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EXPLORING THE PROBIOTIC POTENTIALS OF THREE (3) SELECTED NIGERIA SPICES ESSENTIAL OILS ON HUMAN GUT MICROBIOTA

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Abstract

The probiotic potentials of three (3) (*Clove (Syzygium aromaticum), Garlic (Allium sativum),* and *Turmeric (Curcuma longa*) selected Nigeria spices essential oils on human gut microbiota was explored. The human gut microbiome is a complex and dynamic community of microorganisms that can be influenced by EOs. Comprehensive research directly comparing the probiotic potentials of Cloves, Garlic and Turmeric EOs on human gut microbiota are scanty hence this study. Essential oils were extracted through steam and hydro-distillation, with yields ranging from 1.5–1.6% (highest in Garlic oil). GC–MS analysis revealed major bioactive compounds—Eugenol in Clove, Zingiberene and diallyl disulfide/trisulfide in Garlic and α/β-Turmerone in Turmeric—indicating rich phytochemical diversity and strong bioactivity potential. Microbiological analyses of fecal samples identified diverse gut bacteria, including beneficial (*Lactobacillus, Bifidobacterium, Akkermansia*) and pathogenic (*E. coli, Salmonella, Staphylococcus*) species. When treated with graded EO concentrations (0.1–1.0%), beneficial bacteria maintained high viability (93–99%), while pathogenic strains showed significant inhibition (40–74%), particularly under Garlic and Clove oil treatments. Turmeric essential oil (TEO) exhibited mild antibacterial activity against pathogens and preservation/enhancement of probiotics. Reduction in cell viability were: *E. coli* (49.02%), *Salmonella* (39.50%), *Proteus* (28.56%). *Staphylococcus* (16.19%), and *Citrobacter* (12.34%). Others are *Lactobacillus* (0.73%),

Keywords: Probiotic potentials, Essential oils, Gut microbiome, Spices, α/β-Turmerone

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Bifidobacterium (2.48%) showed minimal reduction. *Akkermansia* viability was high (96.03%). Statistical analyses (ANOVA, $p \leq 0.05$) confirmed significant effects across treatments. Overall, the study demonstrates that essential oils from Nigeria spices possess strong probiotic potentials, capable of enhancing beneficial gut flora, suppressing pathogens. The findings have established a scientific baseline for utilizing local botanicals as natural nutraceuticals to promote gut health.

Introduction

The human gut microbiome is a complex community of microorganisms that plays essential roles in digestion, metabolism, immune regulation, and protection against pathogenic organisms. Maintaining a balanced gut microbiome is vital for overall health, while disturbances in its composition, known as dysbiosis, have been associated with several diseases, including inflammatory bowel disease, obesity, diabetes, and other metabolic and inflammatory disorders (Valdivieso-Ugarte *et al*., 2019; Clemente *et al*., 2012). Consequently, there is increasing interest in identifying natural substances that can help maintain gut microbial balance and promote human health.

Medicinal plants have been used for centuries as sources of therapeutic agents in traditional medicine. In Nigeria, the use of medicinal plants is well established, largely because of their availability and diverse health benefits (Arshao *et al*., 2014). Spices such as turmeric (*Curcuma longa*), garlic (*Allium sativum*), and clove (*Syzygium aromaticum*) are widely used as food ingredients and traditional remedies. These plants contain bioactive compounds with antimicrobial, antioxidant, and anti-inflammatory properties, making them potential candidates for supporting gut microbiome health.

Turmeric, a member of the Zingiberaceae family, is widely recognized for its culinary and medicinal applications, particularly in Asian and African traditional medicine. Its principal bioactive compound, curcumin, is associated with several pharmacological activities, including antioxidant, anti-inflammatory, antimicrobial, and metabolic-regulating effects (Chattopadhyay *et al*., 2004; Cheng, *et al*., 2019). Garlic has also been used traditionally for the prevention and treatment of various ailments. It contains sulfur-containing compounds, particularly allicin, which contributes significantly to its antimicrobial and other biological activities (Bayan *et al*., 2014). Similarly, clove, an aromatic plant belonging to the Myrtaceae family, contains essential oil rich in eugenol, a phenolic compound known for its antimicrobial, antioxidant, analgesic, and anti-inflammatory properties (Cortes-Rojas *et al*., 2014; Gresse *et al*., 2019).

Essential oils are volatile aromatic compounds extracted from plants and are increasingly being investigated for their potential to influence the composition and activity of the gut microbiome. Their biological effects are largely attributed to phytochemicals such as phenolic compounds, flavonoids, and other bioactive constituents that may inhibit harmful microorganisms and influence microbial growth (Bakkali *et al*., 2008; Calo *et al*., 2015). At appropriate concentrations, certain plant-derived compounds may selectively suppress pathogenic bacteria while supporting beneficial microorganisms. However, their effects depend on the type and concentration of the

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compounds, as well as the microbial species involved. Therefore, these essential oils should be investigated as potential microbiota-modulating agents rather than assumed to function directly as probiotics.

Despite growing interest in plant-derived bioactive compounds, conventional probiotic applications may be limited by factors such as microbial viability, storage stability, and survival under gastrointestinal conditions (Zhu and He, 2024). Turmeric, garlic, and clove essential oils may offer complementary approaches to promoting a healthy gut microbial environment. Nevertheless, evidence directly comparing their effects on beneficial gut microorganisms remains limited, particularly within the Nigerian context. Their optimal concentrations, microbial selectivity, safety, and long-term effects on gut microbial diversity also require further investigation.

The study aimed to investigate the probiotic potentials of essential oils extracted from turmeric (Curcuma longa), garlic (*Allium sertivum)* and cloves (*Szygium aromaticum*) by evaluating their effect on the composition, growth and modulation of beneficial human gut microbiota.

Materials and Methods

The study areas: The study was conducted in Isa Mustapha Agwai 1 Polytechnic Lafia and Federal University of Lafia respectively, all situated in Nasarawa State.

Stool sample collection

A total of fifty (50) fresh fecal samples were collected randomly from volunteers aseptically, for the isolation of gut bacteria after obtaining their consent. The fresh fecal samples were collected into sterile specimen bottles immediately after defecation and stored in air tight bags. The samples were then transported to the medical laboratory in IMAPOLY-Lafia Nasarawa State medical center. The stool samples were preserved in the refrigerator at 4°C.

Stool sample processing and isolation of gut bacteria

Each of the samples was mechanically mixed with a sterile spatula and a sterile loop was used to deliver a loop full of the stool sample into selenite broth and peptone water as described by Abubakar, *et al.,* (2020). These were incubated at 37^{oC} aerobically for 24hrs. An aliquot from the Selenite broth was sub-cultured unto *Salmonella shigella* agar. While an aliquot from Peptone water was sub-cultured into each of these media (MRS agar, MacConkey, Simmon citrate agar, Triple sugar iron agar, Sulphide indole motility medium, Blood agar and Eosin methylene blue. One set of inoculated plates were incubated at 37^{oC} for 24hrs and the second set were incubated at 37^{oC} for 5days in an anaerobic chamber. The plates were then observed for bacteria growth and isolates were characterized.

Colonial characteristics of isolates

On each culture plate, the colonies were observed for pigmentation, appearance (dried, mucoid, rhizoid, raised, flat, irregular, concave, and convex),

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Prof. E. Mclenna [Australia]

morphological and biochemical analysis

After incubation and isolation, the isolates were characterized and identified using the standard procedures including colonial characteristics and biochemical tests viz: Gram staining, triple sugar iron test, Nitrate test, Catalase, Oxidase, Citrate, Urease, Sulphide indole motility test, Methyl red and VP test (Cheesbrough, 2006).

Extraction of Essential Oils

Extraction of essential oils from Cloves was done by steam distillation, while Garlic and Turmeric were extracted by hydro-distillation. A total of 6.5kg, of each of the plant material was used for the extraction. 200g pieces of Cloves was loaded into the distillation flask, which is connected to a round bottom flask containing water as described by Giwa, *et al*, (2018). The flask was connected to a condensing unit with its tube. Heating mantle was used for heating the water in the round bottom flask. The essential oil was extracted as the steam passed through the Cloves pieces in the distillation flask. Similarly, essential oils were extracted from Garlic and Turmeric by the process of hydro-distillation using the cleavenger apparatus. 500g of each of these plant materials were placed in a round bottom flask and filled with water to about three quarter full separately as described by Obidi. *et al*., (2013). The distillation apparatus was connected to the flask. A separating funnel was used to collect the essential oil as it floats on top of water. After distillation process, the product obtained was a mixture of oil and water. The separating funnel tap was carefully opened to separate water from the oil. The essential oil was dried over anhydrous sodium sulfate and stored in amber colored bottles.

Composition of Essential oils by (GC-MS)

Composition of essential oils by Gas Chromatography-Mass Spectrometry (GC-MS) of the selected spices namely: Cloves, Garlic, and Turmeric analysis were conducted using a Hewlett-Packard 6870 gas chromatography interfaced with a Hewlett-Packard Mass Spectrometer 5973 (Agilent Technologies, Palo Alto, California. USA) equipped with an HP-SMS capillary column (30m × 0.32mm. i.d. 0.25µm film thicknesses). The GC-MS analysis was performed to identify the chemical constituents present in the essential oils. The EO compounds were identified based on linear retention index(RI) and by comparison of Mass Spectra with MS data of reference compounds.

Preparation of Essential Oils Solutions

Each of the three (3) essential oils was diluted in dimethyl sulfoxide (DMSO) to produce V/V. These were further diluted to working concentrations of 0.1%, 0, 25%, 0.50%, 0.75% and 1% in sterile broth media immediately before use (Kalemba. & Kunicka, 2003; Bakkali, *et al*., 2008).

Treatment of Gut Bacteria

Treatment of the gut bacteria with essential oils was carried out as described by Lynch and Pederson., (2016). DMSO was used as negative control while Ampiclox as positive control. Each bacteria strain suspension was adjusted to optical density of OD_{600}=0.1 approximately 10^7 CFU/ml.

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A volume of 100µL of bacteria suspension was added to each of a sterile 96-well micro titer plates. Essential oil dilutions were added to each of the wells. The plates were sealed and incubated at 37°C under aerobic and anaerobic condition for 24hrs for aerobic and anaerobic bacteria respectively.

The bacteria growth was determined by measuring the optical density at 600nm using a micro plate reader. Viable cell count was performed by plating serial dilutions on Mueller Hinton agar plates and incubated at 37°C for 24hrs after which colonies were counted representing viable cell count.

Analysis of Variance (ANOVA)

A two-way ANOVA was carried out to determine variability of effect of treatment of the three (3) essential oils on the gut bacteria.

Results and Discussion

From the study carried out on the evaluation of the probiotic potentials of essential oils extracted from *Cloves, Garlic and Turmeric* and their effects on the human gut microbiome through in-vitro process, hence the following results and data were obtained.

Table 1 shows yield in percentage for each of the three essential oils extracted. Viz: , Garlic1.6%, Cloves 1.5% and Turmeric 1.5%.

Table 1: Percentage yield of Essential Oils Extracted.

Sample Plant Material	Mass of Plant sample Used (kg)	Essential Oil Obtained (ml)	Percentage % Yield
Garlic	6.5	10.70	1.6
Cloves	6.5	9.50	1.5
Turmeric	6.5	9.65	1.5

Table 2 shows the physical properties for each of the essential oils extracted as follows: Garlic 1.06, Cloves 1.05 and Turmeric 0.92 respectively, while specific density of Garlic 1.05. Cloves 1.04, and Turmeric 0.91. Garlic strong sharp and yellowish in colour, Cloves strong spicy sweet odour with light brownish colour while Turmeric has warm earthy odour and orange yellow.

Table 2: Shows Some Physical Properties of Essential Oils Extracted.

Essential Oil	Density (g/ml)	Specific Density	Odour	Appearance
Garlic	1.06	1.05	strong sharp	yellowish
Cloves	1.05	1.04	strong spicy sweet	light brownish
Turmeric	0.92	0.91	warm, earthy	orange yellow

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Table 3; shows identified components by GC-MS where RIexp = Experimental Retention Index. RIlit = Literature Retention Index.

Table 3: Components of Samples (Cloves, Garlic and Turmeric)

Spice	Components	RIexp.	RIlit	%
1). Cloves	Eugenol	1352	1361	87
	Eugenol acetate	1521	1530	05
	Caryophyllene	1407	1412	03
	α – Humulene	1444	1450	02
	Caryophyllene oxide	1461	1470	01
2). Garlic	Diallyl disulfide	1136	1140	35
	Diallyl trisulfide	1310	1320	20
	Allyl methyl disulfide	945	950	---
	Methyl allyl trisulfide	1220	1245	---
3). Turmeric	α – Turmerone	1550	1560	45
	β - Turmerone	1562	1565	20
	D - Limonene	1028	1030	21
	α – Zingiberene	1440	1445	03
	Curlone	1480	1484	11

Table 4: Shows the Macroscopic characteristics of human stool samples

Table 4: Macroscopic characteristics of human stool samples

S/No	Colour	Consistency	Texture	Mucus	Blood
1).	Brown	formed	hard	+	-
2).	Brown	Semi-formed	soft	+	+
3),	Brown	formed	hard	-	-
4).	Brown	formed	hard	-	-
5).	Dark	formed	hard	-	-
6).	Brown	formed	hard	-	-
7).	Dark	formed	soft	-	-
8).	Brown	semi-formed	soft	+	-
9).	Brown	formed	hard	-	-
10).	Brown	formed	hard	-	-
11).	Brown	formed	hard	+	-
12).	Brown	Semi-formed	soft	+	+
13),	Brown	formed	hard	-	-
14).	Brown	formed	hard	-	-
15).	Dark	formed	hard	-	-

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S/No	Colour	Consistency	Texture	Mucus	Blood
16).	Brown	formed	hard	-	-
17).	Dark	formed	soft	-	-
18).	Brown	semi-formed	soft	+	-
19).	Brown	formed	hard	-	-
20).	Brown	formed	hard	-	-
21).	Brown	formed	hard	+	-
22).	Brown	Semi-formed	soft	+	+
23),	Brown	formed	hard	-	-
24).	Brown	formed	hard	-	-
25).	Dark	formed	hard	-	-
26).	Brown	formed	hard	-	-
27).	Dark	formed	soft	-	-
28).	Brown	semi-formed	soft	+	-
29).	Brown	formed	hard	-	-
30).	Brown	formed	hard	-	-
31).	Brown	formed	hard	+	-
32).	Brown	Semi-formed	soft	+	+
33),	Brown	formed	hard	-	-
34).	Brown	formed	hard	-	-
35).	Dark	formed	hard	-	-
36).	Brown	formed	hard	-	-
37).	Dark	formed	soft	-	-
38).	Brown	semi-formed	soft	+	-
39).	Brown	formed	hard	-	-
40).	Brown	formed	hard	-	-
41).	Brown	formed	hard	+	-
42).	Brown	Semi-formed	soft	+	+
43),	Brown	formed	hard	-	-
44).	Brown	formed	hard	-	-
45).	Dark	formed	hard	-	-
46).	Brown	formed	hard	-	-
47).	Dark	formed	soft	-	-
48).	Brown	semi-formed	soft	+	-
49).	Brown	formed	hard	-	-
50).	Brown	formed	hard	-	-

Key: + = Presence, - = Absence.

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Tale 5: Characteristics Bacterial Isolates.

S/N	Gr	Shp	Cat	Ind	Ur	Mr	Vp	Oxi	Cit	Gas	Mt	Nit	H_2S	A	Co	Org
1	-	Rod	+	+	-	+	-	-	-	+	+	-	-	+	+	E. *coli*
2	-	Rod	+	+	-	+	-	-	-	+	+	-	-	+	+	E. *coli*
3	-	Rod	+	+	-	+	-	-	-	+	+	-	-	+	+	E. *coli*
4	-	Rod	+	-	-	-	-	-	-	-	-	-	-	+	-	*Bact*. Sp
5	-	Rod	+	-	-	-	-	-	-	-	-	-	-	+	-	*Bact*. Sp
6	+	Cocci	-	-	-	+	+	-	-	+	-	-	+	+	-	*Enter*.sp
7	+	Cocci	-	-	-	+	+	-	-	+	-	-	+	+	-	*Enter*. Spp
8	+	Rod	-	-	-	-	-	-	-	+	-	-	-	+	-	*Lact*. Sp
9	+	Rod	-	-	-	-	-	-	-	+	-	-	-	+	-	*Lact*. Sp
10	-	Cocci	-	-	-	-	-	-	-	-	-	-	-	-	-	*Akk*. Sp
11	+	Rod	-	-	-	-	-	-	-	-	-	+	-	+	-	*Cl*. Sp
12	+	Rod	-	-	-	-	-	-	+	+	+	-	+	+	-	*Sal*.sp
13	+	Cocci	+	+	+	+	-	+	+	+	-	+	-	+	+	*Staph*. Sp
14	+	Rod	-	-	-	+	-	-	-	+	-	-	-	+	-	*Bifido*. Sp
15	-	Rod	+	+	-	+	-	-	-	+	+	-	-	+	+	E. *coli*
16	-	Rod	+	+	-	+	-	-	-	+	+	-	-	+	+	E. *coli*
17	-	Rod	+	+	-	+	-	-	-	+	+	-	-	+	+	E. *coli*
18	-	Rod	+	-	-	-	-	-	-	-	-	-	-	+	-	*Bact*. Sp
19	-	Rod	+	-	-	-	-	-	-	-	-	-	-	+	-	*Bact*. Sp
20	+	Cocci	-	-	-	+	+	-	-	+	-	-	+	+	-	*Enter*. Sp
21	+	Cocci	-	-	-	+	+	-	-	+	-	-	+	+	-	*Enter*. Sp
22	+	Rod	-	-	-	-	-	-	-	+	-	-	-	+	-	*Lact*. Sp
23	-	Rod	-	-	-	-	-	-	-	+	-	-	-	-	-	*Lact*. Sp
24	-	Cocci	-	-	-	-	-	-	-	-	-	-	-	-	-	*Akk*. Sp
25	+	Rod	-	-	-	-	-	-	-	-	-	-	+	+	-	*Cl*. Sp
26	+	Rod	-	-	-	-	-	-	+	+	+	-	+	+	-	*Sal*. Sp
27	+	Cocci	+	+	+	+	-	+	+	+	-	+	-	+	+	*Staph*. Sp
28	+	Rod	-	-	-	+	-	-	-	+	-	-	-	+	-	*Bifido*. Sp
29	+	Cocci	+	+	+	+	-	+	+	+	-	+	-	+	+	*Staph*. Sp
30	-	Rod	+	+	-	-	-	-	+	+	+	-	+	+	-	*Prot*.sp

Key: + = Positive, - = Negative. Shp=Shape, Gr = Gram reaction, Cat.= Catalase, Coa.= Coagulase, Ind.= Indole, Ur.= Urase, Mr. = Methyl Red, Vp.= Vogue Proskaure, Oxi.= Oxidase, Cit.= Citrate, Mt= Motility, Nit.= Nitrate, H_2S= Hydrogen Sulfide, A.= Acid, Org.= Organism, *L. bacillus* =

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Lactobacillus spp., Bact. Spp = Bacteriodes, Cit. spp = *Citrobacter* spp., *Prot.* spp = *Proteus* spp., *Ent.* Spp = *Enterococcus spp., Cl.* Spp = *Clostridium* spp., *E. coli = Escherichia coli., Akk.* Spp = *Akkermansia spp. Staph.* Spp = *Staphylococcus spp, Bifido.* Spp. = *Bifidobacterium spp., Sal.* Spp. = *Salmonella* spp.

Table 6: Mean Values of Effect of Treatment on Gut Bacteria at different Concentrations (%) of EOs.

S/N	Org.	V-count before treatment	Cloves	Garlic	Turmeric	Viability (%)	% Reduction after treatment
1	Lacto spp	8.50	7.928	8.412	8.438	93.27 98.97 99.27	Cloves 6.73% Garlic 1.03% Turmeric 0.73%
2	Bact. Spp	8.30	8.212	6.596	8.108	98.94 79.53 101.3	Cloves 1.06% Garlic 20.53% Turmeric - 1.30%
3	Entero spp	8.40	7.316	6.51	8.208	87.10 77.50 97.72	Cloves 12.90% Garlic 22.50% Turmeric 2.28%
4	Clostri spp	8.20	6.296	6.284	6.584	76.78 76.64 80.29	Cloves 23.22% Garlic 23.36% Turmeric 19.71%
5	Bifido. Spp	8.40	8.056	7.346	8.192	95.91 94.72 97.52	Cloves 4.09% Garlic 12.55% Turmeric 2.48%
6	Akk. Spp	6.50	4.794	6.450	6.242	73.75 61.65 96.03	Cloves 26.25% Garlic 0.77% Turmeric 3.97%
7	E. *coli*	9.00	5.086	3.64	4.588	56.51 67.85 50.98	Cloves 43.49% Garlic 59.55% Turmeric 49.02%.
8	Staph. spp	8.10	4.4	4.654	6.788	54.32 65.53 83.81	Cloves 45.68% Garlic 42.54% Turmeric 16.19%
9	Prot. spp	7.90	6.548	6.588	5.644	82.89 83.39 71.44	Cloves 17.11% Garlic 16.61% Turmeric 28.56%
10	Citro. Spp	7.60	4.77	5.72	6.662	62.76 75.26 87.65	Cloves 37.24% Garlic 24.74% Turmeric 12.34%
11	Salm. Spp	8.90	3.246	2.33	5.384	36.47 26.18 60.50	Cloves 63.53% Garlic 73.82% Turmeric 39.50%

Key*: Lacto. bacillus = Lactobacillus* spp., *Bact.* spp = *Bacteriodes, Citro.* spp = *Citrobacter* spp., *Prot.* spp = *Proteus* spp., *Entero.* Spp = *Enterococcus* spp., *Clostri.* spp = *Clostridium* spp., *E. coli =*

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Escherichia coli., Akk. spp = *Akkermansia* spp. *Staph.* spp = *Staphylococcus* spp, *Bifido.* spp. = *Bifidobacterium* spp., *Salm.* spp. = *Salmonella* spp.

Table 7: The Statistical analysis of Treatment of Gut Bacteria with Different Concentrations (0.1, 0.25, 0.5, 0.75, and 1.0%) of EOs.

Source	DF	SS	MS	F-Cal	P-Value	Status
Cloves						
Bacteria	10	147.023	14.702	20.25	0.000	Significant
Concn.	4	60.880	15.220	20.96	0.000	Significant
Error		40	29.044	0.726		
Total		54	236.947			
Garlic						
Bacteria	10	97.330	9.733	19.24	0.000	Significant
Concn	4	60.159	15.040	29.73	0.000	Significant
Error		40	20.233	0.506		
Total		54	177.722			
Turmeric						
Bacteria	10	88.950	8.895	11.27	0.000	Significant
Concn	4	28.343	7.086	8.98	0.000	Significant
Error		40	31.561	0.789		
Total		54	148.855			

Key: DF: Degree of freedom, SS: Sum of square, MS: Means square, F.cal: F: calculated value and P.value: Computed value at 0.05%.

Table 8: Comparative analysis of EOs Treatments against Gut Bacteria at Different concentrations (0.10, 0.25, 0.50, 0.75, and 1.00%)

Bacteria	DF	SS	MS	F	P
Concn	10	88.055	8.806	14.30	0.000
Error		44	27.091	0.616	
Total		54	115.146		

Key: DF: Degree of freedom, SS: Sum of square, MS: Means square, F.cal: F: calculated value and P.value: Computed value at 0.05%.

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Discussion

Table 1: shows yield in percentage for each of the three essential oils extracted. Viz: Garlic 1.6%, Cloves 1.5% and Turmeric 1.5%. All the values obtained fall within the standard values, except for Garlic which is slightly higher. This may be attributed to the varieties used and environmental conditions as well as extraction method (Sharma, *et al*., 2017).

The physical properties for each of the essential oils extracted in Table 2 is as follows: Garlic 1.06, Cloves 1.05 and Turmeric 0.92 respectively, while specific density of Garlic 1.05. Cloves 1.04, and Turmeric 0.91. For odour and appearance, Garlic strong sharp and yellowish in colour, Cloves strong spicy sweet odour with light brownish colour while Turmeric has warm earthy odour and orange yellow. These properties are typical of the three oils studied. These properties are influenced by storage conditions and location, varieties and extraction method (Shahid Ud-Daula & Basher, 2019).

The major components by GC-MS of the three essential oils extracted. In this study the GC-MS analysis revealed the presence of five major compounds in Cloves: Eugenol, Eugenol acetate, Caryophyllene, α-Humulene and Caryophyllene oxide and Eugenol as the most dominant compound with (87%). Study by Yeddes *et al*., (2022) showed cloves to have eight compounds with Eugenol as the dominant with (87.3%) which is similar to that obtained in this study.

Also in Table 3, components of Garlic are shown to be the following: Diallyl disulfide, Diallyl trisulfide, Allyl methyl disulfide and Methyl allyl trisulfide with Diallyl disulfide as the highest component having 35%. Several studies revealed that the major active components of Garlic were, Organosulfur compounds including; Allicin (Diallyl thiosulfonate) and Diallyl disulfide which are responsible for the characteristic odour and pharmacological activities (Lanzotti, 2006). Turmeric in Table 3: shown the following components namely; α-Turemerone, β-Turemerone, D-Limonene, α-Zingibrene and Curlone with α-Turemerone as the major component with 45%. (Guimaries, 2020), reported that the major components identified by GC-MS were ar-Turemerone (40%), α-Turemerone (10%) and Curlone (23%). While Al-Rubaye, *et al.,* (2017), reported Turmeric possesses Sesquiterpenes (53%), Zingiberene (25%), α-Phellandrene (1%), Sabinene (0.6%), Cineol (1%) and Borneol (0.5%). Curcumin is responsible for the yellow colour in Turmeric.

The macroscopic characteristics of the 50 human stool samples, having the following colours and characteristics forms as; formed, semi-formed, mucus, and blood. With 10(20%) of the semi-formed stool samples, 15(30%) of those found with mucus and 5(10%) of those stool samples found with blood, and this is in line with the findings of (Perez-Burillo., 2019).

The isolated gut bacteria as indicated by their characteristics using both morphological and biochemical characterization include; = *Lactobacillus* spp., *Bacteriodes* spp, *Citrobacter* spp., *Proteus* spp., *Enterococcus* spp., *Clostridium* spp., *Escherichia coli., Akkermansia* spp., *Staphylococcus* spp., *Bifidobacterium* spp., *and Salmonella* spp. Gut microbiota is made up of devise group of organisms and constantly dynamic with bacteria being majority (Swamy, *et al*., 2016). This finding is consistent with several studies on gut bacteria. Study by Shen., (2021), showed similar bacteria isolated from human gut. Even though not all organisms were detected, this could be due to the method used for the isolation and detection of the gut microbiota. In the present study *E.*

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Prof. E. Mclenna [Australia]

coli, Bacteriodes spp., *Lactobacillus* spp., *Bifidobacterium* spp., account for 53.3% with each of them 13.33%. These bacteria represent the dominant species found in the human gut. *Lactobacillus* spp., *Bifidobacterium* spp., and *Bacteriodes* spp., are associated with modulation of host immunity and gut health (Kamada, 2013). *E. coli* is a commensal in the gut (Kamada, 2013). Other *organisms which include; Akkermansia* spp., *Clostridium* spp., *Citrobacter* spp. *Enterococcus* spp., and *Salmonella* spp., with each accounting for 6.6%. While *Proteus* spp., 3.3% and *Staphylococcus* spp., 10%. The presence of pathogens which are *Salmonella, Proteus, Enterococcus* and *Citrobacter* spp. is an indication that healthy individual is harbouring these pathogens and are at an asymptomatic stage, as collaborated by Shen (2021).

Essential oils (EOs) from culinary spices exert biologically active effects on microbes and the host immune system. They frequently display bactericidal/bacteriostatic actions against pathogens while exerting variable effects on commensal and probiotic species (Irshad, *et al*., 2024). Interpretation requires careful attention to species-specific responses and concentrations used. Table 6 provides percent reductions (viability changes) in eleven gut bacterial groups following treatment with clove, garlic and turmeric EOs — allowing species-level comparisons of antimicrobial potency and selectivity.

General analysis of the effect of the three (3) essential oils on the different gut bacteria as indicated in table 6. Clove essential oil showed strong antibacterial activity, with the following effect; *Salmonella spp.* (63.53% reduction), *E. coli* (43.49%), *Staphylococcus spp.* (45.68%), *Citrobacter spp.* (37.24%) were highly suppressed. This aligns with reports that eugenol disrupts bacterial membranes and inhibits enzyme activity **(**Marchese., 2017). CEO exhibited moderate suppression of probiotic as shown; *Lactobacillus* (6.73%), *Bifidobacterium* (4.09%), and *Akkermansia* (26.25%) were less affected compared to pathogens. The implication is that COE is selective**,** showing strong anti-pathogen activity while sparing beneficial bacteria to some degree, hence **b**eneficial for controlling enteric infections like *Salmonella* and *E. coli.*

Garlic Essential Oil (GEO) is rich in Allicin and Diallyl sulfides. GEO exhibited strong and marked inhibition of *Salmonella* (73.82%), *E. coli* (59.55%), *Enterococcus* (22.50%), *Staphylococcus* and *Clostridium* (23.36%). While the percentage reduction on probiotic showed: *Lactobacillus* (1.03%), *Bifidobacterium* (12.55%), *Akkermansia* (0.77%). Turmeric Essential Oil (TEO) rich in Curcuminn and Turmerones exhibited mild antibacterial activity against pathogens and preservation/enhancement of probiotics, reduction in cell viability were: *E. coli* (49.02%), *Salmonella* (39.50%), *Proteus* (28.56%). *Staphylococcus* (16.19%), and *Citrobacter* (12.34%). Others are *Lactobacillus* (0.73%), *Bifidobacterium* (2.48%) showed minimal reduction. *Akkermansia* viability was high (96.03%), indicating supportive prebiotic-like effect**.**

Turmeric compounds act as antioxidants, anti-inflammatories**,** and regulate bacterial metabolism without strongly killing commensals (Jagetia and Aggarwal, 2007). Turmeric oil is gut-protective, enhancing beneficial microbes while moderately suppressing pathogens.

Table 6: *Lactobacillus* percentages were barely reduced by Turmeric (0.73%), Garlic (1.03%), and Clove (6.73%). *Bifidobacterium* reductions were small overall (2.48–12.55%).

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

Turmeric appears most sparing of probiotics**,** consistent with preclinical/human studies where ginger and curcumin consumption increases or preserves *Lactobacillus*/*Bifidobacterium* abundance and gut diversity. Polyphenols and Curcuminoids can enhance bifidobacterium growth by acting as probiotic-like compounds (Lopresti, 2018). These EOs may exert selective pressure that suppresses pathogens while leaving beneficial fermenters intact (Park, 2008).
Akkermansia spp. (mucus-degrading beneficial ge**nus).**
Table 6 shows large reductions with Clove (26.25%) but minimal reduction with Turmeric (3.97%) and Garlic (0.77%). Clove EO may damage mucin-associated niches or have components that suppress *Akkermansia*, whereas garlic and turmeric preserve or minimally affect *Akkermansia*. Literature reports are mixed: certain garlic preparations (aged/allicin-free) can *increase Akkermansia* in vivo, whereas raw allicin might be more antimicrobial — this highlights the importance of EO composition and processing (Chen., 2020). *Akkermansia* is a key mucin – degrading commensal link to metabolic health. Turmeric may support its growth indirectly by modulating gut redox balance (Everard, 2013).

Conclusion and Recommendation

The study demonstrated the complexity and diversity of the human gut microbiota and revealed that the essential oils of garlic, clove, and turmeric exhibit concentration- and species-dependent antimicrobial activities. Garlic and clove showed strong inhibitory effects against pathogenic microorganisms but also affected some beneficial probiotic bacteria, whereas turmeric demonstrated more balanced microbiome-preserving and modulatory properties. The study establishes a scientific basis for exploring locally available botanicals as natural nutraceuticals for promoting gut health. It is therefore recommended that further studies determine the optimal safe and effective concentrations of these essential oils, investigate possible synergistic combinations, and explore their applications in functional foods, dietary supplements, and nutraceutical formulations. Furthermore, in-vivo investigations and controlled clinical trials should be conducted to establish their efficacy, safety, and long-term effects on the human gut microbiota. Future research should also investigate the essential oils of other locally available spices and their potential effects on immune cell modulation.

References

Abubakar, M. U., Alao, F. O., Abubakar, S. H., Garba, M. A., & Yakub, A. U., (2020). Isolation of enteric bacteria from asymptomatic food handlers. *India Journal of Microbiology Research. Journal homepage;www.ipinnovative.com*

Arshoa, H.R., Fahad, S.A., & Salad, M A, (2014). Active ingredients of ginger as Potential candidates in prevention and treatment of disease via moderation of biological activities.

Al-Rubaye, A.F., Hameed, I. H. & Kadhim, M. J., (2017). Uses of gas chromatography-mass spectrometer (GC-MS) technique for analysis of bioactive natural compounds of some plants. International Journal of Toxicological and Pharmacological Research, 9(1), 81-85.

Bakkali, F., Averbeck, S., Averbeck, D., & Idaomar, M. (2008). Biological effects of essential oils – A review. *Food and Chemical Toxicology*, 46(2), 446–475. https://doi.org/10.1016/j.fct.2007.09.106

Bayan, L., Koulivand, P. H., & Gorji, A. (2014). Garlic: A review of potential therapeutic effects. *Avicenna Journal of Phytomedicine*.

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

Calo, J. R., Crandall, P. G., O'Bryan, C. A., & Ricke, S. C. (2015). Essential oils as antimicrobials in food systems – A review. *Food Control, 54*, 111–119. https://doi.org/10.1016/j.foodcont.2014.12.040

Chaieb, K., Hajlaoui, H., Zmantar, T., Kahla-Nakbi, A. B., Rouabhia, M., Mahdouani, K., & Bakhrouf, A. (2007). The chemical composition and biological activity of clove essential oil, *Eugenia caryophyllata*. *Phytotherapy Research, 21*(6), 501–506. https://doi.org/10.1002/ptr.2124

Chattopadhyay I, Biswas K, Bandyopadhyay U, & Banerjee, R.K. (2004). Turmeric and curcumin: Biological actions and medicinal applications. Curr Sci India 87:44-53.

Cheesbrough, M. (2006). District Laboratories Practice in Tropical Countries*; Part 2: Cambdridge University Press.*

Cheng, D., Li, W., Wang, L., Lin, T., Poiani, G., Wassef, A., … Wang, X. (2019). Pharmacological effects of turmeric oil and curcumin extract. *Phytotherapy Research, 33*(12), 3024–3038. https://doi.org/10.1002/ptr.6475

Chen, K., (2020). Modulation of Allicin-Free Garlic on the Gut Microbiome. *(Garlic/gut modulation; processing matters)*.

Clemente, J. C., (2012). The impact of the gut microbiota on human health: An integrative view. *Cell, 148*(6), 1258-1270.

Cortés-Rojas, D. F., (2014). Clove (*Syzygium aromaticum*): A precious spice. *Asian Pacific Journal of Tropical Biomedicine, 4*(2), 90-96.

Everard, A., (2013). Cross-talk between *Akkermansia muciniphila* and host: A new therapeutic target in obesity and type 2 diabetes. *Nature Medicine, 19*(10), 1245–1249.

Giwa, S. O., Mohammed, M., & Giwa, A. (2018). Utilizing orange peels for essential oil production. *APRIN Journal of Engineering and Applied Sciences, 13*(1).

Gresse, R., (2019). Gut microbiota dysbiosis in inflammatory bowel disease: Mechanisms and treatment options. *Clin Sci, 133*(9), 1139–1157.

Guimaraes, A. E., et al. (2020). Essential oil of *Curcuma longa* L. rhizomes: chemical composition, yield variation, and stability. *Quimica Nova, 43*, 909-913. https://doi.org/10.21577/0100-4042.20170547.

Irshad, A., Ransane, P. Gurumayum, S., Singh, J., Kaur, S., Patel, A. S., Kumar, A., Kaur, J., Gunjal, M., & Sharma, K,. (2024). *Interaction of Human Gut Microflora with Commonly Consumed Herbs and Spices: A Review*. **Current Nutrition & Food Science**.

Jagetia, G. C., & Aggarwal, B. B. (2007). "Spicing up" of the immune system by curcumin. *Journal of Clinical Immunology, 27*(1), 19–35.

Kamada, N., (2013). Role of the gut microbiota in immunity and inflammatory disease. *Nature Reviews Immunology, 13*(5), 321-335.

Kalemba, D., & Kunicka, A. (2003). Antibacterial and antifungal properties of essential oils. *Current Medicinal Chemistry, 10*(10), 813–829. https://doi.org/10.2174/0929867033457719

Lanzotti, V. (2006). The analysis of onions and garlic sulfur compounds by GC-MS. *Phytochemical Reviews*.

Lynch, S. V., & Pedersen, O. (2016). The human intestinal microbiome in health and disease. *New England Journal of Medicine, 375*(24), 2369-2379

Lopresti, A. L. (2018). The effects of curcumin on the microbiome. *Phytotherapy Research, 32*(3), 477-483.

Marchese, A., (2017). Antimicrobial activity of eugenol and essential oils containing eugenol: A mechanistic viewpoint. *Critical Reviews in Microbiology, 43*(6), 668–689.

Obidi, O.F., Adelowotan, A. O., Ayoola, G. A., Johnson, O. O., Hassan, M. O., & Nwachukwu, S. C. U., (2023). Antimicrobial activity of Orange oil on selected pathogens: *International Journal of Biotechnology*, 2(6), 113-122.

Park, M., (2008). Antibacterial activity of ginger essential oil. *Journal of Food Science, 73*(7), M390-M393.

Pérez-Burillo, S., (2019). Gut microbiota modulation via food bioactives and essential oils. *Food Function, 10*, 4547–4561.

Shahidi Ud-Daula, A. F. M., & Basher, M. A. (2019). A review on chemical composition and antimicrobial activity of essential oils. *Journal of Medicinal Plants Research*.

Sharma, R. K., (2017). Antimicrobial activity of onion (*Allium cepa*) essential oil. *International Journal of Current Microbiology and Applied Sciences, 6*(9), 2400–2406.

Shen, C. L., (2021). Gingerols and shogaols: Effects on gut inflammation and microbiota.

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

Swamy, M. K., Akhtar, M. S., & Sinniah, U. R. (2016). Antimicrobial properties of plant essential oils against human pathogens and their mode of action: An updated review. *Evidence-Based Complementary and Alternative Medicine, 2016*, 3012462. https://doi.org/10.1155/2016/3012462

Valdivieso-Ugarte, M., Gonez-LIorente, C., Plaza-Diaz, J., & Gil, A., (2019). Antimicrobial, antioxidant, and immunomodulatory properties of essential oils; A systematic review. Nutrients, 11(11), 2786. https://doi.org/10.3390/nu11112786.

Yeddes, W., Aidi Wannes, W., Hammami, M., Smida, M., Chebbi, A., Marzouk, B., & Saidani Tounsi, M. (2018). *Effect of environmental conditions on the chemical composition and antioxidant activity of essential oils from Rosmarinus officinalis L. growing wild in Tunisia*. Journal of Essential Oil Bearing Plants, 21, 972–986.

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