimoxazole was (100%), 20% to cefuroxime, 92.2% to chloramphenicol, 78.1% to nalidixic acid and 7.3% to tetracycline. Table 6 and 7 show the respective screening pattern in the two control beaches where it was observed that *E.coli* isolated from *R. argentea* in Dunga beach were 100% resistant to ampicillin and 64% to tetracycline. The same pattern was observed in Uyoma Naya beach where resistance to ampicillin was 100% and 68.8% to tetracycline. *Salmonella* spp were resistant to 20% tetracycline, 20% ampicillin, 50% to chloramphenicol, 10% to streptomycin, 20% to sulfamethoxazole. Citrobacter was resistant to 14.3% nalidixic acid, 71.4% to ampicillin and chloramphenicol respectively, 14.3% to sulphamethoxazole.

Table 6. Percentage antimicrobial resistance patterns of *E. coli* from *R. argentea* and lake water from Dunga beach

Antibiotic agent	Antimicrobial distribution patterns of the *E. coli* isolates from Dunga Beach (n = 25)		
	% Resistant	% Intermediate	% Susceptible
Ampicillin/Cloxacillin (10µg)	100 (25)	0	0
Cefuroxime (30µg)	4 (1)	80 (20)	16 (4)
Chloramphenicol (50µg)	0	8 (2)	92 (23)
Co-Trimoxazole (25µg)	0	0	100 (25)
Gentamicin (10µg)	0	0	100 (25)
Nalidixic Acid (30µg)	0	16 (4)	84 (21)
Tetracycline (30(µg)	64 (16)	28 (7)	8(2)

µg = microgram

Table 7. Percentage antimicrobial resistance patterns of *E. coli* from *R. argentea* and lake water in Uyoma Naya beach

Antibiotic agent	Antimicrobial distribution patterns of the *E. coli* isolates from Uyoma Naya beach (n = 16)		
	% Resistant	% Intermediate	% Susceptible
Ampicillin/Cloxacillin(10µg)	100 (16)	0.0	0.0
Cefuroxime (30 µg)	6.25 (1)	68.75 (11)	25 (4)
Chloramphenicol (50 µg)	0,0	12.5 (2)	87.5 (14)
Co-Trimoxazole (25 µg)	0,0	0,0	100 (16)
Gentamicin (10 µg)	0,0	0,0	100 (16)
Nalidixic Acid(30 µg)	6.25 (1)	25 (4)	68.75 (11)
Tetracycline (30 µg)	68.75(11)	25 (4)	6.25 (1)

µg = microgram

In summary, the profile of antimicrobial resistance patterns observed among isolates recovered from beaches was different from those of the markets as shown in table 8.

4. Discussion

The findings of this study show that *R. argentea* landed by the fishermen in most cases has high APC counts mean range between $\log_{10}$ 5.63 and $\log_{10}$ 6.03 cfu/25g. It is possible that these relatively high levels of APC could be as a result of lack of cooling facilities on the fishing boats, and the design

and construction of the fishing boats that allows for possible cross contamination from the fishing crew and mixing of the catches [25].

Table 8. Frequency distribution table of antibiogram patterns in the respective market (s) and fish landing beaches

	Number of individual resistance per site	
Antibiogram pattern	Market	Landing site
Tet+C	3	-
Amb+Sul	2	-
Amb+C	3	3
Na+Sul	-	1
Na+C	-	1
C+Strep	-	2
Tet+Amb+Sul	2	1
Tet+Amb+C	2	-
Tet+C+Sul	1	-
Na+Tet+C	1	-
C+Strep+Sul	-	1
Na+tet+cipro+C	-	1

Na = Nalidixic acid, Amb = Ampicillin, C = Chloramphenicol, tet = Tetracycline, Sul = Sulfa- methoxazole, Cipro = Ciprofloxacin, Strep = Streptomycin

The study results also show that there is progressive increase in bacterial levels APC and TC as the drying process proceeds, however by the eight hour normally the time the fish is removed from the drying site, there is a general reduction in microbial levels as demonstrated in Tables 4 and 5. This could be attributed to the microbial killing property of UV light as well as handling mode of the fish since coliform counts of recently caught fish are relatively low, but increase considerably during handling [26-29]. However APC levels were generally high (mean range $\log_{10}$ 5.82 – $\log_{10}$ 6.11 cfu/g) when compared to those recorded when the fish are landed and do not comply with local approved fish safety standards creating a course of concerned.

There was however a marked reduction in the APC levels ($\log_{10}$ 5.43 to $\log_{10}$ 5.93 cfu/g) as the fish gets to the markets as shown in Table 2. The same was observed for total coliforms (Table 3 and 4). It extrapolated that the reduction in total coliforms in this fish could be due to the difference in moisture content of the products at the landing site (72.83-76.90% according to [30] compared to that recorded at markets (14.9% according to Onyuka et al., [31] since moisture is one of the basic requires for microbes to thrive. However the APC levels reported did not comply with the local approved safety standards , which specifies TPC values of not more than 100,000 cfu/g ($\log_{10}$ 5cfu/g), zero coliform counts with maximum limits being 2×10^3g for *S. aures* CFU /g (ISO 6888), total viable count of 10^5/g (ISO 4833), yeast and moulds 10^4 (ISO 21527-1) and *Salmonella* in 25 g (ISO 6579), *E.coli* / g (ISO 7251), *Clostridium perfrigens* species (ISO 7937) and *Listeria monocytogenes* (ISO 11290-2) being totally absent [32, 33]. Moisture content has been reported to be an important factor that determines survival and growth of microbes in food products [34, 35]. Based on this finding, it is summarized that traditional sundrying process appears not to be able to attain the acceptable moisture content of 12% maximum (ISO 6496) by the time the fish processors hand pick the fish from the drying site after 8 h making the fish vulnerable to continuous microbial spoilage and deterioration as was supported by the smell of amines in the storage facilities. Sundrying achieves fish preservation by removing water from the fish products, UV is also hypothesized to be involved in the killing of infecting microbes [34, 35]. However it is the reduction of moisture content which is significant in regard to the preservation strategy [36, 37]. Studies have shown that drying fish directly on the ground doesnot achive the intended objective, the drying process is not even, the portion of fish in direct contact with the ground tends to transfer moisture to the ground rather than it being evaporated away from the fish. This provides good grounds for bacterial survival and growth [37].

At the landing sites the fish is however also exposed to contamination that could be attributed to poor handling since the fish is dried on the ground. In this manner, the fish is exposed to both domesticated animals (e.g. cats, chicken and dogs) and wildlife (birds, lizards among others). These animals are known to be important carries of pathogens and other microorganisms [38, 39]. This lead to about 30% loss of fish in landed beaches by microbial flora activities that are of human and verterinary origin supported by environmental contamination [40-42].

Results of this study also depicts the occurrence of *Staphylococcus aureus, Clostridium perfringens* and and *Salmonella* spp as important pathogens recovered from *R. agentea* [43-47]. These indicates poor handling or cross contamination of fish [48-54]. Other studies have also confirmed the occurrence of some of these pathogens in fish sourced from Lake Victoria [55, 56] affirming the level of lake contamination which may be seasonal in regard to stomy weather. The occurrence of such pathogens at both the fish landing site and markets is of public health concern, since the fish products undergo sundrying, before being sold to consumers. The traditional processing of *R. argentea* appears not to be able to eliminate contamination with pathogenic microbes as can be inferred from this study.

The study using antimicrobial resistance patterns demonstrates that contamination at both landing sites and markets may differ. The results show significant differences among the antibiograms observed among markets and landing sites as shown in Table 8. Although these results may present a picture that shows fish being more contaminated at the beaches due to the amount of moisture content, but as the mosture reduces as fish gets to the market, the level of contamination also reduces. The difference in antibiogram patterns could be indicative of possible contamination of fish at the markets attributable to wild life, domesticated animals, insects and poor practices by humans handling the products [57].

Together, the presence of antimicrobial resistance among bacteria recovered from *R. argentea* source from markets and fish landing sites is indicative of additional public health

risks. This makes the fish a health risk since this resistance could be passed to human and livestock when the fish product is used for livestock feed formulation.

5. Conclusions

Our study demonstrates that the traditional sundrying of *R. argentea* practiced along Lake Victoria does not arrest bacterial growth but instead provide an enabling environement for them to proliferate and increase in numbers during the drying process. The drying process does not also eliminate pathogenic microbes that may be present in the fish products although the population levels slightly go down a factor that could be attributed to the direct effect of UV light. Practices at the market further compound the situation as consumers are offered products that are not safe. The study findings show that pathogenic microbes and resistance to antimicrobials as important public health risks that can be associated with *R. argentea* consumption.

5.1. Conflict of Interest

The author(s) declare that they have no competing interests.

5.2. Financial Disclosure

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