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Susceptibility of human microbes to the peel extracts of three species of peanut and their preservative characteristics on some highly perishable fruits and vegetables

Abstract

Background: Peanuts are crucial leguminous crops with global recognition in agricultural, dietary, and medicinal importance. The continuous attention drawn to antimicrobial resistance, and post-harvest losses raises research interests to explore natural alternatives to combat antimicrobial resistance and promote preservation of foods for longer shelf life. For these reasons, we evaluated the antimicrobial and preservative characteristics of three varieties of peanut peel extracts (PPEs).

Methods: 0.5 grams of the PPEs were each soaked in 50 ml of sterile distilled water for 24, 48 and 72 hours. Five concentrations (0.8, 0.85, 0.9, 0.95 and 1%) of the extracts were reacted with *E. coli, S. aureus, S. typhi and K. pneumoniae*, by ascertaining the zones of inhibition, minimum inhibitory and minimum bactericidal concentrations. Also fruits (orange, banana, grape and apple) and vegetables (scotch bonnet pepper, tomato, onion and carrot) were subjected to the extracts for seven days for shelf-life assessment.

Results: The Spanish variety, at the concentration of 1%, inhibited *K. pneumoniae* with a zone of 0.33±0.06 cm, followed by *S. typhi* (0.27±0.08 cm), *S. aureus* (0.15±0.17 cm), and *E. coli* (0.08±0.06 cm). The 0.8% showed no inhibition of *E. coli* and *S. typhi*. The Valencia variety showed the highest inhibition for *K. pneumoniae* at 1% (0.52±0.06 cm). Interestingly, its 0.8% concentration recorded a zone of 0.25±0.09 cm against *E. coli.* Moreover, the Virginia variety inhibited *K. pneumoniae* at 1% (0.53±0.08 cm) and against *S. aureus* at 0.95% (0.33±0.03 cm), while *S. typhi* was modestly inhibited at 0.95% (0.53±0.03 cm). There was no significant difference between the concentrations i.e. $p>0.05$ Furthermore, apple and onion were the most preserved and banana, the least preserved by the Spanish variety. This trend was observed in all the varieties and concentrations, with no significant difference between them ($p>0.05$).

Conclusion: The three PPEs exhibited both antimicrobial and preservative characteristics at varying degrees of efficacy especially with the 72 hours soak duration and can therefore be employed against microbial resistance, and as natural preservatives for fruits and vegetables.

Keywords: Spanish, Valencia, *Virginia cultivar, E. coli, S. aureus, K. pneumonia, S. typhi,* antimicrobial, preservative, susceptibility

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George Aboagye,[1] Sandra K. Enninful,[1] Diana A. Aborgah,[1] Elodie A. Asobayire,[1] Rebecca K. Steele-Dadzie[2]

[1]Department of Nutrition and Dietetics, School of Allied Health Sciences, University of Health and Allied Sciences, Ho, Ghana
[2]Department of Dietetics, School of Biomedical and Allied Health Sciences, University of Ghana, Accra, Ghana

Correspondence: George Aboagye, Department of Nutrition and Dietetics, School of Allied Health Sciences, University of Health and Allied Sciences, Ghana, Tel +233202993078, Email gaboagye@uhas.edu.gh

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Introduction

Arachis hypogea L. commonly known as peanut, monkey nut, or goober is a leguminous crop belonging to the family of Faboideae. It is interesting to note that peanuts play a crucial role in global agriculture, securing the second spot in production in India and contributing significantly to the world's peanut output, with China at the forefront.[1] They are not only widely consumed but also serve as a crucial dietary source, especially in challenging conditions faced during expeditions in various African countries (Figure 1).

Figure 1 Pictorial presentation of the peanut varieties.

Apart from their ability to fight off harmful micro-organisms, peanut peels also have a lot of nutritional value. They are rich in dietary fiber, protein, carbohydrates, fats, vitamins, and minerals, and their high phenolic content and antioxidant capacity make them a valuable nutritional by-product. These nutritional attributes, coupled with documented health benefits, position peanut peels as promising sources of natural antimicrobial agents and other health-promoting products.[2]

Recently, the medicinal properties of the outer peel of peanuts are being explored due to the bioactive compounds they contain, which have antimicrobial properties as acknowledged in various studies.[2-4] Others have also indicated that peanut peel extracts may combat common pathogens such as *E. coli* and *S. aureus*.

Peanut peel has several potential pharmacological properties ranging from antioxidants, anti-inflammatory, anti-bacterial, anti-viral, anti-fungal, anti-cancer and anti-cardiovascular among others.[3]

Furthermore, peanuts have a global presence and are a vital source of income for roughly 90% of families involved in peanut farming, especially in the northern region of Ghana.[5,6] The investigation of raw peanut peel extract for its antimicrobial and preservative benefits is fueled by the need to tackle the challenges posed by antibiotic resistant bacteria and postharvest losses of perishable crops.

Natural products have played a crucial role in drug discovery, with around 61% of new drugs between 1981 and 2002 being derived from them. These products have been particularly effective in treating infectious diseases and cancer.[7] However, the discovery of novel chemical entities has been declining in recent times.[8]

Countries in West Africa including Ghana have been grappling with the challenge of chemical preservatives in the food industry, as revealed by several studies.[9,10] In this regard, the use of raw peanut peel extract as an antimicrobial agent with preservative properties is being explored.

By evaluating the antimicrobial properties of the three varieties of raw peanut peel extracts, this work aimed to contribute to the development of natural antimicrobial agents for enhanced pharmacological uses in Ghana and beyond which could be a promising solution for combating microbial resistance to drugs. Furthermore, it unravelled the application of peanut peel extracts in food preservation to enhance the sensory shelf life of perishable products such as fruits and vegetables for effective post-harvest management and control, as well as promising outcomes against potential side effects posed by pharmaceutical-grade formulations used for similar purposes. Thus, the extracts could be a healthier alternative to chemical preservatives, which have raised concerns about their impact on public health due to their unsafe levels in food products. Invariably, the adoption of the research findings would significantly reduce the risk of food contamination and associated illnesses in Ghana and aligns with broader efforts to enhance food safety practices.

Methodology

Study design

This was an experimental study that employed an empirical survey to comparatively analyse the antimicrobial and preservative characteristics of three varieties of raw peanut peel extracts on human microbial pathogens and selected perishable fruits and vegetables respectively.

Study site

The study was conducted in the University of Health and Allied Sciences Microbiology Laboratory in Ho, the capital city of the Volta region of Ghana.

Subject/study population

The PPEs included Virginia cultivar, Valencia and Spanish varieties.

Inclusion criteria

The PPEs were obtained only from three varieties of peanuts i.e., Virginia cultivar, Valencia and Spanish. Peanuts that showed signs of spoilage, cracks or damage were excluded following a thorough visual inspection.

Fruits and vegetables used showed no signs of spoilage, no damage and no bad odours.

Sample size determination

Three varieties of the peanuts were used in triplicates on four microbial isolates for a total of three days representing the entire period of sampling aliquots of the PPEs. Therefore, a total of 3 varieties x 3 replicates x 5 concentrations × 4 micro-organisms = 180.

However, 60 fruits and vegetables each were used against five concentrations of 72 hours PPEs, and four fruits and vegetables each were used as control.

Sample collection

The peanuts used in this study were obtained from the Ho Central Market, 6.6200' N, 0.4728' E, in the Volta Region of Ghana.

Extraction of the extract from the peanut peels

0.5 grams each of the three varieties of the peanut were weighed into 50 ml of sterile distilled water in triplicates in sequence up to the last day of the three days i.e. 24, 48 and 72 hours respectively. The liquid extracts were drained from the peanuts before being used for the antimicrobial and preservative assays (Figure 2).

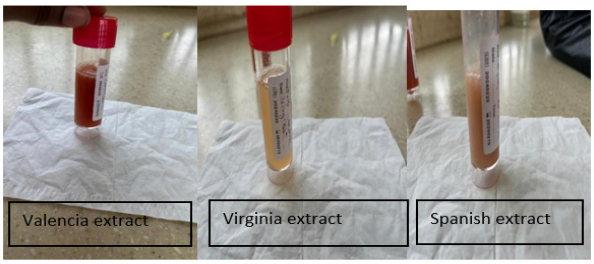

Figure 2 A photograph of the various PPEs.

Sterilization of materials

Sterilisation of the glasswares for microbial tests and other processes requiring sterile reagents was performed by autoclaving at 121°C for 15 minutes.

Culture media

The media used were products of Oxoid and HiMedia laboratories. They included Mueller-Hinton Agar (OXOID CM0337, UK) for supporting the growth of the various micro-organisms, and Mueller-Hinton broth (OXOID TM1577, UK) for culturing the micro-organisms. Peptone water (HiMedia rm001, India) was used to revive the micro-organisms. The media were prepared according to the manufacturer's instruction with sterilisation at 121°C for 15 minutes. The workbench was continuously kept in an aseptic condition by initial cleaning with 70% ethanol (v/v), followed by continuous flame from a Bunsen burner.

The Mueller-Hinton agar was prepared by suspending 38 g in 1 litre sterile distilled water and heating to boil and dissolve completely. It was sterilised in an autoclave at 121°C for 15 minutes in a sealed glass bottle and allowed to cool in a water bath at 50°C before use. The Mueller-Hinton broth was prepared by suspending 21 g in 1 litre sterile distilled water and heating to dissolve completely. It was then sterilised in an autoclave at 121°C for 15 minutes in a sealed glass bottle, and allowed to cool in a water bath at 50°C before use. The peptone water was prepared by suspending 11 g of the powder in 1 litre of sterile distilled water and heating to dissolve completely. It was sterilised in an autoclave at 121°C for 15 minutes in a sealed glass bottle and allowed to cool in a water bath at 50°C before use.

Sub-culturing of the microbial isolates

The microbial isolates i.e. *E. coli, S. typhi, K. pneumoniae, and S. aureus,* were used based on their clinical importance. The isolates were obtained from the Microbiology Department at the Ho Teaching Hospital in Ghana. The isolates were used to evaluate the antimicrobial activity of the PPEs. Freshly cultured bacteria were inoculated in 5 ml of sterile nutrient broth in test tubes for 24 hours at 37°C. The bacterial stock cultures were revived using peptone water, and were grown on Mueller-Hinton agar plates at 37°C and the stock cultures were maintained at 4°C.

Antimicrobial bioassay

The antimicrobial efficacy assay of peanut peel extracts against the four clinical isolates were investigated *in vitro*, using the agar well diffusion and test tube dilution methods.

Agar well diffusion method

This method was adopted and modified from.[14] A set of five concentrations (0.8, 0.85, 0.9, 0.95 and 1%) of the PPEs were prepared from days 1 to 3 in triplicates for the assay. Mueller-Hinton sterile agar was mixed with 1 ml of serial dilution 10^{-4} of a 24-hour exponential growth phase of the bacterial culture using the pour plate method. A cork borer (diameter 0.8 cm) was flamed and used to bore 3 wells representing the triplicates for one peanut extract from days 1 to 3 from the 0.8 to 1% concentrations of the peanut extract. Afterwards, the plates were checked for zones of inhibition using a vernier caliper and a meter rule and followed by the minimum inhibitory and bactericidal concentration determinations.

The dilution tube method

This method was adopted and modified from.[14] The Minimal Inhibitory Concentration (MIC) refers to the in-vitro level of susceptibility or resistance of specific bacterial strains to antibiotics applied, and the Minimum Bactericidal Concentration (MBC) is the lowest concentration of an antibacterial agent, that is required to kill a bacterium over a fixed, somewhat extended duration, such as 18 or 24 hours, under a specific set of conditions. Nine millilitres of Mueller-Hinton broth was inoculated with 100 µl each of the microbial culture and 0.8-1% of the PPEs, followed by incubation at 37°C for 24 hours. One millilitre of the broth was reintroduced following no turbidity.

Preservative potential of the PPEs

A set of five concentrations of the PPEs were prepared for only the 72 hours of the 3 peanut varieties which exhibited inhibition against the microbial isolates. Four each of the fruits and vegetables were immersed in the various concentrations and allowed to dry (Figure 3). After one week of the application of the PPEs, they were assessed for spoilage using organoleptic characterisation to determine the preservative properties of the extracts (Figure 4).

Figure 3 The fruits and vegetables immersed in the 72-hour PPEs and dried.

Data analysis

One-way Analysis of Variance was used to compare the mean inhibition zones of the different organisms. The statistical tools used were Microsoft Excel v16 and Minitab v21.

Ethical issues/consideration

Ethical clearance was sought from the University of Health and Allied Sciences Research Ethics Committee (UHAS-REC) and approval was given with the protocol identification number UHAS-REC A.10 [223] 23-24.

Results

Zone of inhibition

The three peanut peels obtained from the Spanish, Valencia, and Virginia varieties were assessed against four bacterial strains: *E. coli*, *S. aureus*, *K. pneumoniae,* and *S. typhi* incubated for 24, 48 and 72 hours duration of the PPEs.

There were no zones of inhibition recorded for the 24 and 48 hours for all the peanut varieties. However, the 72-hour duration of the three PPE varieties recorded zones of inhibition which are presented in the order of 1, 0.95, 0.9, 0.85 and 0.8% as the mean zone of inhibition ± standard deviation as shown in Table 1 below.

Table 1 The zones of inhibition exhibited by the 72-hour PPEs against the four isolates

	Zone of inhibition (mean ± standard deviation) in cm			
72-hour PPE and concentration (%)	***E. coli***	***S. aureus***	***K. pneumoniae***	***S. typhi***
Spanish				
1	0.08 ± 0.06	0.15 ± 0.17	0.33 ± 0.06	0.27 ± 0.08
0.95	0.05 ± 0.00	0.08 ± 0.06	0.18 ± 0.08	0.15 ± 0.09
0.9	0.05 ± 0.00	0.25 ± 0.05	0.33 ± 0.03	0.23 ± 0.07
0.85	0.00 ± 0.00	0.18 ± 0.03	0.20 ± 0.05	0.00 ± 0.00
0.8	0.00 ± 0.00	0.17 ± 0.08	0.40 ± 0.26	0.08 ± 0.06
Valencia				
1	0.00 ± 0.00	0.25 ± 0.05	0.52 ± 0.06	0.22 ± 0.06
0.95	0.00 ± 0.00	0.22 ± 0.03	0.38 ± 0.06	0.25 ± 0.09
0.9	0.00 ± 0.00	0.18 ± 0.03	0.30 ± 0.10	0.28 ± 0.19
0.85	0.00 ± 0.00	0.07 ± 0.03	0.32 ± 0.08	0.18 ± 0.03
0.8	0.25 ± 0.09	0.08 ± 0.06	0.00 ± 0.00	0.12 ± 0.03
Virginia				
1	0.00 ± 0.00	0.27 ± 0.10	0.53 ± 0.08	0.23 ± 0.03
0.95	0.00 ± 0.00	0.33 ± 0.03	0.47 ± 0.18	0.53 ± 0.03
0.9	0.00 ± 0.00	0.32 ± 0.10	0.45 ± 0.13	0.23 ± 0.10
0.85	0.00 ± 0.00	0.23 ± 0.03	0.23 ± 0.03	0.23 ± 0.08
0.8	0.00 ± 0.00	0.09 ± 0.09	0.17 ± 0.03	0.07 ± 0.03

For the Spanish PPE, at the highest concentration of 1% exhibited the largest inhibition zone (0.33±0.06 cm) against *K. pneumoniae*, followed by *S. typhi* (0.27±0.08 cm), *S. aureus* (0.15±0.17 cm), and *E. coli* (0.08±0.06 cm). Lower concentrations resulted in varying degrees of inhibition, with the 0.8% showing no inhibition for *E. coli* and *S. typhi*. The Valencia PPE showed similar trends, with the highest inhibition observed for *K. pneumoniae* at 1% concentration (0.52±0.06 cm). Interestingly, at the 0.8% concentration, *E. coli* showed a measurable inhibition zone (0.25±0.09 cm), unlike the

other concentrations where no inhibition was observed. The Virginia PPE demonstrated significant inhibition against *K. pneumoniae* at 1% concentration (0.53±0.08 cm) and against *S. aureus* at 0.95% concentration (0.33±0.03 cm). Inhibition of *E. coli* was absent across all concentrations, while *S. typhi* was modestly inhibited, with the highest zone of inhibition at 0.95% concentration (0.53±0.03 cm). There was no statistical difference between the concentrations i.e. $p>0.05$.

Using an organoleptic test scale, the preservative potential of the PPEs on selected fruits and vegetables was ascertained (Figure 4).

Figure 4 The fruits and vegetables 7 days post-immersion in the PPEs.

As observed in Figure 4 above, the apple and onion were the most preserved across all the concentrations of the PPEs. Therefore, their organoleptic properties were maintained. In contrast, the banana was the least preserved across all the concentrations. This trend was seen among all the varieties and concentrations as presented in Table 2 below using the Hedonic scale. There was no significant difference between the concentrations i.e. $p>0.05$.

Table 2 Organoleptic properties of the PPEs-treated fruits and vegetables using the hedonic scale

72-hour PPE and concentration (%) with fruit/vegetable	Appearance	Texture	Taste	Smell	Overall acceptability
Apple					
Virginia					
1	5±0	5 ±0	5 ±0	5±0	5±0
0.95	5±0	5±0	5±0	5±0	5±0
0.9	3.33±0.47	3.67±0.47	5±0	4.67±0.47	4±0.82
0.85	4±0	4.67±0	4.67±0.47	4.33±0.47	4.67±0.47
0.8	4.67 ±0.47	5±0	5±0	4.67±0.47	4.67±0.47
Valencia					
1	5±0	5 ±0	5±0	5±5	5±0
0.95	5 ±0	5±0	5±0	5±5	5±0
0.9	3.67 ±0.47	3.67±0.47	3.67±0.47	5±4.33	3.67±0.15
0.85	4.33 ±0.47	4.67±0.47	4.67 ±0.47	5±5	4.67±0.15
0.8	4.67±0.47	4.67±0	4.67 ±0	5±4.67	4.67±0.15
Spanish					
1	1±0	1.33±0.47	1±0.94	2.33±0.47	1.67±0.47
0.95	3±0	3.33±0.47	2.67±0.47	2.67±0.47	2.67±0.47
0.9	4±0	3.67±0.47	4±0.47	4.33±0.47	3.67±0.47
0.85	4.67±0.47	4.33±0.47	5±0.94	4±0	4±0
0.8	5±0	5±0	5±0.94	5±0	5±0
Banana					
Spanish					
1	1±0	1±0	1±0	1±0	1±0
0.95	1±0	1±0	1±0	1±0	1±0
0.9	1±0	1±0	1±0	1±0	1±0
0.85	1±0	1±0	1±0	1±0	1±0
0.8	1±0	1±0	1±0	1±0	1±0
Valencia					
1	1±0	1±0	1±0	1±0	1±0
0.95	1±0	1±0	1±0	1±0	1±0

Table 2 Continued.....

0.9	1±0	1±0	1±0	1±0	1±0
0.85	1±0	1±0	1±0	1±0	1±0
0.8	1±0	1±0	1±0	1±0	1±0
Virginia					
1	1±0	1±0	1±0	1±0	1±0
0.95	1±0	1±0	1±0	1±0	1±0
0.9	1±0	1±0	1±0	1±0	1±0
0.85	1±0	1±0	1±0	1±0	1±0
0.8	1±0	1±0	1±0	1±0	1±0
Grapes					
Spanish					
1	5±0	4±0	4.67±0.82	4.67±0.47	4.33± 0.47
0.95	5±0	4.33±0.94	4.67±0.82	4.67±0.47	4.33± 0.47
0.9	5±0	4±0.82	3.67±0.47	4±0.82	4.67± 4.67
0.85	5±0	4.67±0.47	3.67±0.47	4.67±0.47	4.33± 0.47
0.8	5±0	3.67±0.47	4.3±0.82	4.67±0.47	4.33± 0.47
Valencia					
1	5 ±0.2	4.67±0	4.67±0.47	5±0	4.67±0.42
0.95	5±0.2	4±0.82	4±0.82	5±0	4.33 ±0.42
0.9	5±0.3	4.67±0.47	4.67 ±0.47	4.67±0.47	4.67 ±0.16
0.85	4.33±0.47	4 ±0.47	4 ±0	5 ±0	4 ±0.82
0.8	3.67±0.47	3.67±0.47	3.67 ±0.47	5±0	4.67±0.16
Virginia					
1	4 ±0.2	4±0.3	4±0.47	4±0.2	4.33±0.47
0.95	4.33±0.4	4±0.47	4±0.47	4±0.3	4±0.82
0.9	3.67±0.47	4±0.82	4±0.2	4±0.47	4±0.2
0.85	4.67 ±047	4±0.3	4±0.94	4±0.47	4.33±.47
0.8	4.33 ±0.47	4±0.47	4±0.47	4±0.47	4±0.36
Orange					
Spanish					
1	3.67±0.47	3±0	3.67±0.47	3.33±0.94	3.67±0.47
0.95	3.33±0.47	2.67±0.47	3.33±0.74	4±0	3.67±0.47
0.9	4±0	3.67±0.47	3±0.47	3.67±0.47	3.33±0.47
0.85	4±0	3±0.82	3±0.47	4.33±0.47	4±0.82
0.8	4±0	3.67±0.47	3.33±0.82	4±0.82	4±0.82
Valencia					
1	4.33±0.47	3.67±3.67	3.67±0.47	4.33±0.47	4±0
0.95	4.33 ±0.47	3±3	3 ±0	3.33±0.47	3.67±0.42
0.9	4.33 ±0.47	3±3	3±0	3.67±0.47	3±0.47
0.85	3 ±0.82	2.33±2.33	2.33±0.47	4.67±0.47	3.33±0.83
0.8	4±0	2±2	2±0	3.33±0.94	3±0
Virginia					
1	4.33 ± 0.47	0±0.47	0 ±0.47	0 ±0.47	3.67 ±0.47
0.95	3.67±0.47	0±0.83	0 ±0.47	0 ±0.47	3.67 ±0.47
0.9	3.67±0.47	0±0.82	0 ±0.47	0 ±0.47	3.33±0.47
0.85	4.67 ±0.81	0±0.47	0 ±0.82	0 ±0.47	3.33±0.94
0.8	4±0.82	0±0.82	0 ±0.47	0 ±0.47	3±0.82
Carrot					
Spanish					
1	1.33±0.47	1.67±0.47	1±0	2±0.82	2.33±0.47
0.95	2±0	1.67±0.47	1±0	3±0	2.67±0.47
0.9	2.67±0.47	1.67±0.47	1±0	2.67±0.47	2.33±0.47
0.85	2.33±0.47	2.33±0.47	1±0	2.33±0.47	2±0.47
0.8	1±0	1.33±0.47	1±0	2.67±0.47	2.67±0
Valencia					
1	2±0	1.33±0.47	1.33±0.47	2.67±0.47	2±0

Table 2 Continued.....

0.95	2±0	1 ±0.47	1±0.47	2.67±0.47	2.33±0.42
0.9	2.33±0.47	2±0	2±0	2.33±0.82	2.33±0.42
0.85	1.33±0.47	1.67±0.47	1.67±0.82	2±0.47	2.33±0.42
0.8	1.33±0.47	2 ±0.82	2 ±0.94	2±0	2.33 ±0.42
Virginia					
1	2±0.82	0±0.47	0±0.47	0±0.47	2.67±0.67
0.95	3±0	0±0.47	0±0.82	0±0	2.33±0.94
0.9	2±0.82	0±0.47	0±0.47	0±0.47	2.67±0.47
0.85	3.33±0.47	0±0.47	0±0.94	0±82	2±0.82
0.8	2.67±0.47	0±0.47	0±0.94	0±0.94	2.67±0.47
Onion					
Spanish					
1	5±0	5±0	5±0.94	4.67±0.47	5±0
0.95	5±0	4.33±0.47	4.67±0.82	5±0	4.67±0.47
0.9	5±0	5±0	4.67±0.94	4.330.47±	4.67±0.47
0.85	5±0	5±0	5±0.94	5±0	5±0
0.8	5±0	5±0	5±0.94	5±0	5±0
Valencia					
1	4.67±0.47	5±0	5±0	4.33±0.47	5±0
0.95	4.67±0.47	5±0.47	5±0	5 ±0	5±0
0.9	4.67±0.47	5±0.47	5±0	4.67±0.47	5±0
0.85	4.67±0.47	5 ±0.47	5±0	4.67±0.47	5±0
0.8	4.67±0.47	4.67±0	4.67±0.47	4.67±0.47	5±0
Virginia					
1	4.67±0.47	4.33 ±0.47	4.33 ±0.47	5±0	5±0
0.95	5±0	5± 0	4.67±0.47	5±0	5±0
0.9	4.67 ±0.47	4.67±0.47	4.67±0.47	5±0	5±0
0.85	5±0	5±0	5±0	4.33±0.47	5±0
0.8	4.67±0.47	4.67±0.47	5±0	5±0	5±0
Pepper					
Spanish					
1	4.33±0.47	4.67±0.47	4.33±0.82	4±0.82	4.33±0.47
0.95	3.67±0.47	4±0.82	4.67±0.82	4.33±0.47	4±0.82
0.9	2.67±0.47	3.3±0.47	4.67±0.94	4.67±0.47	4.33±0.47
0.85	2.67±0.47	3.67±0.47	3.67±0.47	3.67±0.47	3.33±0.47
0.8	2±0.82	3.33±0.47	4.33±0.47	3.67±0.7	3.33±0.47
Valencia					
1	2±0.82	3±0.82	3±0	3.67±0.47	2.33±0.42
0.95	3.67±0.47	3.33±0.47	3.33±0.47	2.67±0.47	3±0.82
0.9	2.33±0.47	3±0.47	3±0.82	3.33±0.47	3±0
0.85	3±0.82	3.33±0.47	3.33±0.47	3±0.82	2.67±0.42
0.8	1.33±0.47	3.33±1.24	3.33±0.47	3.33±0.47	2.67±0.16
Virginia					
1	3 ±0.82	3.67 ±0.47	3.67 ±0.47	3 ±0	3.33±0.47
0.95	3 ±0.82	3.33 ±0.47	3.67 ±0.47	3.33±0.47	3.33±0.47
0.9	3 ±0.47	3.33±0.47	3.33 ±0.47	3.67±0.47	3.67±0.47
0.85	2.67 ±0.47	3.67 ±0.47	3.33 ±0.47	3.33±0.47	2.67±0.47
0.8	2.67±0.82	2.67 ±0.47	3±0.82	3±0.47	2 ±0.82
Tomatoes					
Spanish					
1	4.33±0.47	4.67±0.47	4.33±0.82	4±0.82	4.33±0.47
0.95	4±0	4±0.82	4.67±0.94	4.33±0.47	4±0.82
0.9	2.67±0.47	3.33±0.47	4.67±0.82	4.67±0.47	4.33±0.47
0.85	2.67±0.47	3.67±0.47	3.67±0.47	3.67±0.47	3.33±0.47
0.8	2±0.82	3.33±0.47	4.33±0.82	3.67±0.47	3.33±0.47
Valencia					

Table 2 Continued.....

1	2±0.82	4±0.47	4±0.82	4.67±0.47	4.33±0.16
0.95	3.67±0.47	4.33±0.47	4.33±0.47	4.33±0.47	4.67±0.42
0.9	2.33±0.47	4.33±0	4.33±0.47	4.33±0.47	4.33±0.42
0.85	3±0.82	4.67±0.47	4.67±0.47	3.67±0.47	4±0
0.8	1.33±0.47	4.67±0	4.67±0.47	3±0.82	4.33±0.42
Virginia					
1	3.33±0.47	3.67±0.47	3.67±2.67	3.67 ±0.47	4.33±0.47
0.95	1.67 ±0.47	3.33 ±0.47	3.33 ±3	3 ±0	4.67±0.47
0.9	2.67 ±0.47	3 ±0	3.67 ±0.47	3.33 ±0.47	4.33±0.47
0.85	3 ±0.82	3.33±0.47	3.33 ±0.47	3 ±0.82	4.33±0.47
0.8	3±0	3 ±0	3.67 ±0.82	3 ±0	3±2.26

Where, 1=dislike extremely, 2=dislike slightly, 3=neither dislike nor like, 4=like slightly, 5=like extremely.

Discussion

Antimicrobial characteristics of the PPEs on the clinical isolates

The research assessed the antimicrobial efficacy of Spanish, Valencia and Virginia varieties of peanut peels (Figures 1 & 2) against four bacterial strains: *E. coli*, *S. aureus*, *K. pneumoniae*, and *S. typhi*. The primary method employed for the assessment was the zone of inhibition, which provided a quantitative measure of the antimicrobial activity of the extracts. The samples were incubated for 24, 48 and 72 hours, however, no zones were observed for the 24 and 48-hour samples.

The findings show that the extracts obtained from the peanut varieties possess notable antimicrobial activity, particularly against *K. pneumoniae*. At 1% concentration, the Virginia sample had the highest inhibition against *K. pneumoniae* (0.53±0.08 cm) and significant inhibition against *S. aureus* at 0.95% concentration (0.33±0.03 cm). The Valencia sample also showed high inhibition against *K. pneumoniae* at 1% concentration (0.52±0.06 cm) and measurable inhibition against *E. coli* at 0.8% concentration (0.25±0.09 cm). The Spanish sample exhibited the greatest inhibition against *K. pneumoniae* (0.33±0.06 cm) at 1% concentration (Table 1).

Previous studies have documented the antimicrobial effects of peanut-derived materials. For instance, peanut skin extracts have been shown to inhibit various pathogens, including *E. coli* and *S. typhi*.[11,12] Another study by Nepote et al.,[12] evaluated the antimicrobial activity of peanut skin extracts against various bacteria. They found that the extracts exhibited significant inhibition against *S. aureus* and *S. typhienteritidis*, which aligns with the results of the current study showing inhibition of *S. aureus* and *S. typhi* by the peanut peels. Similarly, Ahn et al.,[13] reported that peanut skin extracts were effective against *E. coli* O157:H7 and *S. typhimurium*, further supporting the antimicrobial potential of peanut-derived materials.

The findings of this study align with the broader literature, which indicates that the efficacy of plant extracts can vary significantly based on the type of extract and the specific bacteria tested as reported by Adegbenu et al[14] on susceptibility of bacterial and fungal isolates to spices commonly used in Ghana. The observed resistance by *E. coli* in this study is consistent with findings that suggest that certain strains possess mechanisms to counteract plant-derived antimicrobials.[16] While the current study found minimal inhibition of *E. coli* by peanut peels, other studies have reported more potent antimicrobial activity against this bacterium. For instance, Nepote et al.,[12] observed that peanut skin extracts effectively inhibited the growth of *E. coli*. This discrepancy may be attributed to differences in the specific strains of *E. coli* used or variations in the extraction methods and concentrations of the antimicrobial compounds. Thus, the antimicrobial properties of peanut peels are highly influenced by their phytochemical constituents, primarily polyphenols and flavonoids, which are known for their antimicrobial activities.[3,11] The variation in inhibition zones among the different peanut varieties suggests that genetic factors may play a role in the concentration and efficacy of these bioactive compounds. This observation is supported by research indicating that different plant varieties can yield varying levels of antimicrobial agents.[16] The ability of peanut peels to inhibit pathogenic bacteria suggests their potential use as natural preservatives in food products, which could reduce reliance on synthetic additives. Furthermore, utilising agricultural by-products such as peanut peels aligns with sustainable practices, hence promoting the valorisation of waste materials.[12,17]

The absence of observable zones of inhibition at 24 and 48 hours, with significant results only at 72 hours, can be attributed to several factors related to the dynamics of bacterial growth and the antimicrobial activity of the extracts. Initially, the extracts may require a longer incubation period to exert their full antimicrobial effects, as the time needed for the compounds to penetrate bacterial cell walls and disrupt metabolic processes can vary. During the first 48 hours, bacterial populations may have been in a logarithmic growth phase, where rapid division could have outpace the inhibitory effects of the extracts.[18]

Additionally, the concentrations tested may not have been sufficient to induce immediate inhibition; lower concentrations, particularly at 0.8%, showed no inhibition for certain strains, indicating that higher concentrations or longer exposure times are necessary to achieve measurable effects. Bacterial growth inhibition is highly dependent on the concentration of the inhibitory agent. As the concentration decreases, the bactericidal effect diminishes until a threshold is reached where the bacteria neither grow nor die.[19,20] The gradual accumulation of the active compounds in the growth medium over time could also contribute to the delayed response. Furthermore, the specific characteristics of the bacterial strains, such as their growth rates and resistance mechanisms, might influence the time required to observe inhibition. These findings are consistent with published reports which also observed significant antimicrobial activity only after 72 hours.[21,22]

Preservative potential of the PPEs on the selected fruits and vegetables

Shelf-life of food relates to the period during which a product could be stored until it becomes unacceptable from safety, nutritional or sensory perspective.[22]

According to Man. D,[23] three types of shelf-life exists namely microbiological, chemical and sensory. This study also assessed the preservative potential of the extract of Spanish, Valencia, and Virginia peels with different concentrations on four fruits and vegetables each i.e. apple, banana, grape, orange, carrot, onion, scotch bonnet pepper and tomato. The primary method employed for this evaluation was the design as proposed by Lawless and Heymann.[24] The fruits and vegetables were immersed in the 72-hour extract for 2 minutes (Figure 3). The samples were then left in a cool dry place for 7 days after which organoleptic properties were assessed (Table 2, Figure 4). All the fruits and vegetables maintained their organoleptic properties for the first two days. On the third day, black patches were seen on the bananas across all concentrations of the PPEs. This could have indicated an initiation of spoilage. On the seventh day, the apples and onions were the most preserved across all concentrations thus their organoleptic properties were maintained. This trend was observed across all varieties. Thus, the PPEs exhibited preservative properties and may be employed for the maintenance of organoleptic properties of some fruits and vegetables. The control for the fruits and vegetables, however, were spoilt under the same storage conditions. There was no significant difference between the concentration of the PPEs and organoleptic properties of the fruits and vegetables i.e $p>0.05$.

Conclusion

The research findings showed that peanut peels from Spanish, Valencia, and Virginia varieties possess notable antimicrobial activity, particularly against *K. pneumoniae.* The Virginia and Valencia samples demonstrated the highest inhibition, with significant effects observed only after 72 hours of the extracted PPEs.

Also, the PPEs of all the three varieties exhibited preservative properties particularly with apple and onion where their organoleptic properties were preserved. This is particularly intriguing and seeks to address the myriad of food safety issues contributed by agrochemicals when used along the food chain. Thus, the PPEs demonstrate promising alternatives for preservation and shelf-life extension of perishable products and present no observed risks to human health.

Consent for publication

The manuscript does not contain any human data, therefore consent for publication is not applicable.

Availability of data and materials

Additional information or data related to the study shall be made available on request.

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Authors' contributions

George Aboagye: Conceptualisation, Methodology, Writing – Review and Editing, Validation, Investigation, Resources, Supervision.

Sandra K. Enninful: Conceptualisation, Writing – Original Draft, Investigation, Validation, Resources

Diana A. Aborgah: Conceptualisation, Writing – Original Draft, Investigation, Validation, Resources.

Elodie A. Asobayire: Conceptualisation, Writing – Original Draft, Investigation, Validation, Resources.

Rebecca Kissiwa K.Steele-Dadzie: Writing – Review and Editing, Validation, Resources.

All authors read and approved the final manuscript.

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Conflicts of interest

The authors declare no conflicts of interest.

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