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Research article

Bacterial diversity, antibiogram and nutritional assessment of cowhide (Ponmo) in Ilishan-Remo central market, Nigeria

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ABSTRACT

The demand for cowhide (ponmo) is currently very high, particularly in Nigeria, due to rising commodity prices, including animal proteins, which has forced a larger percentage of the population who cannot afford meat, chicken, turkey or eggs to rely on other meat products such as "ponmo," "kundi," and "tinko" as an alternative source of protein. This research aims to identify microorganisms associated with ponmo, determine the antibiogram of the isolates, and assess the nutritional value of ponmo marketed in Ilishan-Remo central market. Six ponmo vendors were sampled for Dry White Ponmo (DWP), Wet White Ponmo (WWP), Wet Brown Ponmo (WBP) and Brown Ponmo Water (BPW) and transported in sterile containers to the Laboratory for analysis to determine the microbial load, sensitivity, and proximate analysis using standardized methods. For microbiological analysis, samples were tested in triplicate. All samples analyzed had a high microbial load count (from 1.1×10^6 to 1.4×10^7). The organisms isolated were *Escherichia coli* (34.21 %), *Staphylococcus aureus* (26.31 %), *Klebsiella* spp. (18.42 %), *Pseudomonas* spp. (13.15 %) and Coagulase-negative staphylococci (7.89 %). All the isolates were multidrug-resistant (MDR). Septrin had the highest resistivity (86.84 %) while gentamicin had the lowest resistance (7.89 %). Pefloxacin sensitivity was observed in 37 of the 38 isolates (97.37 % sensitivity). Ciprofloxacin and gentamicin came second and third (84.2 % and 73.68 % sensitivity) respectively. According to the proximate analysis, the WWP has more protein, fat, and fiber, whereas the WBP has more moisture. Food handlers should follow Good Hygiene Practices and take a Food Handlers Test regularly.

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1. Introduction

Animal hides, popularly known as "ponmo" in Yoruba, "Kanda" in Hausa, and "Welle" in Ghana is popular and widely consumed in West Africa and West Africa enclaves of Europe such as in the UK [1]. It is an indigenous delicacy loved and enjoyed by all economic classes and tribes in Nigeria. It is a delicious part of beef used as a condiment for preparation of soups, stew, various vegetables, sauces, snacks to finger food. Ponmo is widely believed to contain little or no nutritional value, however, recent reports suggest ponmo may be rich in fiber, collagen, carbohydrate as well as protein (although, deficient in some essential amino acids), calories, certain vitamins and low in cholesterol [[2,3]].

Meat and dairy products are important parts of the human diet because they are very good sources of protein, vitamins, and amino acids as they nourish the body cells, repair body tissues and promote growth [4]. However, the high nutritional qualities of meat and dairy products make them to be highly perishable and an ideal culture medium for the growth of spoilage microorganisms. Therefore, several means of preservation are been employed to increase and improve the shelf life of meat and other meat products.

Globally, the major means of preservation is by thermal processing, freezing and/or refrigerating. However, traditional methods such as boiling, frying, drying, grilling and smoking are used for the preservation of meat produce especially in rural areas of low and middle-income countries, due to inconsistence and epileptic power supply. Commonly preserved meat and meat product in Nigeria include Tinko, Kundi or Banda (sun-dried meat of cow, donkey, horse or camel), Kilishi (smoked-dried cow meat), and Ponmo - a by-product of slaughtered animals which is originally meant for leather works and production such as bags, shoes, belt etc. [5] is obtained by tenderization of hide in hot water. It could either be white or brown depending on the method of dehairing which is either by shaving with a razor, knife, or other sharps (white ponmo) or singeing (brown ponmo) method [[6,7]].

Traditionally, dried meat microbiology has involved a natural development of wild fermentation in which microbial successions occur; however, homogeneous salting over the entire surface is most important to suppress pathogens and spoilage organisms [8]. Meat and meat products, on the other hand, provide an ideal environment for pathogenic microorganisms including *Listeria monocytogenes, Salmonella* spp., *Campylobacter* spp., and verotoxigenic *Escherichia coli* to thrive, posing the largest risk of meat-borne diseases [[6,9]]. Due to the presence of foodborne pathogens, dried foods, especially meat products, have been increasingly documented to be involved in outbreaks and recalls [10]. In 2019, the National Agency for Food and Drugs Administration and Control (NAFDAC) raised concern over possible chemical contamination of hides and skin which poses a serious health risk to consumers and therefore warned against the consumption of animal skin [11]. In February 2022, they also raised alarm over the circulation of contaminated ponmo in Lagos, Nigeria [12].

Foodborne bacterial pathogen contamination could have occurred during primary production (particularly antibiotic-resistant pathogens) as a result of on-farm drug misuse, as well as during and after harvest - handling, processing, storage, and transportation. Antibiotic overuse in food-producing animals has been associated with the development of antimicrobial-resistant organisms, which can spread from animals to humans via direct contact or through ingestion of contaminated food and meat products when infections are carried down the food chain and into the environment [13].

Antibiotic usage is a crucial factor in antimicrobial resistance development. Antibiotics are widely utilized in agriculture, particularly in livestock production and slaughter animals, where little care is paid [14]. To ensure the safety of meat and meat products, foodborne pathogens must be controlled at all stages of the food processing chain, beginning with the farm and continuing through the handling, processing, preservation, and storage of meat and products until they are consumed [13]. Therefore, this study was aimed at the isolation, and identification of microorganisms associated with this meat product, determining the antibiogram of these isolates as well as to evaluate the nutritional content of ponmo sold within Ilishan-Remo.

2. Materials and method

2.1. Study area

This study was carried out in Ilishan-Remo town, located within Irepodun district in Ikenne Local Government Area of Ogun State, within the South-Western political region of Nigeria.

2.2. Sample collection

All six ponmo vendors in Ilishan Central Market at the time this study was conducted were sampled. There was one dry white ponmo (DWP), two wet white ponmo (WWP), and three wet brown ponmo (WBP) sellers, and two of the wet brown ponmo vendors provided ponmo water. Samples were obtained in a sterile container and transported on ice to Babcock University Microbiology Laboratory within 2 h of collection for the commencement of microbiological and proximate analysis.

2.3. Microbiological assay

Twenty-five grams of ponmo samples were weighed into a sterile blender. Two hundred and 25 mL (225 ml) of sterile distilled water were added to the ponmo sample and blended at a speed of 15000 rpm for about 5 min for a smooth consistency to be formed or obtained (this served as the stock solution). One milliliter (1 ml) of the suspension was dispensed into 9 ml sterile peptone water and further diluted serially up to the fifth test tube 10^{-5}. With a sterile pipette, 1 ml of each of the diluent was pipetted into each corresponding Petri dish. Approximately 20 ml of sterilized Nutrient Agar was then poured into the dishes and mixed evenly by gentle

rotation, the agar plate and diluent mixture were then allowed to solidify. The culturing was done in triplicate. Thereafter, the plates were incubated at 37 °C to obtain the viable total count, total bacteria count, total coliform count using the Multiple Tube Fermentation as well as the total heterotrophic count using the pour plate method [15].

2.4. Enumeration of Colony Forming Unit

After 24 h of incubation, the plates were counted. Petri dishes containing between 30 and 300 colonies were selected after counting and recorded as results per dilution. In instances where more than one plate falls within the rank, the average count was taken and expressed as Colony Forming Unit per gram (CFU/g) of cow skin.

2.5. Isolation and identification

Pure cultures were obtained according to the method described by the Clinical and Laboratory Standards Institutes [16], using Nutrient agar, MacConkey agar, Mannitol Salt agar, Cetrimide agar, and Eosin Methylene Blue agar plates were each streaked using a wire loop with inoculum obtained from the prepared ponmo samples and incubated at 37 °C for 24 h. The isolates obtained were observed for morphological and cultural characteristics in each of the cultured media for all the samples, Gram stained for presumptive identification and further subjected to biochemical tests such as Oxidate, Catalase, Coagulase, Hydrogen Sulfite, Urease, Citrate, Methyl Red and Voges Proskauer and confirmed with Bergey's manual [17].

2.6. Antimicrobial susceptibility testing

A suspension of the isolates was prepared and the turbidity of the bacterial suspension was adjusted to 0.5 McFarland standard. One milliliter of the suspension was pipetted into an already prepared Mueller Hinton agar plate and spread evenly using a sterile glass rod. The susceptibility pattern of the isolates was determined using the standard Kirby-Bauer-NCCLS single disc diffusion method [[16,18]] was employed using antibiotic-impregnated discs: ciprofloxacin 5 μg, septrin 25 μg, gentamycin 10 μg, pefloxacin 5 μg, streptomycin 25 μg, ampiclox 30 μg, zinacef 30 μg, amoxicillin 25 μg, rocephin 30 μg, ciprofloxacin 5 μg, erythromycin 15 μg and augmentin 30 μg. The plates were then incubated for 24h at 37 °C. The zones of inhibition were observed and measured in mm. Susceptibility categorization [susceptible (S), intermediate (I) and resistant (R)] was performed according to the Clinical and Laboratory Standards Institute for result interpretation as shown in Table 1 below [16]. The class definitions of antibiotics used were aminoglycosides, cephalosporin, β-lactam, fluoroquinolone/quinolone, nitrobenzene derivatives, sulfur/sulfonamides, and macrolide. Multidrug resistance (MDR) was defined as resistance to three or more antimicrobial classes [19 in 20].

2.7. Proximate analysis

Chemical analysis of the samples was carried out according to the official method of analysis described by the Association of Official Analytical Chemists [21] as follows. All analyses were carried out in duplicate.

2.8. Dry Matter and moisture determination

Two grams of the sample was weighed into a previously weighed crucible. The sample was then oven-dried at 100 °C with measurements taken at regular intervals of between 3 and 4 h and cooled in the desiccator until a constant weight was recorded.

$$\%\ \text{Dry Matter} = \frac{W_3 - W_0}{W_1 - W_0}\ \text{X}\ 100$$

Table 1
Table of interpretation for the determination susceptibility categorization.

ANTIBIOTIC	SENSITIVE	INTERMEDIATE	RESISTANT
Septrin 25 μg	≥16	11–15	≤10
Ciprofloxacin 5 μg	≥26	22–25	≤21
Amoxicillin 25 μg	≥17	15–16	≤14
Gentamycin 10 μg	≥15	13–14	≤12
Pefloxacin 5 μg	≥24	–	≤23
Streptomycin 25 μg	≥15	12–14	≤11
Ampiclox 30 μg	≥15	12–14	≤11
Zinacef 30 μg	≥23	15–22	≤14
Rocephin 30 μg	≥23	15–22	≤14
Erythromycin 15 μg	≥23	14–22	≤13
Augmentin 30 μg	≥18	14–17	≤13

Zone diameter of antimicrobial agents according to CLSI guidelines 2021. Zone diameters are in mm.

$$\% \text{ Moisture} = \frac{W_1 - W_3}{W_1 - W_0} \text{ X } 100$$

Where W_0 is the weight of the empty crucible, W_1; is the weight of the crucible plus sample, and W_3 is the weight of the crucible and oven-dried sample.

2.9. Ash content

Two grams of the sample was weighed into a porcelain crucible and transferred into the muffle furnace set at 550 °C for about 4 h or till it turned to white ash. The crucible and its content were cooled to about 100 °C in air, then to room temperature in a desiccator and weighed. The percentage ash was calculated as shown in the formula below:

$$\% \text{ Ash content} = \frac{W_3 - W_1}{W_2 - W_1} \text{ X } 100$$

Where W_1 is the weight of an empty porcelain crucible, W_2 is the weight of porcelain crucible and sample before burning, and W_3; the weight of porcelain and ash.

2.10. Crude fibre determination

Two grams of the sample was measured into a fiber flask, and 100 ml of 0.255 N H_2SO_4 was added and heated under reflux for 1 h on the heating mantle and then filtered. The residue was resuspended in 100 ml 0.313 N NaOH heated under reflux for another 1 h and filtered. After which, 10 ml acetone was added to dissolve any organic constituent. The residue was washed with about 50 ml hot water on the sieve cloth, transferred into a weighed crucible and then oven-dried at 105 °C overnight. After cooling in a desiccator, it was transferred to the muffle furnace for ashing at 550 °C for 4 h, cooled, and weighed.

$$\% \text{ Fibre} = \frac{W_1 - W_2}{W_0} \text{ X } 100$$

Where; W_1 is oven-dried sample plus crucible; W_2 is the weight of crucible and ash and W_0, weight of the sample.

2.11. Crude protein determination

Determination of crude protein in the sample was by the Kjeldahl method [22] as modified by Barbano and Clark [23] which involves three steps namely: Digestion, Distillation and Titration.

Concentrated H_2SO_4, heat, K_2SO_4 (to raise the boiling point), and a catalyst (e.g., selenium) are used to speed up the digestion of organic material. Any nitrogen in the sample is converted to ammonium sulfate during this process. The ammonium sulfate in the digestate is converted to ammonia, which is distilled out and collected in a receiving flask with sufficient boric acid to generate ammonium borate. The total nitrogen concentration of the sample is then estimated by titrating the leftover boric acid with standard acid and an appropriate end-point indicator. Following the determination of total nitrogen, the determined nitrogen content was converted to crude protein content using a specified conversion factor.

$$\% \text{ Protein} = \frac{(b - a) \text{ X } 0.1 \text{ X } 14.00}{W} \text{ X } 100 \text{ X } \frac{6.25}{W\ 1000}$$

Where W = sample weight (g)
a = volume (ml) of 0.1 N H_2SO_4 used in the blank titration
b = volume (ml) of 0.1 N H_2SO_4 utilized in sample titration.
14.00 = atomic weight of nitrogen.
1000: the conversion of mgN/100 g to gN/100 g sample.
6.25: the protein-nitrogen conversion factor for meat and meat products.

2.12. Crude fat determination (Soxhlet extraction method)

The Soxhlet method is a solvent extraction method that is semicontinuous. In this process, a continuous flow of petroleum ether from a boiling flask is poured over the sample. The sample was completely soaked in the petroleum ether for 10–12 min before being drained back into the boiling flask. The weight of fat loss of the sample is used to determine fat content.

$$\% \text{ Crude fat} = \frac{(W_2 - W_1)}{W_0} \text{ x } 100$$

where W_1 is weight of empty flask; W_2 weight of flask and extracted fat while W_0 is weight of sample.

3. Results

There was a high microbial load count of all the samples analyzed ranging from 1.1 x 10^6 to 1.4 x 10^7 (Table 2). The result of the morphological characteristics and biochemical tests is presented in Table 3. A total of 38 isolates were recovered from the ponmo samples. The organisms isolated were preliminarily identified as *Escherichia coli* (34.21 %), *Staphylococcus aureus* (26.31 %), *Klebsiella* spp. (18.42 %), *Pseudomonas* spp. (13.15 %), Coagulase negative staphylococci (7.89 %) (Table 4). All the organisms isolated from the ponmo samples showed multidrug resistance as all of them were resistant to at least three classes of antibiotics (Table 5). The resistance pattern of the various isolates is shown in Table 6. The highest resistance was observed in septrin with *E. coli*, *Klebsiella* spp., and *Pseudomonas* spp. showing 100 % resistance while 0 % resistance was recorded for pefloxacin and ciprofloxacin. The proximate analysis showed that contrary to popular opinion, that "ponmo" is rich in nutrients such as protein ranging from 16.13 to 36.01, fiber from 0.98 to 1.97, fat ranging from 3.8 to 4.15, and it's also a good source of metabolizable energy (ME) with a range of 3643 kcal–3690 kcal (Table 7).

4. Discussion

Because of its impact on population health, food plays a critical part in the growth and decline of any nation. Consumption of contaminated foods, on the other hand, might result in foodborne infections, which can cause morbidity and fatality. As a result, there has been a widespread understanding of the role of food in the transmission of disease, as well as the need for increased public awareness to establish food safety and quality standards [24]. Meat is high in carbohydrates, which bacteria may use for energy, as well as numerous proteins, which putrefactive bacteria can use for energy. It also has a high-water content, which is necessary for bacteria growth [6]. Meat and its products have high nutritional content and as a result, it has become essential to process and preserve to increase the shelf life, therefore, the evolution of meat products such as kundi, tinko and ponmo. Ponmo is particularly popular due to its availability, affordability, and ease of preparation compared with tinko, kundi, or banda.

The microbial count in this current work was high for all the samples (range between 1.1 x 10^6 in wet white ponmo (WWP) to 1.4 x 10^7 in both brown ponmo water (BPW) and wet brown ponmo (WBP), this result is consistent with [[4,6,24]] who all reported a similar high microbial load as well. The least microbial load obtained in the WWP may be because it is still relatively fresh from the slaughterhouse and has not been exposed to other environmental factors and handling that could have contributed to an increase in the bacterial load. The highest microbial count obtained from BPW and WBP is corroborated with the report of [6] who reported a Total Bacterial Count of 4.1 x 10^5 cfu/g of meat product tissue soaked in water. He also analyzed the effect of the duration of soaking of kundi on microbial load in water and found that the microbial load increased with an increase in the soaking time or duration [6]. This could be as a result of the various processing such as singeing and drying which is usually done in an open area, handling (from the processor to the distributor to wholesaler and finally to the retailer) and transportation of the singe (brown) ponmo.

In this present study, a total of 38 isolates belonging to five (5) bacterial genera were isolated from ponmo. The probable identity of the isolates is: *E. coli, S. aureus, Klebsiella* spp., *Pseudomonas* spp., Coagulase negative staphylococci (34.21; 26.31 %; 18.42 %; 13.15 %; 7.89 % respectively). This is similar to the studies of [4,24] who isolated *Staphylococcus epidermis, Staphylococcus aureus, Bacillus subtilis, Streptococcus mitis, Escherichia coli, Micrococcus leteus, Salmonella typhimorium* and *Shigella dysenteriae* from both processed and unprocessed ponmo in Ogbese market, Ondo and *Bacillus* spp., *Pseudomonas aeruginosa, Staphylococcus aureus, Escherichia coli Shigella dysenteriae, Salmonella* spp., *Klebsiella* spp. and *Shigella* spp., from fresh cow hide in Birnin Kebbi, Kebbi respectively. The difference in the isolated bacteria may be due to environmental factors because of the different locations and the type of cowhide used in the studies.

Bacterial contamination of meat and meat products has been frequently reported from around the world [[25,26]]. The presence of these bacteria could be owing to a lack of sufficient quality control methods in meat handling and processing. Unhygienic meat processing techniques, such as talking, coughing, and sneezing on the meat, have been documented as sources of contamination [[27–29]]. In all the studies reported and in this present one, *E. coli* happens to have the highest bacterial prevalence and this should speak volumes about the hygiene of the food handlers. The presence of *E. coli* in the food sample is an indication of a faecal contaminant which also is an indicator that more pathogenic organisms may be present in the sample.

Generally, the Gram-negative isolates in this study were more resistant to the antibiotics tested than the Gram-positives. This may be because of the inherent nature of their cell wall. The highest resistivity was recorded with septrin (86.84 %) followed by

Table 2
Microbiological load count of ponmo sold Ilishan market.

Sample	Plate 1	Plate 2	Plate 3	Dilution Factor	Mean Plate Count	CFU/ml
DWP	172	92	128	10^5	131 ± 40.10	1.31 x 10^7
WWP1	66	163	72	10^4	108 ± 54.25	1.08 x 10^6
WWP2	66	160	70	10^5	99 ± 53.15	9.9 x 10^6
WBP1	115	146	103	10^5	121 ± 22.19	1.21 x 10^7
WBP2	125	112	112	10^5	116 ± 7.51	1.16 x 10^7
WBP3	123	164	128	10^5	138 ± 22.37	1.38 x 10^7
BPW1	60	60	40	10^5	53 ± 11.55	5.3 x 10^6
BPW2	123	164	131	10^5	139 ± 21.73	1.39 x 10^7

Key:DWP – Dry White Ponmo; WWP – Wet White Ponmo; WBP – Wet Brown Ponmo; BPW – Brown Ponmo Water; 1 – Vendor one; 2 – Vendor two; 3 – Vendor three.

Table 3
Microscopic characteristics and biochemical reaction of bacterial isolates from ponmo.

GRT	ARN	CAT	COA	OXI	URS	CIT	MR/VP	H_2S	Suspected Organisms
+ cocci	cluster	+	–	–	+	–	–/+	+	Coagulase-ve staphylococci
+ cocci	cluster	+	+	–	+	+	+/+	–	*Staphylococcus aureus*
- rod	short chains	+	–	–	–	+	+/–	–	*Escherichia coli*
- rod	pairs	+	–	+	–	+	–/–	–	*Pseudomonas* spp.
- rod	short chains	+	–	–	+	+	–/+	–	*Klebsiella* spp.

KEY.
+ = positive, - = negative,GRT = Gram reaction, ARN = arrangement, CAT = catalase, COA = coagulase, OXI = oxidase, URS = Urease, CIT = Citrate, MR = methyl red, VP=Voges Proskauer, H_2S = Hydrogen sulfite.

Table 4
Microbial diversity and prevalence of bacterial isolates from ponmo samples.

Bacterial Isolates	Frequency (n)	Prevalence (%)
E. coli	13	34.21
S. aureus	10	26.31
Klebsiella spp	7	18.42
Psuedomonas spp	5	13.15
Coagulase -ve staphylococci	3	7.89
Total	38	100

Key: ve = negative.

Table 5
Susceptibility pattern of the bacterial isolates from ponmo.

antibiotics	Sensitive		Ntermediate		Resistant	
	No of isolate	Percentage	No of isolate	Percentage	No of isolate	Percentage
Septrin 25 μg	0	0.0	5	13.16	33	86.84
Ciprofloxacin 5 μg	32	84.2	6	15.8	0	0.0
Amoxicillin 25 μg	8	21.1	14	36 8	16	42.1
Gentamycin 10 μg	28	73.68	7	18.42	3	7.89
Pefloxacin 5 μg	37	97.37	1	2.63	0	0.0
Streptomycin 25 μg	10	26.32	0	0.0	28	73.68
Ampiclox 30 μg	5	13.16	5	13.16	28	73.68
Zinacef 30 μg	12	31.56	19	50.0	7	18.42
Rocephin 30 μg	5	13.16	5	13.16	28	73.68
Erythromycin 15 μg	5	13.16	19	50.0	14	36.82
Augmentin 30 μg	0	0.0	19	50.0	19	50.0

Table 6
Resistance Pattern (% resistance) of various Isolates.

Antibiotics tested/Isolates	*E. coli* (13)	*S. aureus* (10)	*Klebsiella* spp. (7)	*Psuedomonas* spp. (5)	Coagulase -ve staphylococci (3)
Septrin	13 (100 %)	8 (80 %)	7 (100 %)	5 (100 %)	2 (66.6 %)
Ciprofloxacin	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)
Amoxicillin	5 (38.4 %)	3 (30 %)	4 (57.1 %)	3 (60 %)	1 (33.3 %)
Gentamycin	1 (7.69 %)	0 (0 %)	1 (14.2 %)	1 (20 %)	0 (0 %)
Pefloxacin	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)
Streptomycin	10 (76.9 %)	5 (50 %)	6 (85.7 %)	5 (100 %)	2 (66.6 %)
Ampiclox	9 (69.2 %)	4 (40 %)	7 (100 %)	5 (100 %)	3 (100 %)
Zinacef	2 (15.3 %)	1 (10 %)	2 (28.5 %)	2 (40 %)	0 (0 %)
Rocephin	10 (76.9 %)	5 (50 %)	6 (85.7 %)	5 (100 %)	2 (66.6 %)
Erythromycin	5 (38.4 %)	1 (10 %)	4 (57.1 %)	4 (80 %)	0 (0 %)
Augmentin	8 (61.5 %)	3 (30 %)	4 (57.1 %)	3 (60 %)	1 (33.3 %)

streptomycin, ampiclox, and rosephin (73.68 % each). The least resistance was observed in gentamicin (7.89 %) followed by zinacef (18.42 %). Almost all the isolates (37 of 38) were susceptible to pefloxacin (97.37 % sensitivity) followed by ciprofloxacin and gentamicin (84.2 % and 73.68 %) respectively. The Gram-negative organisms were susceptible to ciprofloxacin and pefloxacin. *Staphylococcus aureus* showed resistance to augmentin, gentamycin, and ampiclox. This report is similar to Ref. [4] who observed a similar pattern.

The result of the proximate analysis shows that the WWP (36.01 %) is richer in protein than the WBP and DWP (16.13 % each). This

Table 7
Nutrient composition/nutritional value of ponmo in Ilishan market.

Nutrient	Value/Sample		
	WBP	DWP	WWP
(%) Crude protein	16.13 ± 0.02^{a}	16.13 ± 0.01^{a}	36.01 ± 0.00^{b}
(%) Ash	1.98 ± 0.01^{a}	2.01 ± 0.02^{ab}	2.04 ± 0.02^{c}
(%) Ether Extract	3.80 ± 0.06^{a}	3.90 ± 0.03^{b}	4.15 ± 0.01^{c}
(%) Crude Fibre	1.02 ± 0.02^{b}	0.98 ± 0.01^{a}	1.97 ± 0.02^{c}
(%) Moisture content	68.73 ± 0.03^{c}	18.63 ± 1.15^{a}	29.12 ± 0.02^{b}
(%) Dry Matter	31.27 ± 0.01^{a}	81.37 ± 0.04^{c}	70.88 ± 0.04^{b}
ME (Kcal/kg)	3690.78 ± 0.02^{c}	3648.63 ± 0.03^{b}	3643.10 ± 0.05^{a}

Values are means of triplicate determination ± SD.
Mean with different superscript letters within the same column are significantly different ($P < 0.05$). The probability value is ($P \leq 0.05$).
Key: ME = Metabolizable Energy.

may be because it was fresh and usually contained some meat layer known as “Agemawo”. It can also be a result of the heating process of singeing, frying, and drying employed in the processing of the brown and dry white ponmo samples as it is a general knowledge that heat denatures protein. Whereas the moisture content of the WBP was higher than the WWP and DWP, the ash content, fat as well as fibre content values were higher in the WWP when compared with the other two samples. The process of frying may account for the observed difference in the moisture content of the DWP which caused the collagen fibre to shrink and lose more moisture while the high moisture recorded for the WBP could have resulted from the soaking which allowed it to absorb more moisture and weight gain than WWP. This result is consistent with the study of [30] who analyzed the proximate composition of white-scaled ponmo and black-singed ponmo and reported that the white ponmo shows significantly high nutrient value for all the parameters (moisture, energy, protein, and ash) tested or analyzed. However, there was no difference in the energy value for all the samples analyzed in this study. This is contrary to Ref. [30] who reported a significant higher energy value for white ponmo.

5. Conclusion and recommendation

Contrary to the insinuation that ponmo does not contain any nutritional value, this study has been able to demonstrate and show that ponmo actually contains specific nutrient and these nutrients varies depending on the type of ponmo. The wet white ponmo in this case contain the highest nutritional value (fiber, protein and fat). However, all types may serve as a good source of energy. In this present study, both the ponmo and the water used in soaking it had the highest bacterial count. Thus, it is advisable that ponmo vendors change the water they use for soaking at regular intervals to reduce the bacterial count. Furthermore, the presence of *E. coli* indicates possible faecal contamination, therefore, both the processor, handler, and vendors along the food chain are strongly advised to ensure and practice Good Hygiene Practices (GHPs) and go for regular Food Handlers tests. Finally, further study on molecular screening of the isolated organisms is advised for the definitive identity of the organisms.

Data availability statement

Data associated with this study has not been deposited into any publicly available repository but will be made available on request.

CRediT authorship contribution statement

Mensah-Agyei Grace Oluwatoyin: Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Conceptualization. **Adaramola Feyisara Banji:** Writing – review & editing, Validation, Supervision, Project administration, Methodology. **Akpan Nevillah Nice:** Investigation. **Egbeobawaye Jennifer Orobosa:** Investigation. **Akeredolu Abosede Abolanle:** Resources. **Enitan Seyi Samson:** Writing – review & editing. **Ajibade Oluwatosin:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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