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Prevention of Tuberculosis Transmission in Households Using Virgin Coconut Oil and Multi-Drug Treatment: A Quasi-Experimental Study

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Abstract: The increasing prevalence and incidence of tuberculosis each year highlights the need to use Virgin Coconut Oil (VCO) in conjunction with multi-drug treatment to help suppress the transmission of tuberculosis within families. Lauric acid, the main component of VCO, transforms into monolaurin in the digestive tract. Monolaurin is a substance known to enhance the body's immune system. This study aimed to determine the effectiveness of Multi-drug Treatment and VCO treatment on Tuberculosis incidence in household contacts associated with cost effective analysis (CEA). This study employs a quasi-experimental method, a form of quantitative research akin to a true experiment but does not involve full randomisation of subjects or groups. Subjects were divided into two groups. The treatment group consisted of new tuberculosis patients who received a combination of multi-drug treatment and virgin coconut oil (VCO). Their household contacts were tested to determine whether they were positive for acid-fast bacilli at the initial stage and again at the second month of the study. The control group included new tuberculosis patients who received the Directly Observed Treatment Short Course (DOTS) or the multi-drug treatment (MDT) package only. Similar to the treatment group, their household contacts were also tested. After two months of treatment for tuberculosis among individuals in the same household, a follow-up showed significant differences between the intervention and control groups. In the intervention group, all 81 participants (100%) tested negative for acid-fast bacilli in the second month. In contrast, the control group had 3 participants (4.3%) who tested positive for acid-fast bacilli. The effectiveness of tuberculosis drug therapy is assessed by examining whether patients test negative for acid-fast bacilli during their second examination. The results indicate that patients receiving a combination of multi-drug treatment and VCO intervention have a higher rate of negative testing for acid-fast bacilli compared to those receiving only multi-drug treatment.

Keywords: DOTS; Household contact; Multy-drug treatment; Tuberculosis; VCO

Introduction

The World Health Organization's Global Tuberculosis Report 2024 provides the latest comprehensive assessment of the global TB epidemic and the progress made in prevention, diagnosis, and treatment. In 2024, an estimated 10.7 million people worldwide fell ill with tuberculosis, corresponding to an

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incidence of 131 cases per 100 000 population. Among these cases, about 5.8 % occurred in people living with HIV. The highest burden of TB was seen in the WHO regions of South-East Asia (34 %), the Western Pacific (27 %) and Africa (25 %), with smaller proportions in the Eastern Mediterranean, the Americas, and Europe. Although progress continued in many countries and improvements were noted in the coverage of preventive therapy and treatment success rates, global progress remains insufficient to reach the targets of the End TB Strategy. The report also highlights that despite measurable gains in diagnosis, treatment, and health service recovery following the COVID-19 pandemic, TB continues to cause over one million deaths annually, with about 1.2 million deaths reported in 2024, posing an ongoing public health challenge. Persistent challenges include funding gaps that threaten to reverse gains, uneven progress across regions, and continued high incidence in major burden countries (WHO, 2024a)

In Indonesia, the number of new tuberculosis cases reaches 460,000 each year, according to the 2018 Global Tuberculosis Report (WHO, 2020). Pulmonary tuberculosis patients can spread germs into the air as droplet nuclei when they cough or sneeze. One cough can release approximately 3,000 phlegm droplets. These droplets contain tuberculosis germs and can remain viable in the air at room temperature for several hours (Etim, Mirabeau, Olorode, & Nwodo, 2024). Anyone can become infected if they inhale these droplets into their respiratory tract (Medscape, 2024).

Mycobacterium tuberculosis is the bacterium that causes tuberculosis, a disease that primarily affects the lungs and is transmitted through the air (Tobin & Tristram, 2025). Transmission occurs when individuals with pulmonary tuberculosis who have a positive sputum smear for acid-fast bacilli cough, sneeze, speak, or sing, thereby producing droplet nuclei of very small size, less than five micrometers, that contain tubercle bacilli. These droplet nuclei can remain suspended in the air for prolonged periods, particularly in enclosed spaces with poor ventilation, thereby increasing the risk of transmission. When such droplets are inhaled by another individual, the bacilli enter the respiratory tract and reach the pulmonary alveoli. In the alveoli, the bacteria interact with the host immune system and may multiply. This process may result in latent tuberculosis infection, in which the bacteria persist in the body without causing symptoms and are not transmissible, or progress to active tuberculosis, which is characterized by clinical symptoms and the ability to transmit the disease to others (CDC, 2025). The transmission process and disease progression are influenced by individual immune status as well as environmental factors such as household crowding and the quality of ventilation (WHO, 2024b)

To address the high burden of tuberculosis, the World Health Organization (WHO) recommends the Directly Observed Treatment, Short-course (DOTS) strategy. This strategy aims to interrupt the chain of tuberculosis transmission and prevent the development of drug resistance. The DOTS strategy consists of five core components: government commitment, case detection through sputum smear microscopy, standardized treatment with direct observation, an effective recording and reporting system, and a reliable supply of anti-tuberculosis drugs (WHO, 2024b)

The implementation of the Directly Observed Treatment, Short-course (DOTS) strategy remains a central pillar in tuberculosis (TB) control. However, although DOTS has proven effective in improving treatment adherence and reducing therapeutic failure rates, it has not been fully successful in interrupting the chain of disease transmission, particularly in countries with a high TB burden(Wu et al., 2025). Factors such as individual immune status, malnutrition, delayed diagnosis, and high levels of exposure in densely populated environments contribute to the persistence of tuberculosis transmission. Therefore, additional or adjunctive strategies are required that not only focus on pathogen eradication but also emphasize strengthening the host immune response (Floyd, Glaziou, Zumla, & Raviglione, 2018)

The rising incidence of tuberculosis is attributed to the significant number of individuals suffering from pulmonary tuberculosis who are undergoing treatment through the DOTS program but have not fully recovered. A person with acid-resistant bacilli in pulmonary tuberculosis can potentially infect 10 to 15 people each year. As a result, it is likely that every contact with an infected individual may contract tuberculosis (Williams, 2024).

The still high prevalence of tuberculosis has led to significant challenges in managing the disease. The Directly Observed Treatment, Short-course (DOTS) strategy has not been effective in breaking the chain of transmission of tuberculosis. Research conducted by (Arifin, Hadju, Astuti, & Wahyuni, 2014) and (Montolalu, Hadju, Lawrence, Wahyuni, & Maryunis, 2017) on multi-drug therapy (MDT) demonstrates that a combination of MDT and virgin coconut oil (VCO) showed an adequate conversion rate of approximately 80% during the 2nd and 3rd months of treatment. These findings offer hope for reducing the incidence of tuberculosis by breaking the chain of transmission and minimizing the time it takes for acid-resistant bacteria to spread from infected individuals to their household contacts.

Tuberculosis treatment involves the use of multi-drug therapy (MDT), which consists of a combination of several anti-tuberculosis drugs administered over a

defined period (Lange et al., 2019). The use of combination therapy aims to effectively eliminate *Mycobacterium tuberculosis*, prevent disease relapse, and reduce the risk of drug-resistant tuberculosis (Pai et al., 2016). The implementation of the DOTS strategy in combination with multi-drug therapy has been shown to improve treatment success rates and reduce tuberculosis transmission within the community (Dheda et al., 2017)

The increasing prevalence and incidence of tuberculosis each year necessitates the implementation of Exit Strategy Treatment (EST). One effective option for EST is Virgin Coconut Oil (VCO), which can help protect the body against various harmful microorganisms (Nevin & Rajamohan, 2004). VCO is a natural coconut oil obtained without high-heat processing or chemical modification, thereby preserving its content of medium-chain fatty acids (MCFAs), particularly lauric acid, which constitutes the dominant fatty acid component of VCO (Mikołajczak, Tańska, & Ogrodowska, 2021). These bioactive components have been reported to exhibit antimicrobial and immune-enhancing properties, making VCO a promising adjunctive agent in supporting host immune responses (Nitbani, Tjitda, Nitti, Jumina, & Detha, 2022)

In addition to their direct antimicrobial activity, virgin coconut oil (VCO) and its derivative monolaurin have also been reported to exert immunomodulatory effects (Deen et al., 2021). Experimental animal studies have demonstrated that VCO supplementation can enhance macrophage phagocytic activity, promote lymphocyte proliferation, and increase antibody production, reflecting strengthened cellular and humoral immune responses (Nevin & Rajamohan, 2004). Other studies have reported that monolaurin is capable of modulating inflammatory responses by suppressing excessive production of pro-inflammatory cytokines without impairing protective immune functions, thereby potentially preventing tissue damage associated with chronic inflammation (Yoon, Jackman, Valle-González, & Cho, 2018)

Lauric acid in the human body can be metabolized into monolaurin (glycerol monolaurate), a monoglyceride that has been reported to exhibit a broad range of biological activities. Various *in vitro* studies have demonstrated that monolaurin exerts antimicrobial effects through disruption of microbial lipid membranes, leading to the inactivation of Gram-positive bacteria, lipid-enveloped viruses, and certain fungal species (Dayrit, 2015). This mechanism is particularly relevant in the context of chronic infectious diseases, in which pathogen persistence and host immune responses play critical roles in disease progression (Al-Qahtani, Alhamlan, & Al-Qahtani, 2024)

In the context of tuberculosis, the successful elimination of *Mycobacterium tuberculosis* is highly dependent on the effectiveness of cellular immunity, particularly macrophage activation and T-lymphocyte responses (Esmail et al., 2018). Dysregulation of immune responses is known to play a significant role in disease progression and failure to control infection. Therefore, immunomodulatory agents that are capable of enhancing host immune function without interfering with standard therapy hold strategic value as adjunctive treatments in tuberculosis management (Ahmad et al., 2022)

Based on the available evidence, virgin coconut oil (VCO) and monolaurin have the potential to be developed as part of a complementary approach in the control of infectious diseases, including tuberculosis. Although most of the existing evidence is still derived from *in vitro* studies and *in vivo* animal experiments, these findings provide a strong scientific basis for further exploration through well-controlled clinical studies in humans. The integration of nutrition-based immunomodulatory agents such as VCO is expected to enhance host immune responses, accelerate recovery, and contribute to reducing the risk of disease transmission

The intervention involving a combination of multiple drug treatments and virgin coconut oil (VCO) is expected to reduce the incidence of tuberculosis among household contacts by successfully converting acid-resistant bacilli within the second month of contact. It is assumed that tuberculosis patients pose the highest risk of transmission within their families. Therefore, accelerating the conversion of acid-resistant bacilli in these patients can help mitigate the potential source of transmission at home. (Nuzula, Isa, Juhairina, & Ansori, 2024)

The key question is whether the incidence of tuberculosis in households is lower among those receiving the VCO and multiple drug treatment compared to those receiving only multiple drug treatment. Additionally, what are the costs associated with the treatment group compared to the control group?

Method

This study employs a quasi-experimental method, a form of quantitative research akin to a true experiment but does not involve full randomisation of subjects or groups. In this approach, the researchers still implement interventions, but the division of participants into groups is non-random. The objective is to observe the changes in the conversion from positive acid-resistant basil to negative acid-resistant basil in patient samples, and to monitor the conversion from negative acid-resistant basil to positive acid-resistant basil in family samples. The research was conducted in Pangkep

Regency, specifically in Balocci, Minasate'ne, and Pangkajene Districts, as well as Bungoro, Taraweang, and Bantimala Districts, from August 2019 to November 2019. The focus of this study was to assess the incidence of the second month regarding the effects of virgin coconut oil (VCO) in preventing tuberculosis transmission within families in a home setting.

The population of this study consisted of all new tuberculosis patients (hereinafter referred to as "contacts") who sought treatment at the community health center in the research area. This population also included their household members (hereinafter referred to as "household contacts"). The study was conducted in the Balocci Community Health Center work area, which served as the treatment group, and the Bungoro Community Health Center work area, which served as the control group.

The sample in this study consisted of two groups. The treatment group included new tuberculosis patients who received Multi-Drug Treatment (MDT) along with Virgin Coconut Oil (VCO). Their household contacts were tested to determine if they were positive for acid-resistant bacilli both at the initial stage and at the end of the second month of the study.

The control group consisted of new tuberculosis patients who received either Directly Observed Treatment Short Course (DOTS) or only Multi-Drug Treatment (MDT). Similarly, their household contacts were also tested in the same manner as those in the treatment group.

The sampling technique used in this study was purposive sampling, specifically targeting new tuberculosis patients and their families who were selected as participants based on specific research criteria. The research criteria are as follows:

1. *Inclution criteria:*

a. *Intervention Group*
   1) The subjects were residents of the working areas surrounding Balocci, Minasate, and Pangkajene Health Centers at the time of the study.
   2) The subjects' ages ranged from 19 to 75 years.
   3) The subjects were classified as new patients who had never received multi-drug treatment.
   4) The subjects were confirmed to have pulmonary tuberculosis based on the results of an acid-resistant bacilli sputum examination.
   5) The subjects were experiencing tuberculosis without a history of complications.
   6) The subjects agreed to participate in the study and completed the informed consent form.

b. *Control Group*
   1) Participants in the study were residents of the working areas served by the Bungoro, Taraweang, and Bantimala Health Centers at the time of the research.
   2) Participants were aged between 19 and 75 years.
   3) Participants were classified as new patients who had never received multi-drug treatment before.
   4) Participants were confirmed to have pulmonary tuberculosis based on acid-resistant bacilli detected in sputum examinations.
   5) Participants were diagnosed with tuberculosis (TB) without any history of complications.
   6) Participants willingly agreed to take part in the study and completed the informed consent form.

c. *Exclution Criteria*

The exclusion criteria for both sample groups were as follows:
   1) Subject moved domicile when the research was conducted
   2) Died

To prevent dropout in this research, we included 30 samples for each treatment group, along with 30 samples for the control group. To ensure the accuracy and purity of the sputum examination results, we utilized the GeneXpert (GX) Instrument. This machine employs an automated system that integrates specimen purification, nucleic acid amplification, and target sequence detection. The data collection procedure for this study is as: (1) Recording related to demographic characteristics and occupation of the subject and clinical conditions aimed at the patient and the household contacts; (2) Observation of the progress of the contact therapy and the development of the family life at home.

Data analysis was carried out on the treatment group and control group as follows.

1. *Intervention Group*
   a. Household contacts are calculated by how many conversions of Acid-Resistant Bacilla to Negative in the 2nd month
   b. Household contacts are calculated by how many conversions of Acid-Resistant Bacilla (-) to (+) in the 2nd month
2. *Control Group*
   a. Contacts are calculated by how many conversions of Acid-Resistant Bacilla (+) to (-) in the 2nd month
   b. Household contacts are calculated by how many conversions of Acid-Resistant Bacilla (-) to (+)
   c. Calculate the negative conversion ratio in both groups, Calculate the incidence of Acid-Resistant Basil (+) sufferers from household contacts in the treatment group and the control group. Analyze the costs incurred and the difference in household contacts in both groups.

The baseline characteristics of the subjects, including nutritional status, HIV status, and comorbidities, were analyzed to ensure homogeneity between groups. No statistically significant differences were found in these variables ($p > 0.05$). A normality test was conducted

prior to comparative analysis to determine the appropriate statistical tests to be applied.

Result and Discussion

The following is a presentation of the research results:

Research Variables of Respondents

Table 1. Research Variables of Respondents of Intervention and Control Groups of Tuberculosis Patients in the Household contacts in Pangkep Regency,2019

Characteristic	Intervention		Control	
	N	%	n	%
Immunization History				
Ever	25	83.33	29	96.67
Never	5	16.67	1	3.33
Initial Examination Acid-Fast Basil				
Acid-fast basil +++	19	63.33	14	46.67
Acid-fast basil ++	11	36.67	16	53.33
Second Examination Acid-Fast Basil				
Acid-fast basil +	0	0	4	33.33
Acid-fast basil -	30	100.00	26	86.67
Contact Investigation				
Acid-fast basil +	0	0	4	33.33
Acid-fast basil -	30	100.00	26	86.67
Type of Residential House				
Semi-Permanent Stone House	13	43.33	10	33.33
Stilt House	17	56.67	20	66.67

Table 1 shows that nearly all respondents in both the control and intervention groups have been immunised. At the beginning of the examination in the intervention group, 19 individuals (63.33%) were positive for acid-resistant bacilli. However, the second examination revealed that all respondents in the intervention group tested negative for acid-resistant bacilli. During the contact investigation, it was noted that four respondents did not convert and remained positive for acid-resistant bacilli, which accounts for 13.33% of the respondents.

Results of Acid-Fast Bacillus Examination

Table 2. Results of Acid-Fast Bacillus Examination in the Intervention and Control Groups After Two Months of Treatment for Tuberculosis Patients in Pangkep Regency, 2019

Group	Acid-resistant bacil +		Acid-resistant bacil -		Total	
	n	%	n	%	n	%
Intervention	0	0	30	100	30	100
Control	4	13.33	26	86.67	30	100

Table 2 shows the results of the examination in the second month for the intervention group, where all 30 respondents (100%) tested negative for acid-fast bacilli. In contrast, among the control group, 26 out of 30 respondents (86.67%) were negative for acid-fast bacilli, while 4 respondents (13.33%) tested positive. To determine whether there were differences in treatment between the intervention and control groups, an unpaired T-test was employed, as the intervention and control groups utilized different samples.

Results T-test Examination

Table 3. T-Test Results in the Intervention Group and Control Group After Two Months of Treatment for Tubercolosis Patients in Pangkep Regency, 2019

		Levene's Test fot Equality of Variances		t-test Equality of Means						
		F	Sig.	t	df	Sig. (2 tailed)	Mean Difference	Std. Error Difference	95% confidence interval of the difference	
									Lower	upper
Second Examination of ACID RESISTANT BACILLA	Equal Variances assumed	24.926	.000	2.112	58	.039	.133	.063	.007	.260
	Equal Variances non-assumed			2.112	29.00	.043	.133	.063	.004	.262

The output in the Independent Samples Test table reveals that the calculated F value from Levene's test for Equality of Variances is 24.926, with a p-value of 0.001, which is less than 0.05. This indicates that the variances of the two groups are not homogeneous. In the same table, the calculated t value is presented as 2.112. Since the p-value is 0.039, which is also less than 0.05, so the null hypothesis (Ho) is rejected.

The combination of multi-drug treatment and VCO affects the treatment of tuberculosis patients.

This study is in line with previous findings demonstrating that the addition of virgin coconut oil to standard multi-drug antituberculosis therapy may increase the rate of acid-fast bacilli sputum conversion

(Djannah et al., 2022; Nuzula et al., 2024).

The higher rate of acid-fast bacilli (AFB) negativity observed among patients receiving a combination of multi-drug antituberculosis treatment and virgin coconut oil (VCO) may be explained by the complementary biological effects of VCO alongside pharmacological therapy. Virgin coconut oil is rich in medium-chain fatty acids, particularly lauric acid, which has been shown to possess antimicrobial properties through disruption of bacterial cell membranes, potentially reducing the viability of *Mycobacterium tuberculosis* and enhancing the bactericidal effect of standard anti-TB drugs (Dalmacion, Ortega, Pena, & Ang, 2012). In addition, experimental studies have demonstrated that VCO can inhibit the growth of *M. tuberculosis* isolates in vitro, suggesting a direct suppressive effect on mycobacterial proliferation (Suryani et al., 2024). Beyond its antimicrobial activity, VCO has also been reported to exert immunomodulatory effects by enhancing macrophage function and innate immune responses, which are critical for intracellular clearance of *M. tuberculosis* (Sebayang & Hasibuan, 2021). Improved host immune function may facilitate more effective bacterial clearance when combined with standard multi-drug therapy. Furthermore, narrative reviews have suggested that VCO supplementation may contribute to improved sputum conversion rates by supporting both antimicrobial action and host defense mechanisms, thereby accelerating bacteriological response to treatment (Djannah et al., 2022). Collectively, these mechanisms provide a plausible explanation for the higher AFB-negative conversion rates observed in patients receiving combined multi-drug therapy and VCO compared to those receiving pharmacological treatment alone.

Beside that, to examine the conversion benefits of Acid-Resistant Bacilla in the treatment group compared to the control.

Profit Difference Due to Conversion of Acid-Resistant Basil

The profit difference is the amount of costs used to treat TUBERCOLOSIS with VCO intervention and without VCO. The amount of expenditure is calculated for 6 months of treatment where the first two months are given VCO supplements.

Table 4. Cost Components of Intervention Group in the 2nd Month of Treatment Intensive Phase of Tubercolosis Sufferers in the household contacts in Pangkep Regency, 2019

Weight (Kg)	RifaSTAR® 4FDC (caplet/consumption)	Number of sufferers	Length of treatment (hr)	Unit price	Tab required	VCO Price	VCO x Number of sufferers	Total Price of Drug Procurement x Number of sufferers	Drug Procurement Price + VCO
30 – 37	2	9	60	6,51	540	Rp320.100	Rp 2.880.900	Rp7.030.800	Rp 9.911.700
38 – 54	3	18	60	6,51	180	Rp320.100	Rp .761.800	Rp 21.092.400	Rp26.854.200
55 – 70	4	3	60	6,51	240	Rp320.100	Rp 960.300	Rp4.687.200	Rp5.647.500
> 71	5	0	60	6,51	300	-	-	-	-
TOTAL		30					Rp. 9.603.000	Rp 32.810.400	Rp 42.413.400

Table 4 clearly outlines the financing component for the intervention group, which encompasses the costs associated with procuring RifaStar drugs and virgin coconut oil (VCO). The financial breakdown is as follows:

- The 30-37 kg body weight group, consisting of 9 participants, incurs a cost of Rp. 9,911,700.
- The 38-54 kg body weight group, with 18 participants, has a total cost of Rp. 26,854,200.
- The 55-70 kg body weight group, comprised of 3 participants, costs Rp. 5,647,500.

Table 5. Cost Components of Advanced Phase Treatment for Tuberculosis Patients in the household contactsin Pangkep Regency, 2019

Weight (Kg)	*RifaNH®*	Number of sufferers	*Length of treatment (hr)*	Unit price	Tab required	Total Price (4 mnth)	Price VCO/ 1 lt	TOTAL (6 mnth) (RifaStar+ RifaNH + VCO)
30 - 37	2	9	120	2,940	2,160	6,350,400	320,100	13,701,300
38 - 54	3	18	120	2,940	4,320	19,051,200	320,100	40,463,700
55 - 70	4	3	120	2,940	720	4,233,600	320,100	9,240,900
> 71	5	0	120	2,940	-	-	320,100	320,100
TOTAL		30				29,635,200		63,726,000

Table 5 illustrates the financing components of the intervention group, which includes the procurement costs of RifaStar, RifaNH, and VCO. For the weight group of 30-37 kg, with a sample size of 9 participants, the total cost is Rp. 13,701,300. For the weight group of 38-54 kg, with a sample size of 18 participants, the total cost is Rp. 40,463,700. Lastly, for the weight group of 55-70 kg, with a sample size of 3 participants, the total cost is Rp. 9,240,900.

Table 6. Cost components for the control group during the intensive phase of tuberculosis treatment for patients from the household contactsin Pangkep Regency, 2019

Weight (Kg)	*RifaNH®*	Number of sufferers	*Length of treatment (hr)*	Unit price	Tab required	Total Price (2 mnth)
30 - 37	2	6	60	6,510	120	4,687,200
38 - 54	3	16	60	6,510	180	18,748,800
55 - 70	4	8	60	6,510	240	12,499,200
> 71	5	0	60	6,510	300	-
TOTAL		30				35,935,200

Table 6 shows that the financing components in the control group, consisting of the procurement costs of RifaStar for the 30-37 kg weight group with a sample size of 6 people, are Rp. 6,687,200, for the 38-54 kg weight group with a sample size of 16 people, is Rp. 18,748,800, and for the 55-70 kg weight group with a sample size of 8 people, is Rp. 12,499,200.

Table7. Cost Components of the Advanced Phase Treatment Control Group for Tuberculosis Patients from the household contactsin Pangkep Regency, 2019

Weight (Kg)	*RifaNH®*	Number of sufferers	*Length of treatment (hr)*	Unit price	Tab required	Total Price (4 mnth)	TOTAL (6 mnth) (RifaStar+ RifaNH)
30 - 37	2	6	120	2,940	1,440	4,233,600	8,920,800
38 - 54	3	16	120	2,940	3,840	16,934,400	35,683,200
55 - 70	4	8	120	2,940	1,920	11,289,600	23,788,800
> 71	5	0	120	2,940	-	-	-
TOTAL						32,457,600	68,392,800

Table 9 presents the financing components for the control group, which includes the procurement costs of RifaStar and RifaNH for various weight categories. For the 30-37 kg weight group, which had a sample size of 6 participants, the total costs amounted to Rp 8,920,800. In the 38-54 kg weight group, with a sample size of 18 participants, the total costs reached Rp 35,683,200. Lastly, for the 55-70 kg weight group, comprised of 3 participants, the costs were Rp 23,788,800.

This detailed breakdown unequivocally demonstrates the necessary financing for each group within the intervention. The financing required for each intervention group reflects the distinct cost components associated with standard anti-tuberculosis pharmacotherapy and adjunctive supplementation. Procurement of rifampicin-based fixed-dose combination therapy such as RifaStar constitutes a substantial proportion of tuberculosis treatment costs, as anti-TB drugs are a core element of provider expenditure in drug-susceptible tuberculosis management (WHO, 2024b).

Global estimates indicate that the median provider cost per treated TB patient exceeds USD 700, with pharmaceutical procurement representing a major cost driver within TB care services (WHO, 2024b). In the intervention group receiving additional virgin coconut oil (VCO), supplementary financing is required to cover the cost of VCO procurement, which is not included in standard TB treatment packages and is typically categorized as a nutritional or adjunctive intervention. Studies on tuberculosis-related patient expenditures further demonstrate that non-program items, including nutritional supplements, contribute to additional direct costs beyond routine drug provision, thereby necessitating separate budget allocation for intervention arms incorporating such products (D'Silva et al., 2025). Consequently, the higher financial requirement observed in the multi-drug plus VCO group can be attributed to the combined costs of standard anti-TB drug procurement and the added expense of VCO supplementation, underscoring the need for clearly defined financing mechanisms for each intervention group.

Conversion Protection Benefits Due to VCO Use

The cost-effectiveness of using Virgin Coconut Oil (VCO) refers to the effective cost incurred for each patient, whether they receive VCO treatment or not. The

benefits of the treatment are assessed using a Cost-Effectiveness Analysis that compares both groups of patients. The effectiveness of tuberculosis drug therapy in patients is measured by the percentage of individuals who test negative for acid-resistant bacilli on the second examination. Table 4 indicates that patients receiving multi-drug treatment combined with VCO intervention have a higher rate of negative acid-resistant bacilli compared to those who receive only multi-drug treatment.

Table 8. Effectiveness Percentage of Tuberculosis Treatment for Family Patients After 2 Months in Pangkep Regency, 2019

Treatment method	Number of patients	Number of Patients Declared Recovered	Effective-ness
MDT + VCO	30	30	100.0
MDT	30	26	86.7

The costs calculated in this study are for Multi-Drug Treatment combined with VCO treatment, as well as for Multi-Drug Treatment alone. MDT + VCO showed to be more effective than MDT only.

Table 9. Difference Total Cost of TUBERCOLOSIS patient medication for 2 months on household contactsin Pangkep regency, 2019

Treatment method	Total Cost (Rp)
MDT + VCO	Rp. 42,413.400
MDT	Rp. 35.935.200

Two types of treatment for different patient groups incur varying costs and therapeutic effectiveness.MDT + VCO takes higher cost than MDT only.

Table 10. Comparison of ACER (average cost effectiveness ratio) Calculation of TUBERCULOSIS Patients' Treatment for 2 Months in the Household contacts in Pangkep Regency, 2019

Treatment method	Unit Cost (C) dalam Rp	Effectiveness (E) in %	ACER (C/E)
MDT + VCO	Rp. 42,413.400	100.0	Rp.424.134
MDT	Rp. 35.935.200	86.67	Rp. 414.621

Based on the results from the ACER (average cost effectiveness ratio) calculation, the cost of tuberculosis treatment using Multi-Drug Treatment combined with VCO was Rp. 424,134 for 30 tuberculosis patients. All samples showed a conversion from positive acid-resistant bacilli to negative acid-resistant bacilli within two months of treatment. In contrast, the cost for tuberculosis treatment using standard Multi-Drug Treatment was Rp. 414,621 for 30 samples; however, these patients had not yet experienced conversion as they had not completed the standard treatment duration of six months.

Table 11. Comparison of the Total Cost of Tuberculosis Treatment for Six Months in the Household contacts in Pangkep Regency, 2019

Treatment method	Total Cost (Rp)
MDT + VCO	Rp. 63.726.000
MDT	Rp. 68.392.800

The highest cost of treatment for 6 month is MDT method with the cost of Rp. 68.392.800

Table 12. Comparison of the Average Cost-Effectiveness Ratio (ACER): Calculation of Six Months of Tuberculosis Treatment in the Household contactsin Pangkep Regency, 2019.

Treatment method	Unit Cost (C) in Rp	Effectiveness (E) in %	ACER (C/E)
MDT + VCO	Rp. 63.726.000	100.0	Rp.637.260
MDT	Rp. 68.392.800	86.67	Rp. 789.117

Based on the results obtained from the ACER calculation, the cost of tuberculosis treatment using Multi-Drug Treatment combined with Virgin Coconut Oil (VCO) was Rp. 637,260 for 30 tuberculosis patients. All samples converted from positive Acid-Resistant Bacilli to negative Acid-Resistant Bacilli over the six months of treatment. In contrast, the cost of standard tuberculosis treatment using Multi-Drug Treatment was Rp. 789,117 for the same 30 patients. In this case, 26 samples converted to negative Acid-Resistant Bacilli during the six-month treatment period, while 4 samples did not convert and remained as tuberculosis hosts.

Based on the results obtained from the average cost-effectiveness ratio (ACER) calculation, tuberculosis treatment using multi-drug therapy combined with virgin coconut oil (VCO) demonstrated superior economic and clinical outcomes, with a total cost of Rp 637,260 for 30 patients and complete conversion from positive to negative acid-fast bacilli over the six-month treatment period. This finding is consistent with economic modeling studies indicating that adjunct nutritional or food-based interventions in tuberculosis care can improve treatment effectiveness while maintaining favorable cost-effectiveness ratios, particularly when the supplement cost is relatively low (Bhargava et al., 2023). The improved bacteriological conversion observed in the multi-drug plus VCO group may be explained by the antimicrobial activity of medium-chain fatty acids present in VCO, especially lauric acid, which has been shown to inhibit bacterial growth and enhance membrane disruption, thereby

supporting faster mycobacterial clearance when used alongside standard anti-tuberculosis drugs (Nakatsuji et al., 2009). In contrast, standard multi-drug tuberculosis treatment alone incurred a higher total cost of Rp 789,117 for the same number of patients and resulted in incomplete bacteriological conversion, with four patients remaining acid-fast bacilli positive after six months of treatment. Persistent sputum positivity has been associated with prolonged treatment duration, increased monitoring costs, and higher risk of treatment failure, all of which contribute to reduced cost-effectiveness of tuberculosis interventions. (Fitzpatrick & Floyd, 2012; WHO, 2024b) Therefore, the lower ACER observed in the multi-drug plus VCO group can be rationally attributed to the combination of improved treatment effectiveness and minimal incremental supplementation costs, supporting the economic advantage of incorporating VCO as an adjunct to standard tuberculosis therapy.

Conclusion

From This study concludes that patients receiving multi-drug treatment combined with virgin coconut oil (VCO) achieved higher rates of acid-fast bacilli negativity than those receiving multi-drug treatment alone, indicating greater treatment effectiveness, including among household contacts. Despite its limitations, this pilot study provides preliminary empirical and methodological evidence to support further investigation. The findings suggest potential implications for public health policy as a complementary intervention to strengthen tuberculosis control programs; however, larger multi-center randomized controlled trials are needed to confirm clinical effectiveness, safety, optimal dosage, and long-term cost-effectiveness, including patient and societal costs.

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Author Contributions
The First Author and Second Author were responsible for the conceptualization of the study. The First Author conducted the methodology development, software handling, formal analysis, investigation, data curation, visualization, project administration, and prepared the original draft of the manuscript. Validation of the study was carried out collaboratively by the First, Second, Third, and Fourth Authors. The Second Author provided overall supervision and was responsible for funding acquisition. The First and Second Authors jointly reviewed and edited the manuscript. All authors read, critically reviewed, and approved the final version of the manuscript.

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The authors declare no conflict of interest.

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