



Effects of Coconut (*Cocos nucifera* Linn.) Water and Oil on the Ileal Bacterial Flora of Apparently Healthy Wistar Albino Rats

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Authors' contributions

This work was carried out in collaboration between both authors. Author DOA carried out the research, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author TTA designed and supervised the research. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAMB/2020/v20i730268

Editor(s):

(1) Dr. Foluso O. Osunsanmi, University of Zululand, South Africa.

Reviewers:

(1) Chatragadda Ramesh, National Centre for Coastal Research (NCCR), India.

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Complete Peer review History: <http://www.sdiarticle4.com/review-history/52414>

Original Research Article

Received 14 September 2019

Accepted 17 November 2019

Published 15 August 2020

ABSTRACT

In this study, the biosafety of the consumption of coconut water and oil was investigated. This was carried out by assessing their effects on the types and population of bacterial flora in the ileum of Apparently Healthy Wistar (AHW) rats. Both the *in vitro* and *in vivo* assays were employed. The *in vitro* assay was used for the assessment of the antibacterial activity of coconut water and oil on the bacteria isolated from the ileum of AHW rats while the *in vivo* assay was carried out in AHW rats (n=100) orally administered either coconut water or oil to monitor the effect *in situ*. In the *in vivo* assay, the albino rats (n= 100) were divided into 8 groups (A-H) of 12 rats each while the remaining four rats were put in another group to serve as a control. The first four groups (A-D) were daily orogastrically administered different volumes of coconut oil, 0.5 ml, 1.0 ml, 1.5 ml, 2.0 ml respectively for 4 weeks while groups E-H were daily orogastrically administered different volumes of coconut water, 0.5 ml, 1.0 ml, 1.5 ml, 2.0 ml respectively for four weeks. The control rats (Group I) however were not administered either coconut water or coconut oil. All the rats were allowed free

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access to rat chow and water. Seven distinct bacterial species were isolated from the ileum of (AHW) rats used in this study. These are *Escherichia coli*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Shigella flexneri*, *Serratia marscense*, and *Morganella morganii*. Both the coconut water and oil used inhibited the growth of all the bacteria isolated from the ileum of the rats with diameter zones of inhibition ranging from 7.50±0.50 mm to 23.00±2.00 mm and 4.25±0.25 mm to 19.00±1.00 mm respectively. The growth inhibition exerted by both, however, was lower than that of the conventional antibiotic (Ciprofloxacin) used as control which ranged from 12.00±0.50 mm to 42.50±2.50 mm. In the *in vivo* assay, coconut oil reduced the population of the ileal bacterial flora of the rats with the highest effect on *Escherichia coli* from 2.39×10^6 to 8.3×10^5 cfu/ml while coconut water had minimal growth inhibitory activity on the bacterial load from 2.39×10^6 to 1.23×10^6 cfu/ml after 28 days of administration. These growth inhibitions, however, did not become significant ($p < 0.05$) on the population of most of the bacterial flora until after 7 d of administration of either coconut water or oil with a dose between 0.5 and 1.0 ml. On the other hand, the administration of either coconut water or oil did not alter the types of bacterial flora in the ileum of the rats throughout this study. In conclusion, the administration of coconut water or oil to AHW rats did not significantly ($p \leq 0.05$) affect the population of the bacterial flora in their ileum within the first 7 days of consumption and also did not affect the bacterial types, therefore when consuming either, the duration should not exceed 7 d at a stretch so that the bacterial flora inhabiting the gut of consumers will not be adversely affected.

Keywords: Coconut water; coconut oil; antibacterial effect; ileal bacterial flora.

ABBREVIATION

AHW: Apparently Healthy Wistar.

1. INTRODUCTION

Gut microbiota or gastrointestinal microflora is the complex community of microorganisms that live in the digestive tracts of humans and other animals, including insects. It is established at one to two years after birth. It provides a barrier to pathogenic organisms, help in food digestion and also production of vitamins among other benefits [1,2]. Factors affecting the distribution of intestinal microflora according to Blaabjerg, et al. [2] include age and diet, while some factors affecting the population of intestinal microflora are antibiotic use, pregnancy and probiotics. Coconut (*Cocos nucifera* Linn.) is a common fruit in the tropics. It consists of a fibrous outer layer called coconut husk (mesocarp), which covers a hard layer shell (endocarp). Inside the shell is a kernel (endosperm) which contains water referred to as "coconut water" [3]. This water contains some sugars such as glucose, fructose, and sucrose and also contains vitamins such as vitamin B1, vitamin B2, and vitamin C. Coconut water is used in folklore medicine as an adjunct to treat various ailments. Coconut oil, on the other hand, is the edible oil extracted from the "meat" of matured coconuts [3,4]. It has several applications in the food industry and it is also used as a moisturizer in cosmetics and detergents [5]. It is also used as an antibacterial,

antifungal, antiviral and anti-dermatophytes agent [6,7]. It is also consumed in folklore medicine to treat various ailments and also to delay ageing. Therefore, based on the many uses of coconut water and coconut oil, it became of interest to investigate whether the consumption of either has any deleterious effect on the microbial flora of the consumers as do many antibiotics that are used to treat bacterial infections. This study, therefore, is to assess the effects of the consumption of coconut water or coconut oil on the ileal bacterial flora of Wistar rats as a guide to the possible effects in humans when consumed for a considerable period.

2. MATERIALS AND METHODS

2.1 Coconut Water

Fresh coconut water was drilled from cleaned coconuts bought from the commercial fruit market in Akure, Nigeria.

2.2 Coconut Oil

Coconut oil (AQUILLA 100% Virgin Coconut Oil with NAFDAC Reg. No. 08-1725L) was used for this study.

2.3 Experimental Animals

Healthy Wistar (AHW) rats, age 6-8 weeks were used for this study.

2.4 In vitro Assay

Four AHW rats were dissected, the ileum cut and the different types of bacteria present in the ileum were isolated and identified. Each of the isolated bacteria was then assessed for its susceptibility to coconut water and coconut oil using agar well diffusion assay using standard microbiological techniques according to Oladejo and Adebolu [8]. Ciprofloxacin (30 ug) was used as the positive control. Five wells of 5 mm diameter were made using a sterile cork borer on the plates already seeded with a particular bacterial isolate. Different volumes of coconut oil; 0.5 ml, 1.0 ml, 1.5 ml, 2.0 ml was added into 4 different wells respectively and ciprofloxacin into the 5th well. Plates were labelled accordingly and incubated at 37°C for 24 h. After incubation, the diameter of the clear zones around each well was recorded as a measure of susceptibility. The assay was done in triplicates. Coconut water was also assayed using the same procedure.

2.5 In vivo Assay

AHW rats (n=100) were divided into 8 groups (A-H) of 12 rats each while the remaining four rats were put in another group to serve as the control. The first four groups (A-D) were daily orally administered different volumes of coconut oil; 0.5 ml, 1.0 ml, 1.5 ml, 2.0 ml respectively for 4 weeks while groups E-H were daily orally administered different volumes of coconut water; 0.5 ml, 1.0 ml, 1.5 ml, 2.0 ml respectively for four weeks. The control rats (Group I) however were not administered either coconut water or coconut oil. All the rats were allowed free access to rat chow and water. At intervals of 1 week, 3 rats were randomly picked from each group, anaesthetized, dissected and an inch of the ileum was cut and collected into sterile distilled water for the analysis of bacterial loads and types using the method of Oloyede, et al. [9]. The dissected ileum was rinsed in 10ml sterile distilled water after which dilutions were made to 10⁻⁵ before plating on agar (Nutrient Agar, Mac-Conkey Agar, Eosin Methylene Blue Agar, Salmonella-Shigella Agar). The number of colony-forming units (CFU) of bacteria that grew after incubation at 37°C for 24 hrs was enumerated visually using a Gallenkamp colony counter.

2.6 Statistical Analysis

Data generated from the study were subjected to three-way Analysis of Variance (ANOVA).

Treatment means were compared using Duncan's New Multiple Range Test (DNMRT) at 5% level of significance using SPSS version 26.

3. RESULTS

Seven distinct bacterial species were isolated from the ileum of AHW rats used in this study. They are *Escherichia coli*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Shigella flexneri*, *Serratia marscesens*, and *Morganella morganii*. The coconut oil and coconut water used inhibited the growth of all these bacteria that were isolated from the ileum of AHW rats with diameter zones of inhibition ranging from 7.50±0.50 mm to 23.00±2.00 mm and 6.35±0.15 mm to 19.00±1.00 mm respectively. That is, the inhibition exerted by the coconut oil was superior to that mediated by coconut water on all the isolates except for *K. pneumoniae*. The growth inhibitions exerted by either coconut oil or coconut water were, however, inferior to that mediated by the conventional antibiotic (ciprofloxacin) used as control which ranged from 12.00±0.50 mm to 42.50±2.50 mm. It was only on *Serratia marscesens* that the growth inhibition exerted by the oil was comparable to that exerted by the control (Ciprofloxacin) which ranged between 14.25±0.75 mm and 14.50±0.50 mm respectively (Table 1). In the *in vivo* assay, administration of coconut oil at a dose not greater than 1.0 ml did not cause any significant reduction in the population of *E. coli* by 7th day of administration to the rats while it was a dose not greater than 0.5 ml using coconut water (Table 2). Although both the coconut oil or water caused a reduction in the population of the bacterial species present in the ileum of AHW rats (Tables 4-9), they, however, did not affect the types of bacteria present in the ileum. That is all the types of bacteria present in the rats that were not administered either coconut oil or water were also isolated in the rats administered either coconut oil or water but with the addition of another bacterial species, *Enterococcus intermedius* (Table 10).

4. DISCUSSION

In this study, the effect of the consumption of either coconut oil or coconut water on the ileal bacterial flora of AHW rats was carried out. Both the *in vitro* and *in vivo* assays used revealed that both exerted growth inhibitory activity on the isolated bacteria from the ileum of AHW rats on agar plates and also *in situ*. However, the growth

Table 1. Comparative growth-inhibitory antibacterial activities of coconut oil, coconut water and ciprofloxacin on the isolated ileal bacterial flora

Treatment	Isolated bacteria/Diameter of zone of inhibition(mm)							
	<i>E. coli</i>	<i>K. pneumoniae</i>	<i>P. aeruginosa</i>	<i>P. mirabilis</i>	<i>S. flexneri</i>	<i>E. inter</i>	<i>S. marcescens</i>	<i>Morganella</i>
Ciprofloxacin	42.50±2.50 ^c	29.5±0.50 ^b	28.05±0.45 ^c	24.50±0.55 ^b	37.50±2.50 ^c	31.75±0.75 ^b	14.50±0.50 ^b	12.00±0.50 ^b
Coconut Water	19.00±1.00 ^a	13.75±0.75 ^{ab}	4.25±0.25 ^a	6.35±0.15 ^a	4.75±0.25 ^a	9.00±1.00 ^a	8.50±0.50 ^a	6.60±0.40 ^a
Coconut oil	23.00±2.00 ^b	10.20±0.30 ^a	9.20±0.30 ^b	9.25±0.25 ^{ab}	9.00±1.00 ^b	9.00±0.50 ^a	14.25±0.75 ^b	7.50±0.50 ^a

Data are presented as Mean ± S.E (n=3). Values with the same superscript letter(s) along the same column are not significantly different (P>0.05)

Table 2. Effects of administration of coconut water or oil on the colony counts (10⁶) of *Escherichia coli* (cfu/ml) in the ileum of AHW rats

Sample	Days of assay	Doses of sample administered				
		0.0 ml	0.5 ml	1 ml	1.5 ml	2.0 ml
Coconut oil	Day 0	2.39±0.00 ^a	2.39±0.00 ^{cd}	2.39±0.00 ^d	2.39±0.00 ^c	2.39±0.00 ^c
	Day 7	2.39±0.00	2.35±0.00 ^c	2.28±0.00 ^d	1.99±0.50 ^{bc}	1.65±0.00 ^b
	Day 14	2.39±0.00	1.85±0.00 ^b	1.75±0.50 ^{bc}	1.54±0.50 ^{ab}	1.26±0.00 ^{ab}
	Day 21	2.39±0.00	1.54±0.00 ^{ab}	1.42±0.50 ^{ab}	1.22±0.00 ^a	0.94±0.00 ^a
	Day 28	2.39±0.00	1.29±0.00 ^a	1.09±0.00 ^a	0.96±0.00 ^a	0.83±0.00 ^a
Coconut water	Day 0	2.39±0.00 ^a	2.39±0.00 ^b	2.39±0.00 ^b	2.39±0.00 ^c	2.39±0.00 ^b
	Day 7	2.39±0.00	2.25±0.00 ^b	1.69±0.00 ^a	1.57±0.50 ^b	1.53±0.00 ^a
	Day 14	2.39±0.00	1.67±0.00 ^a	1.59±0.50 ^a	1.53±0.50 ^a	1.52±0.00 ^a
	Day 21	2.39±0.00	1.62±0.50 ^a	1.53±0.50 ^a	1.47±0.50 ^a	1.44±0.50 ^a
	Day 28	2.39±0.00	1.41±0.50 ^a	1.27±0.50 ^a	1.27±0.50 ^a	1.23±0.00 ^a

Data are presented as Mean±S.E (n=3). Values with the same superscript letter(s) along the same column are not significantly different (P>0.05)

Table 3. Effects of administration of *Cocos nucifera* Linn. water and oil on the colony counts (10^6) of *K. pneumoniae* (cfu/ml) in the ileum AHW rats

Sample	Days of assay	Doses of sample administered				
		0.0 ml	0.5 ml	1 ml	1.5 ml	2.0 ml
Coconut oil	Day 0	2.42±0.00 ^a	2.42±0.00 ^b	2.42±0.00 ^c	2.42±0.00 ^d	2.42±0.00 ^c
	Day 7	2.42±0.00	2.31±0.33 ^b	2.29±0.00 ^b	2.12±0.33 ^{cd}	1.94±0.50 ^{bc}
	Day 14	2.42±0.00	1.92±0.50 ^b	1.72±0.00 ^{ab}	1.58±0.50 ^{bc}	1.39±0.00 ^{ab}
	Day 21	2.42±0.00	1.36±0.00 ^a	1.32±0.00 ^a	1.19±0.00 ^{ab}	1.06±0.50 ^a
	Day 28	2.42±0.00	1.31±0.00 ^a	1.18±0.00 ^a	1.02±0.00 ^a	0.88±0.33 ^a
Coconut water	Day 0	2.42±0.00 ^a	2.42±0.00 ^b	2.42±0.00 ^a	2.42±0.00 ^b	2.42±0.00 ^b
	Day 7	2.42±0.00	2.35±0.00 ^b	2.25±0.00 ^c	2.34±0.00 ^b	2.32±0.50 ^b
	Day 14	2.42±0.00	2.23±0.00 ^b	2.01±0.50 ^b	1.98±0.50 ^{ab}	1.84±0.50 ^{ab}
	Day 21	2.42±0.00	1.73±0.50 ^a	1.95±0.50 ^{ab}	1.85±0.00 ^{ab}	1.42±0.50 ^a
	Day 28	2.42±0.00	1.36±0.00 ^a	1.84±0.50 ^d	1.61±0.50 ^a	1.41±0.50 ^a

Data are presented as Mean±S.E (n=3). Values with the same superscript letter(s) along the same column are not significantly different ($P>0.05$)

Table 4. Effects of administration of *Cocos nucifera* Linn. water and/or oil on the colony counts (10^6) of *Pseudomonas aeruginosa* (cfu/ml)

Sample	Days of assay	Doses of sample administered				
		0.0ml	0.5ml	1ml	1.5ml	2.0ml
Coconut oil	Day 0	2.34±0.33 ^a	2.34±0.33 ^b	2.34±0.33 ^c	2.34±0.33 ^d	2.34±0.33 ^c
	Day 7	2.34±0.33	2.32±0.50 ^b	2.28±0.00 ^c	2.06±0.00 ^c	1.94±0.33 ^b
	Day 14	2.34±0.33	1.74±0.00 ^{ab}	1.72±0.33 ^b	1.57±0.50 ^b	1.42±0.50 ^{ab}
	Day 21	2.34±0.33	1.34±0.33 ^a	1.40±0.50 ^{ab}	1.05±0.50 ^a	1.03±0.50 ^a
	Day 28	2.34±0.33	1.35±0.50 ^a	1.12±0.50 ^a	0.99±0.00 ^a	0.92±0.00 ^a
Coconut water	Day 0	2.34±0.33 ^a	2.34±0.33 ^b	2.34±0.33 ^{cd}	2.34±0.33 ^c	2.34±0.33 ^e
	Day 7	2.34±0.33	2.32±0.50 ^b	2.31±0.00 ^c	2.20±0.50 ^b	2.20±0.00 ^d
	Day 14	2.34±0.33	1.94±0.50 ^{ab}	2.13±0.33 ^b	1.95±0.50 ^{ab}	1.95±0.00 ^c
	Day 21	2.34±0.33	1.63±0.33 ^{ab}	1.80±0.50 ^a	1.84±0.50 ^a	1.74±0.00 ^b
	Day 28	2.34±0.33	1.55±0.00 ^a	1.73±0.50 ^a	1.63±0.50 ^a	1.50±0.33 ^a

Data are presented as Mean ±S.E (n=3). Values with the same superscript letter(s) along the same column are not significantly different ($P>0.05$)

Table 5. Effects of administration of *Cocos nucifera* Linn. water and oil on the colony counts (10^6) of *Proteus mirabilis* (cfu/ml)

Sample	Days of assay	Doses of sample administered				
		0.0ml	0.5ml	1ml	1.5ml	2.0ml
Coconut oil	Day 0	2.40±0.50 ^a	2.40±0.50 ^c	2.40±0.50 ^c	2.40±0.50 ^c	2.40±0.50 ^d
	Day 7	2.40±0.50	1.90±0.00 ^b	2.12±0.50 ^{bc}	2.02±0.50 ^{bc}	2.02±0.50 ^c
	Day 14	2.40±0.50	1.71±0.50 ^{ab}	1.95±0.00 ^b	1.71±0.00 ^b	1.75±0.00 ^{bc}
	Day 21	2.40±0.50	1.73±0.00 ^{ab}	1.52±0.00 ^{ab}	1.43±0.50 ^{ab}	1.53±0.50 ^{ab}
	Day 28	2.40±0.50	1.55±0.50 ^a	1.25±0.00 ^a	1.15±0.33 ^a	0.99±0.50 ^a
Coconut water	Day 0	2.40±0.50 ^a	2.40±0.50 ^c	2.40±0.50 ^c	2.40±0.50 ^e	2.40±0.50 ^c
	Day 7	2.40±0.50	2.30±0.00 ^b	2.08±0.33 ^{bc}	2.20±0.50 ^d	2.29±0.50 ^{bc}
	Day 14	2.40±0.50	1.95±0.00 ^{ab}	1.91±0.50 ^b	1.89±0.50 ^c	1.86±0.50 ^b
	Day 21	2.40±0.50	1.85±0.50 ^{ab}	1.82±0.50 ^{ab}	1.69±0.50 ^b	1.47±0.50 ^a
	Day 28	2.40±0.50	1.69±0.00 ^a	1.55±0.00 ^a	1.52±0.50 ^a	1.44±0.50 ^a

Data are presented as Mean±S.E (n=3). Values with the same superscript letter(s) along the same column are not significantly different (P>0.05)

Table 6. Effects of administration of *Cocos nucifera* Linn. water and oil on the colony counts (10^6) of *Shigella flexneri* (cfu/ml)

Sample	Days of assay	Doses of sample administered				
		0.0 ml	0.5 ml	1 ml	1.5 ml	2.0 ml
Coconut oil	Day 0	2.39±0.50 ^a	2.39±0.50 ^d	2.39±0.50 ^d	2.39±0.50 ^d	2.39±0.50 ^c
	Day 7	2.39±0.50	2.37±0.65 ^c	1.72±0.24 ^c	1.52±0.24 ^c	1.34±0.24 ^{bc}
	Day 14	2.39±0.50	1.96±0.50 ^b	1.53±0.53 ^b	1.43±0.65 ^b	1.22±0.24 ^b
	Day 21	2.39±0.50	1.55±0.24 ^a	1.39±0.12 ^{ab}	1.27±0.24 ^{ab}	1.05±0.65 ^{ab}
	Day 28	2.39±0.50	1.55±0.41 ^a	1.34±0.41 ^a	0.98±0.82 ^a	0.86±0.12 ^a
Coconut water	Day 0	2.39±0.50 ^a	2.39±0.50 ^d	2.39±0.50 ^{cd}	2.39±0.50 ^d	2.39±0.50 ^d
	Day 7	2.39±0.50	2.32±0.50 ^c	2.29±0.00 ^c	2.32±0.50 ^c	2.30±0.50 ^c
	Day 14	2.39±0.50	2.25±0.50 ^{bc}	1.96±0.50 ^{bc}	1.97±0.00 ^b	1.97±0.50 ^b
	Day 21	2.39±0.50	1.82±0.00 ^{ab}	1.89±0.40 ^b	1.82±0.00 ^{ab}	1.50±0.50 ^{ab}
	Day 28	2.39±0.50	1.61±0.00 ^a	1.70±0.50 ^a	1.50±0.50 ^a	1.33±0.20 ^a

Data are presented as Mean±S.E (n=3). Values with the same superscript letter(s) along the same column are not significantly different (P>0.05)

inhibition mediated by either coconut oil or coconut water on the agar plate was inferior to that exerted by the control antibiotic (Ciprofloxacin) used. That is, both the coconut oil and the coconut water exerted a milder effect on the isolated ileal bacteria flora than ciprofloxacin. The implication of this is that when either coconut oil or coconut water is consumed, they might not disrupt the gut bacterial flora of consumers. However, the *in vivo* assay revealed that the duration of administration of either coconut oil or coconut water and the dose administered play a significant role in the ileal bacterial flora of AHW rats. For instance, the administration of coconut oil or coconut water at a dose of ≤ 1.0 ml did not cause a significant ($p < 0.05$) reduction in the population of the ileal bacterial flora of AWR rats by day 7 of daily administration but when the dose was increased to 2.0 ml, the reduction became significant ($p < 0.05$) irrespective of the duration of administration. That is, the higher the dose of the coconut water or coconut oil

administered to the rats, the greater the reduction in the population of the ileal bacterial flora and the longer the duration of administration, the greater the reduction of the population of the ileal bacterial flora. Coconut oil was observed to exert greater inhibitory activity on the ileal bacterial flora than coconut water which shows that coconut water has a milder effect on the ileal bacterial flora of the rats. However, the administration of either coconut oil or coconut water did not affect the types of bacterial flora present in the ileum of the rats. The antibacterial activity of coconut oil has been attributed to the presence of carboxylic acid-monolaurin which metabolizes to lauric acid in the body as reported by Oyi, et al. [10] who studied the effectiveness of Virgin coconut oil in the treatment of skin infections caused by *Pseudomonas aeruginosa*, *Escherichia coli*, *Proteus vulgaris*, *Bacillus subtilis* and *Candidia albicans*. Dierick, et al. [5] also reported that the controlled release of medium-chain fatty acids

(MCFA) from coconut oil results in significant suppression of the intestinal flora (total bacterial count). *Escherichia coli* was the most susceptible to the inhibitory activity of either coconut oil or coconut water out of all the bacterial species present in

Table 7. Effects of administration of *Cocos nucifera* Linn. water and oil on the colony counts (10^6) of *Enterobacter intermedius* (cfu/ml)

Sample	Days of assay	Doses of sample administered				
		0.0 ml	0.5 ml	1 ml	1.5 ml	2.0 ml
Coconut oil	Day 0	2.73±0.50 ^a	2.73±0.50 ^c	2.73±0.50 ^c	2.73±0.50 ^d	2.73±0.50 ^d
	Day 7	2.73±0.50	2.70±0.77 ^c	2.50±0.10 ^{bc}	1.93±0.50 ^{cd}	1.67±0.50 ^{bc}
	Day 14	2.73±0.50	2.53±0.89 ^b	2.10±0.50 ^{bc}	1.76±0.50 ^c	1.72±0.50 ^c
	Day 21	2.73±0.50	1.71±0.82 ^a	1.63±0.40 ^b	1.51±0.50 ^{ab}	1.28±0.33 ^{ab}
	Day 28	2.73±0.50	1.70±0.41 ^a	1.34±0.50 ^a	1.18±0.33 ^a	1.05±0.40 ^a
Coconut water	Day 0	2.73±0.50 ^a	2.73±0.50 ^c	2.73±0.50 ^c	2.73±0.50 ^d	2.73±0.50 ^d
	Day 7	2.73±0.50	2.51±0.00 ^{bc}	2.72±0.50 ^{bc}	2.62±0.33 ^c	2.72±0.00 ^d
	Day 14	2.73±0.50	2.31±0.50 ^b	2.00±0.90 ^{ab}	1.34±0.50 ^a	2.05±0.00 ^c
	Day 21	2.73±0.50	1.88±0.00 ^a	1.90±0.50 ^{ab}	1.42±0.00 ^{ab}	1.71±0.00 ^b
	Day 28	2.73±0.50	1.81±0.50 ^a	1.82±0.50 ^a	1.53±0.00 ^b	1.40±0.10 ^a

Data are presented as Mean±S.E (n=3). Values with the same superscript letter(s) along the same column are not significantly different (P>0.05)

Table 8. Effects of administration of *Cocos nucifera* Linn. water and oil on the colony counts (10^6) of *Serratia marcescens* (cfu/ml)

Sample	Days of assay	Doses of sample administered				
		0.0 ml	0.5 ml	1 ml	1.5 ml	2.0 ml
Coconut oil	Day 0	2.53±0.40 ^a	2.53±0.40 ^c	2.53±0.40 ^d	2.53±0.40 ^d	2.53±0.40 ^e
	Day 7	2.53±0.40	2.52±0.40 ^c	2.24±0.50 ^c	1.99±0.40 ^c	1.92±0.50 ^d
	Day 14	2.53±0.40	2.03±0.33 ^{bc}	1.83±0.40 ^{bc}	1.60±0.40 ^c	1.49±0.50 ^c
	Day 21	2.53±0.40	1.64±0.50 ^{bc}	1.42±0.40 ^b	1.38±0.50 ^b	1.27±0.00 ^b
	Day 28	2.53±0.40	1.53±0.00 ^a	1.08±0.33 ^a	1.07±0.33 ^a	1.10±0.00 ^a
Coconut water	Day 0	2.53±0.40 ^a	2.53±0.40 ^d	2.53±0.40 ^e	2.53±0.40 ^{bc}	2.53±0.40 ^d
	Day 7	2.53±0.40	2.49±0.50 ^c	2.52±0.40 ^d	2.45±0.40 ^b	2.52±0.50 ^c
	Day 14	2.53±0.40	1.90±0.50 ^{ab}	2.12±0.50 ^c	1.98±0.33 ^b	1.86±0.50 ^{bc}
	Day 21	2.53±0.40	1.73±0.50 ^a	1.71±0.50 ^b	1.90±0.60 ^b	1.78±0.40 ^b
	Day 28	2.53±0.40	1.58±0.50 ^a	1.58±0.50 ^a	1.40±0.50 ^a	1.30±0.60 ^a

Data are presented as Mean±S.E (n=3). Values with the same superscript letter(s) along the same column are not significantly different (P>0.05)

Table 9. Effects of administration of *Cocos nucifera* Linn. water and oil on the colony counts (10^6) of *Morganella morganii* (cfu/ml)

Sample	Days of assay	Doses of sample administered				
		0.0 ml	0.5 ml	1 ml	1.5 ml	2.0 ml
Coconut oil	Day 0	1.96±0.50 ^a	1.96±0.50 ^a	1.96±0.50 ^a	1.96±0.50 ^a	1.96±0.50 ^c
	Day 7	1.96±0.50	1.96±0.00 ^a	1.95±0.10 ^a	1.82±0.33 ^a	1.72±0.33 ^{bc}
	Day 14	1.96±0.50	1.60±0.20 ^a	1.75±0.00 ^a	1.38±0.50 ^a	1.42±0.33 ^{abc}
	Day 21	1.96±0.50	1.53±0.50 ^a	1.48±0.50 ^a	1.27±0.50 ^a	1.19±0.20 ^{ab}
	Day 28	1.96±0.50	1.57±0.50 ^a	1.35±0.50 ^a	1.16±0.33 ^a	0.91±0.00 ^a
Coconut water	Day 0	1.96±0.50 ^a	1.96±0.50 ^a	1.96±0.50 ^a	1.96±0.50 ^a	1.96±0.50 ^b
	Day 7	1.96±0.50	1.93±0.50 ^a	2.48±0.50 ^a	1.74±0.50 ^a	1.62±0.00 ^{ab}
	Day 14	1.96±0.50	1.62±0.33 ^a	2.11±3.50 ^a	1.62±0.33 ^a	1.40±0.00 ^a
	Day 21	1.96±0.50	1.47±0.33 ^a	1.70±0.50 ^a	1.27±0.40 ^a	1.20±0.00 ^a
	Day 28	1.96±0.50	1.37±0.50 ^a	1.61±0.50 ^a	1.22±0.40 ^a	1.17±0.50 ^a

Data are presented as Mean±S.E (n=3). Values with the same superscript letter(s) along the same column are not significantly different (P>0.05)

Table 10. Bacterial species isolated from the ileum of AHW rats after administration of either coconut water or oil

Bacterial species	Group A	Group B	Group C	Group D	Group E	Group F	Group G	Group H	Group I
<i>Escherichia coli</i>	+	+	+	+	+	+	+	+	+
<i>Klebsiella pneumoniae</i>	+	+	+	+	+	+	+	+	+
<i>Proteus mirabilis</i>	+	+	+	+	+	+	+	+	+
<i>Serratia marcescens</i>	+	+	+	+	+	+	+	+	+
<i>Pseudomonas aeruginosa</i>	+	+	+	+	+	+	+	+	+
<i>Enterobacter intermedium</i>	-	-	-	-	-	-	-	-	+
<i>Morganella morganii</i>	+	+	+	+	+	+	+	+	+
<i>Shigella flexneri</i>	+	+	+	+	+	+	+	+	+
	7	7	7	7	7	7	7	7	8

Key; I- control; A, B, C, D (0.5 ml, 1.0 ml, 1.5 ml, 2.0 ml coconut oil respectively); E, F, G, H (0.5 ml, 1.0 ml, 1.5 ml, 2.0 ml coconut water respectively), + (present), - (not present)

the ileum of the rats at day 28. The implication of this is that the consumption of either coconut oil or water can affect the roles that *E. coli* plays in the gut of the rats which might include digestion, production of vitamins B and K as well as metabolizing bile acids, sterols and xenobiotics [1].

Since prolonged administration of either coconut oil or coconut water can lead to the significant reduction of the population of the ileal bacterial flora of rats, it is conceivable that they might also affect the gastrointestinal flora of humans when consumed to treat different ailments. Further work is, therefore, being recommended to determine the dose that will not have deleterious effect on the consumption of either coconut oil or coconut water in humans and the duration of consumption so as to prevent the reduction of beneficial bacterial flora in the gut which can lead to the upset in the microbial balance in the gut.

5. CONCLUSION

In conclusion, in the interim, it is imperative that the duration of consumption of either coconut oil or coconut water should not exceed 7 days and that the dose to be administered should not be such that will eliminate the beneficial bacteria inhabiting the gut because prolonged consumption of coconut products especially coconut oil could lead to significant reduction of the population of the beneficial microflora in the gut of consumers.

ETHICAL APPROVAL

As per international standard written ethical approval has been collected and preserved by the author(s).

ACKNOWLEDGEMENT

This goes out to all the authors whose works were reference points for this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:

The peer review history for this paper can be accessed here:
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