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Antimicrobial Effects of Coconut Oil on Athletic Foot

Iyevhobu, K.O.[1,2], Okparaku, S.O.[1], Omokpo, V.O.[3], Malgwi, J.M.[4], Oruah-Ureki, O.[5], Ehikioya, G.[6], Ken-Iyevhobu, B.A.[2,6]

[1]*Department of Medical Microbiology, Faculty of Medical Laboratory Science, Ambrose Alli University, Ekpoma, Edo State, Nigeria.*

[2]*St. Kenny Research Consult, Ekpoma, Edo State, Nigeria.*

[3]*Department of Biological Sciences, School of Applied Science, Auchi Polytechnic Auchi, Edo State, Nigeria*

[4]*Department of Biochemistry, Modibo Adama University, Nigeria*

[5]*Federal Neuropsychiatric Hospital, Benin City, Edo State, Nigeria*

[6]*Department of Microbiology, Faculty of Life Sciences, Ambrose Alli University, Ekpoma, Edo State, Nigeria*

Abstract: Coconut oil, and many other portions of the plant Cocos nucifera L, have been hypothesized to have antimicrobial and antifungal activity. Medium-chain fatty acid constituents of coconut oil including lauric acid, capric acid, and others provide antimicrobial effect. This study evaluates the effect of coconut oil on athletes' foot and describes the proposed use of coconut products for athletes' foot. Samples were collected from students of who are always putting on covered shoes using sterile cotton swabs, swabbed over the foot between the toes, and were immediately transferred for analysis. The bacteria isolates were Staphylococcus aureus and Klebsiella spp while the fungal isolates were Rhizopus spp, Candida spp, Penicillium spp, Trichophytum spp and Aspergillus spp. Out the 100-subject sampled, 46 of them were within the age range of 19 – 21 years which where the highest group in the study, while those within the age range of 16 – 18 years and 22 – 25 years where 27 in each group. From the study, the coconut oil extract had effects on the fungus with Aspergillus spp having zone of inhibition (ZI) of 21mm which was the highest ZI in the group of fungi isolated followed by Penicillium spp (18mm), Candida spp (16.8mm), Trichophytum spp (15.1mm) and Rhizopus spp (11mm) which was the least inhibited. In conclusion, the results obtained in this study have elucidated the use of coconut oil in complementary and alternative medicine, especially in this era of emerging drug-resistant Candida species and other forms of microorganisms.

Keywords: Antimicrobial, Coconut, Oil, Athletic, Foot

Supplementary information The online version of this article (https://doi.org/xx.xxx/xxx.xx) contains supplementary material,which is available to autho-rized users.

Corresponding Author: Iyevhobu Kenneth Oshiokhayamhe†, Department of Medical Microbiology, Faculty of Medical Laboratory Science, Ambrose Alli University, Ekpoma, Edo State, Nigeria.

Introduction

Cocos nucifera (L.) is an important member of the family Arecaceae (palm family) popularly known as coconut, coco, coco-da-bahia, or coconut-of-the-beach [1]. *Cocos nucifera* (coconut) belongs to the family *Arecaceae*. Coconut (*Coccus nucifera*) is a palm tree growing in the tropics. The nut contains white meat and sweet water. These have anti-bacterial and antifungal, anti-viral anti-inflammatory [2], *antioxidant* activity [3]. The coconut Fruit comprises an outer epicarp, a mesocarp, and an inner endocarp. The epicarp, which is the outer skin of the fruit, and the mesocarp, which is heavy, fibrous, and tanned when dry, has many industrial uses. The endocarp is the hard dark core. Inside is a solid white albumen of varied thickness, depending on the age of the fruit, and with an oily pulp consistency and a liquid albumen called coconut water that is thick, sweet, and slightly acidic [4][5].

Athlete's foot is an infection that can make the skin on your feet flaky and itchy. It isn't serious. But it's better to treat it sooner rather than later. Otherwise the infection might spread and become harder to treat. Athlete's foot is caused by a fungus. The types of fungus that cause athlete's foot live in warm, damp places, such as around swimming pools and in changing areas and showers in gyms that are shared by many people.

Coconut oil is fatty oil that comes from the white pulp of the coconut. The oil is said to have many health benefits, including: aiding digestion, boosting metabolism, reducing seizures, reducing hunger, etc. Coconut oil has been touted in a recent years as a 'super food' with claims of numerous benefits ranging from ability to promote increased weight loss , improved (healthier) lipid profile during dieting to its antimicrobial, antiviral and antifungal properties. Although the health benefits of coconut oil are regularly suggested to be plentiful in the media (much like several other 'miracle foods'), there seems to be some scientific support for the claims for coconut oils [6]. Additionally, according to some research, coconut oil has antibacterial, antifungal, and antiviral agent for the treatment of dermal infections [7] [8].

Coconut oil has a record in the Ayurvedic script of India of being used as food and to cure illness as far back as 4,000 years ago. The Chinese had used it for more than 2,000 years to cure 69 diseases [9]. Likewise, people in most other lands where the coconut palms are grown have made use of it to cure all kinds of ailments for thousands of years. Similarly, coconut oil, together with its precursor, the coconut milk, has been used as foods in most countries from time immemorial. In this connection, Thailand is number one in the world in using coconut milk as a food ingredient. It is fair to say that it is the coconut milk that has made Thai dishes one of the most popular foods in the world [10]. Anyone who experiences a fungal infection knows just how frustrating it can be. Fungal infections can often cause much discomfort or even embarrassment (think stinky feet), but they rarely threaten your health in a serious way. There are many types of fungal infections, but some more common ones are athlete's foot, toenail or fingernail fungus, jock itch, candida or yeast infections, oral thrush, ringworm and meningitis [11]. The aim of this study is to evaluate the effect of coconut oil on athletes' foot.

Materials and Methods

Study Area: This study was carried out in Ekpoma, Esan West Local Government Area of Edo State. Edo state lies between longitude 06° 04ᴵE and 06° 43ᴵE and latitude 05° 44ᴵN and 07° 34ᴵN with a land mass of 17, 450 sq.km located in the South-South geopolitical zone of Nigeria with a population of 3.1 million people. Ekpoma is a semi- urban town with the major occupation of farming, trading, civil servants and students [12].

Ethical Permission: Ethical approval was obtained from the Management Ambrose Alli University Ethics committee; and informed consent was also sought from the subjects prior to sample collection.

Sample Collection: Samples were collected from students of Ambrose Alli University, Ekpoma, Edo State who are always putting on covered shoes using sterile cotton swabs, swabbed over the foot between the toes, and were immediately transferred to the Microbiology Laboratory of the Department of Microbiology Ambrose Alli University, Ekpoma, Edo State for microbiological analysis.

Sample Analysis: The samples were streaked onto Sabouraud dextrose agar (HI Media) plates and incubated in a 5%CO_2 enriched atmosphere at 37∘C for 24hours and left at room temperature for further 24 hours. Growth of *Candida* appeared as cream or white coloured, smooth, and pasty colonies. Culture is said to be negative if there is no growth even after 72 hours of incubation. Candidal species identification was done by Germ tube test which was read after 48 hours.

Fresh coconut (*Cocos nucifera*) was obtained from Ekpoma main market, Ekpoma, Edo State. The fresh coconut meat was grated and pressed using a sterilized sieve to produce coconut milk, which was allowed to ferment for 48 hours, after which the solids and water content were separated from the oil. The oil was then heated slightly to remove remaining moisture. The oil was then filtered by passage through a millipore size filter to give an aqueous extract of coconut oil. This was collected in a sterile vial (bottle) and stored at 4°C until use.

Sterility test: Extracted coconut oil was cultured on chocolate and Mac-Conkey's agar plates and incubated overnight at 37°C, the MacConkey's agar aerobically and the chocolate agar in a candle extinction jar.

Antimicrobial (Antibiogram) Activity Test: The antifungal susceptibility was determined by using using the disc diffusion method as described by Kirby-Bauer, (1966). The antifungal disc was locally prepared by

punching out disc 6mm in diameter from a good quality Whatmann no 1 filter paper and was sterilized for 25 minutes with autoclave. The fungal isolates were first inoculated in peptone water and incubated for 8 hours and were sub-cultured on nutrient agar, excess broth was tilled off and allowed to dry. Using a sterile forceps, the prepared sterile disc was picked and impregnated with the various extract with different concentration (15mg/ml, 30mg/ml and 60mg/ml) in 0.01ml and the disc placed on the inoculated agar plate equidistant from each other alongside with one locally prepared antifungal disc (fluconazole and ketoconazole) (4.0 μL/disc) and allowed to dry as positive control and diluents as negative control. It was incubated at 37^0C for 48 hours in an incubator and inhibition zone (IZ) was measured by using ruler calibrated in millimeters.

Results

The bacteria isolates were *Staphylococcus aureus* and *Klebsiella* spp while the fungal isolates were *Rhizopus* spp, *Candida* spp, *Penicillium* spp, *Trichophytum* spp and *Aspergillus* spp (Table 1).

Table 2 represents the Age, location of sample collected from the study, Number of positive and percentage prevalence of infection in the study. A total of 58 subjects were examined from Main campus while 42 were examined from College of Medicine in the study. Out the 100-subject sampled, 46 of them were within the age range of 19 – 21 years which where the highest group in the study, while those within the age range of 16 – 18 years and 22 – 25 years where 27 in each group.

Table 3 shows the Organisms Isolated according to Location. From the main campus, 50 bacteria and 32 fungi were isolated while from college of medicine, 40 bacteria and 28 fungi were isolated bringing it to a totl of 150 organisms that were isolated in all.

Table 4 shows the relationship between age range and organisms isolated in the study. *Staphylococcus aureus, Penicillium* spp and *Candida* spp were isolated from subjects within the age range of 16 – 18 years while, *Staphylococcus aureus, Klebsiella* spp, *Penicillium* spp, *Rhizopus* spp, *Aspergillus* spp, *Trichophytum* spp and *Candida* spp were isolated from subjects within the age range of 19 – 21 and 22 – 25 years.

Table 5 represents the antibacterial effects of coconut oil on the isolated bacteria with their zone of inhibition *Staphylococcus aureus* (16mm) and *Klebsiella* spp (13mm). The zone of inhibition of the control group are represented in the table below with both organisms been resistance to only Rifampicin.

Table 6 represents the antifungal effects of coconut oil on the isolated fungi from athletic foots. From the study, the coconut oil extract had effects on the fungus with *Aspergillus* spp having zone of inhibition (ZI) of 21mm which was the highest ZI in the group of fungi isolated followed by *Penicillium* spp (18mm), *Candida* spp (16.8mm), *Trichophytum* spp (15.1mm) and *Rhizopus* spp (11mm) which was the least inhibited. The control antifungal susceptibility test showed that clotrimoxazole had more effects on the fungus than fluconazole.

Table 1: Organisms isolated from subjects in the study

Class of Organism	Organisms Isolated	No Isolated	Percentage prevalence (%)
Bacteria	*Staphylococcus aureus*	86	57.3
	Klebsiella spp	4	2.7
Fungi	*Candida* spp	22	14.7
	Penicillium spp	4	2.7
	Aspergillus spp	8	5.3
	Rhizopus spp	20	13.3
	Trichophytum spp	6	4
Total		**150**	**100**

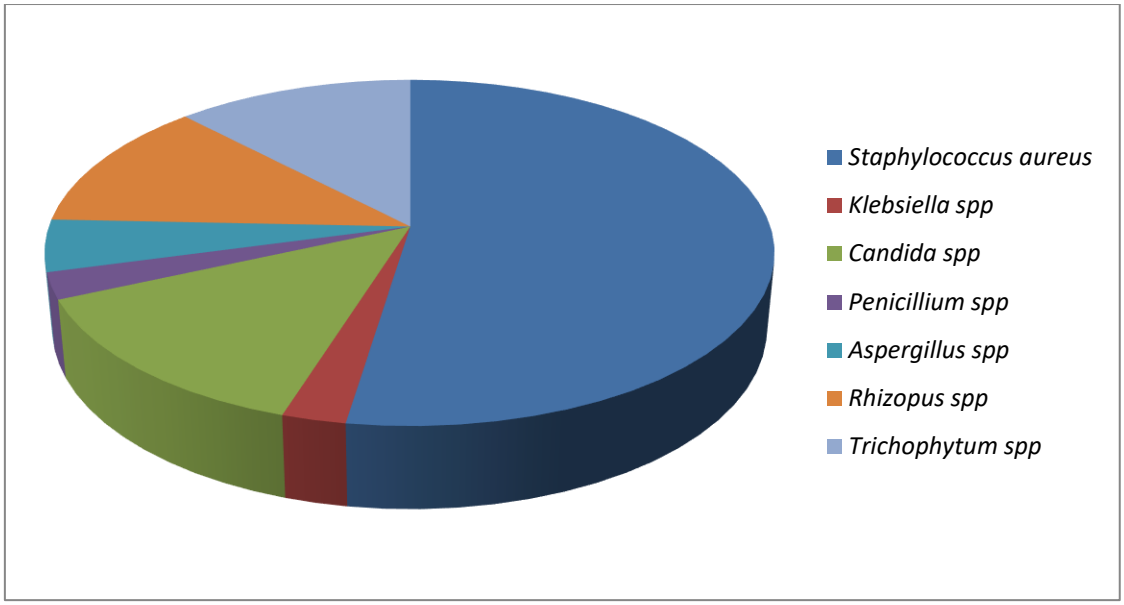

Figure 1: Percentage prevalence of Infection in the study

Table 2: Age, location of sample collected from the study, Number of positive and percentage prevalence of infection in the study.

Age Range	Main Campus (+ve)	College of Medicine (+ve)	Total No Examined (+ve)
16 – 18	18	9	27
19 – 21	29	17	46
22 – 25	11	16	27
Total	58	42	100

Table 3: Organisms Isolated according to Location

Location	Bacteria	Fungi	Total
Main Campus	50	32	82
College of Medicine	40	28	68
Total	**90**	**60**	**150**

Table 4: Relationship between Age range and Organisms isolated in the Study

Age range	Bacteria	Fungi
16 – 18	*Staphylococcus aureus* (17)	*Candida* spp (4) *Penicillium* spp (1)
19 – 21	*Staphylococcus aureus* (58) *Klebsiella* spp (3)	*Candida* spp (13) *Penicillium* spp (2) *Rhizopus* spp (12) *Trichophytum* spp (4) *Aspergillus* spp (6)
22 – 25	*Staphylococcus aureus* (11) *Klebsiella* spp (1)	*Candida* spp (5) *Penicillium* spp (1) *Rhizopus* spp (8) *Trichophytum* spp (2) *Aspergillus* spp (2)
TOTAL	**90**	**60**

Table 5: Antibiotic Susceptibility Table

Antibiotics	Zone of Inhibition	
	Staphylococcus aureus	*Klebsiella* spp
Coconut Extract	16mm	13mm
Control		
Ciprofloxacin	S (33mm)	S (20mm)
Norfloxacin	R (0mm)	R (2mm)
Gentamycin	S (21mm)	S (18mm)
Amox**acil**l**in**	S (42mm)	S (35mm)
Streptomycin	S (36mm)	S (28mm)
Rifampicin	S (35mm)	S (32mm)
Erythromycin	S (33mm)	S (30mm)
Chloramphanicol	S (22mm)	S (18mm)
Ampiclox	S (27mm)	S (24mm)
Levofloxacin	S (40mm)	S (38mm)

Table 6: Antifungal Susceptibility Table

Antifungal	Zone of Inhibition				
	Candida spp	*Penicillium* spp	*Aspergillus* spp	*Rhizopus* spp	*Trichophytum* spp
Coconut Extract	16.8mm	18mm	21mm	11mm	15.1mm
Control					
Fluconazole	6mm	13mm	11mm	10mm	5mm
Clotrimoxazole	23mm	32mm	19mm	18mm	24mm

Table 7: Phytochemical Composition of Coconut oil.

Phytochemical	Observations	Concentrations (mg/g)
Flavoniods	+	0.230.08
Phenols	-	-
Tannins	-	-
Saponnins	+	0.03±0.01
Phlobatanins	-	-
Alkaloids	+	0.11±0.01
Steriods	+	NQ
Terpenoids	+	NQ
Cardiac glycosides	-	-
Anthraquinones	-	-

+ = Present; - = Not Detected; NQ = Not Quantified

Discussion

Cultures across the globe have used the *Cocos nucifera L.* plant for many generations. Constituents of coconut oil, predominantly lauric acid, have *in vitro* and *in vivo* evidence for killing a wide variety of bacteria and fungi species. Though lauric acid has a lower MIC compared to other fatty acids, it does not achieve the same bacteriostatic or bactericidal potential as commercially available antibiotics. Coconut oil can be prepared in emulsions and liposomes and retain anti-infective properties. Given the low side effect burden, it may be a reasonable option for patients with mild to moderate dermal infections, especially acne vulgaris caused by *P. acnes*, polymicrobial atopic dermatis, impetigo, or wound infections. Additional randomized controlled trials are needed to solidify the place in therapy of *C. nucifera* as a treatment of dermal infections.

Coconut oil is known to exhibit antimicrobial activity against bacteria and fungi [13]. It has a unique role in the diet as an important physically functional food and is composed of medium chain fatty acids. It contains 92%

saturated fatty acids, approximately 50% of which is lauric acid [14]. Monolaurin and other medium chain monoglycerides are shown to have the capacity to alter microbial cell walls, penetrate and disrupt cell membranes, and inhibit enzymes involved in energy production and nutrient transfer, leading to the death of the bacteria [15]. Bergsson *et al.* [16] showed the susceptibility of *Candida albicans* to several fatty acids and their 1-monoglycerides. In the present study coconut oil has shown antifungal activity that is comparable to that of ketoconazole. *C. albicans* was found to be highly susceptible to coconut oil in a similar study by Ogbolu *et al.* [17]. Coconut oil is also known to cause a significant reduction in gingivitis which can be attributed to decreased plaque accumulation and the anti-inflammatory, emollient effect of coconut oil [18].

In this study *Candida* spp was the most common fungi isolate from the clinical specimens. This correlates with the work of Hiroshige *et al*., [19] in which 24 of 72 isolates were *Candida* spp. Generally, coconut oil showed a remarkable activity against the *Candida* species. Bergsson *et al*. [16] tested the components of coconut oil (capric acid, lauric acid) for cytotoxicity, and it was stated that even if lipids are toxic in cell cultures, other studies have shown that they are not toxic to skin and mucosa at much higher concentrations. If these chemical constituents are extracted and made into cream, there might be better activity, and the MIC would be much reduced [16].

Candida isolates had higher susceptibility to coconut oil than to fluconazole (Table 4.7) but *Aspergillus* spp. was more susceptible among the fungi group. Also *Candida* spp isolates were more susceptible to clotrimoxazole than coconut oil, of which *Penicillum* spp had the highest susceptibility to clotrimoxazole. It has been reported that fluconazole even at higher concentrations is fungistatic rather than fungicidal [20]. Although it may not be clear in this study whether the zone of inhibition depicts a fungicidal or fungistatic activity, another study that tested the *in vitro* killing of *Candida* spp. by capric acid and lauric acid (both components of coconut oil) counted calories and analyzed lipid–yeast mixtures by the Turkey-Kramer method of multiple comparisons. The reduction in infectivity titers suggested some fungicidal activity by capric acid and lauric acid [21]. It can thus be said, through this study and previous ones, that coconut oil is active in killing *Candida* species. We suggest that coconut oil should be used for infection caused by *Candida* species.

Conclusion

In conclusion, the results obtained in this study have elucidated the use of coconut oil in complementary and alternative medicine, especially in this era of emerging drug-resistant *Candida* species and other forms of microorganisms. The results of this study indicate that coconut oil exerts an antibacterial and antifungal effect. The findings as reported in the present study indicate a strong potential therapeutic value of coconut oil against some isolated bacteria and fungi. Oral therapeutic products from coconut oil should be safe, effective and efficient alternative in antifungal therapy clinically. This will certainly increase the quality of life and decrease morbidity of the chronic fungal oral lesion that are seen associated with several debilitating diseases especially in the extremes of life.

- It is therefore important to carry out preventative measures, such as regular change of hosiery, alternation of footwear, allowing circulation of air to feet where possible and use of antifungal powders, sprays or creams.
- While research has revealed no ill side effects from coconut oil, people should still exercise caution before using it to treat yeast infections.
- Anyone who is allergic to coconuts or coconut oil should not use it under any circumstances.
- Additionally, people should not use coconut oil to treat yeast infections if:
    - Another form of treatment including over the counter or prescription treatments are in use.
    - It is not certain that there is a yeast infection present.
    - Yeast infections are recurring.
- People with other health conditions or who are pregnant should consult their doctor before using coconut oil to treat a yeast infection.
- Further studies should be carried out to determine the MIC, and MFC of these agents and more clinical studies have to be conducted to validate the same.

Conflict of Interest

The authors declare no conflicts of interest. The authors alone are responsible for the content and the writing of the paper.

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Authors' Contributions

The entire study procedure was conducted with the involvement of all writers.

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