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THE EFFECTIVENESS OF THE USE OF AQUAPONIC SYSTEMS USING CHITOSAN FILTERS ON WATER QUALITY IN AMMONIA, NITRITE, AND NITRATES TEST PARAMETERS

Efektivitas Pemanfaatan Sistem Akuaponik Menggunakan Filter Kitosan Terhadap Kualitas Air Pada Parameter Uji Amonia, Nitrit, dan Nitrat

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ABSTRACT

Chitosan is a polysaccharide compound derived from chitin obtained from marine animal shell waste and can act as a biocoagulant and bioflocculant in maintaining water quality. This study aims to determine the effectiveness of chitosan with different concentrations in improving water quality as seen from the content of ammonia, nitrite, and nitrates in the aquaponic system. This study was carried out for 30 days in Banjar Tegal Village, Buleleng District, Buleleng Regency, Bali Province using a Complete Random Design (RAL) with three treatments and three replicas. The treatments used include A (Aquaponic system without chitosan filter), B (Aquaponic system with the addition of chitosan filter with a dose of 30 mg/L), C (Aquaponic system with the addition of chitosan filter with a dose of 50 mg/L). Data was collected using a simple random sampling method and analyzed using quantitative and qualitative descriptive data analysis techniques. The results showed that the water quality performance (ammonia, nitrite, and nitrate test parameters) of the aquaponic system in the treatment of adding chitosan filters with a concentration of 50 mg/L (Treatment C) was better when compared to the control and with the treatment of adding chitosan filters with a concentration of 30 mg/L.

Keywords: Ammonia (NH_3), Chitosan, Nitrate (NO_3), Nitrite (NO_2)

ABSTRAK

Kitosan merupakan senyawa polisakarida turunan dari kitin yang diperoleh dari limbah cangkang hewan laut dan dapat berperan sebagai biokoagulan dan bioflokulan dalam menjaga mutu kualitas air. Penelitian ini bertujuan untuk mengetahui efektivitas kitosan dengan konsentrasi yang berbeda dalam memperbaiki kualitas air dilihat dari kandungan amonia, nitrit, dan nitrat pada sistem akuaponik. Penelitian ini dilaksanakan selama 30 hari di Kelurahan Banjar Tegal, Kecamatan Buleleng, Kabupaten Buleleng, Provinsi Bali menggunakan Rancangan Acak Lengkap (RAL) dengan tiga perlakuan dan tiga ulangan. Perlakuan yang digunakan meliputi A (Sistem akuaponik tanpa filter kitosan), B (Sistem akuaponik dengan penambahan filter kitosan berdosis 30 mg/L), C (Sistem akuaponik dengan penambahan filter kitosan berdosis 50 mg/L). Data dikumpulkan dengan metode simple random sampling dan dianalisis menggunakan teknik analisis data deskriptif kuantitatif dan kualitatif. Hasil penelitian menunjukkan bahwa performa kualitas air (parameter uji amonia, nitrit, dan nitrat) sistem akuaponik pada perlakuan penambahan filter kitosan dengan konsentrasi 50 mg/L (Perlakuan C) lebih baik bila dibandingkan dengan kontrol maupun dengan perlakuan penambahan filter kitosan dengan konsentrasi 30 mg/L.

Kata Kunci: Amonia (NH_3), Kitosan, Nitrat (NO_3), Nitrit (NO_2)

INTRODUCTION

Aquaculture involves the rearing, grow-out, and breeding of aquatic commodities within a controlled system, a process closely linked to feed administration. Feed provided to cultured organisms is not always fully consumed, leading to the generation of waste. This waste generally consists of solids and dissolved nutrients derived from uneaten feed and metabolic feces; notably, an estimated 60%–80% of the feed's protein content is converted into ammonia waste, which pollutes the aquatic environment (da Silva et al., 2010; Samadan et al., 2023). Effective waste management in tilapia farming is essential to maintain water quality (Wulandari et al., 2024). Water quality plays a crucial role in aquaculture, as it directly influences farming success by affecting fish health and growth (Martini, 2024). Furthermore, water quality often serves as a standard indicator of the health of aquatic ecosystems. Maintaining high water quality in aquaculture operations can be achieved through the implementation of recirculation systems, such as aquaponics.

Aquaponics is an integrated system combining aquaculture and hydroponics that utilizes aquaculture wastewater—specifically uneaten feed and metabolic byproducts from fish rearing tanks—as a nutrient source for plants (Baganz et al., 2022). It is an environmentally friendly system that employs water recirculation; water from fish rearing tanks is filtered—utilizing plant roots capable of absorbing dissolved nutrients—and then returned to the tanks. The use of filter media in recirculating aquaculture systems, particularly those based on aquaponics, can significantly improve water clarity (Swardiani et al., 2022). Efforts to enhance the effectiveness of filtration systems are continuously being developed, including the incorporation of natural materials—such as chitosan—as filter media.

Chitosan is a polysaccharide derived from chitin, which is obtained from the shell waste of marine animals like shrimp, crabs, and shellfish. It can function as both a biocoagulant and a bioflocculant in water purification processes, making it highly suitable for aquaponic systems that prioritize sustainability (Susiana et al., 2025). Biocoagulants are natural substances used to bind particles or impurities present in water, whereas bioflocculants are natural compounds—typically polysaccharides or proteins produced by microorganisms—that aggregate these bound particles into larger, easily settleable flocs (Achmad, 2023).

Incorporating chitosan into the filter media is expected to maintain water quality at optimal levels for aquaculture operations. This study aims to identify the most effective treatment for improving water quality in aquaponic systems, specifically by evaluating ammonia, nitrite, and nitrate parameters.

RESEARCH METHODS

Place and Time

This study was conducted over a 30-day period from January 2026 to February 2026 in Banjar Tegal Urban Village, Buleleng District, Buleleng Regency, Bali.

Tools and Materials

This study utilized equipment such as colorimetric analytical test kits (to measure ammonia, nitrite, and nitrate parameters), a thermometer, a pH meter, a DO test kit, a graduated cylinder, a citrus juicer, a dosing syringe, a 50 cm x 50 cm x 50 cm tarpaulin tank, a water pump, a scale, a ruler, a spoon, and 600 ml sample bottles. The materials used included rockwool, tilapia, net pots, bok choy seedlings, filter wool, Japanese matting, seashells, powdered shrimp chitosan, wood, 3D and 1D pipes, water hose, distilled water, and limes.

Research Design

This study employs an experimental method using a Completely Randomized Design (CRD), consisting of three treatments and three replicates, resulting in nine experimental units. The treatments selected for this study are based on research conducted by Lembang and Widiawati (2022) regarding the use of chitosan as a filter medium in a recirculation system.
The treatments to be tested are as follows:
A: Aquaponic system without a chitosan filter.
B: Aquaponic system with the addition of a chitosan filter at a dosage of 30 mg/L.
C: Aquaponic system with the addition of a chitosan filter at a dosage of 50 mg/L.

The test fish used were tilapia fingerlings obtained from UPTD BBI Ringdikit, measuring approximately 5–7 cm in length and weighing around 6–8 grams, with a stocking density of 45 fish per pond.

Research Procedure

The initial phase of the study involved constructing aquaponic systems using nine tarpaulin tanks (50 cm x 50 cm x 50 cm) supported by wooden frames. Plant containers were made from PVC pipes (50 cm in length) featuring six planting holes spaced 13 cm apart. Bok choy seedlings were germinated in rockwool media until they developed four true leaves. After 14 days, the seedlings—still in their rockwool—were transplanted into net pots, which were then placed into the pre-drilled pipe channels. Prior to this, tilapia fingerlings were stocked at a density of 45 fish per tank. Following the stocking and transplanting processes, a chitosan solution was added to the physical filter on the second day: 30 mg/L for Treatment B and 50 mg/L for Treatment C.

To prepare the 50 mg chitosan solution, the chitosan was first dissolved in a mixture of 10 ml key lime extract and 90 ml distilled water, then stirred with a spoon for one hour. Similarly, the 30 mg chitosan solution was prepared by dissolving the chitosan in a mixture of 6 ml key lime extract and 60 ml distilled water, followed by stirring with a spoon for one hour. According to Sinardi et al. (2013), 1 g of chitosan can be dissolved in 100 ml of 1% acetic acid (solution pH 2.37); however, this study utilized a natural solvent—key lime extract mixed with distilled water—to dissolve the chitosan.

Water quality data—specifically ammonia, nitrite, and nitrate levels—were collected by taking water samples from the tanks using 600 ml bottles and analyzing them with colorimetric analytical test kits. Measurements of these parameters were conducted every seven days throughout the 30-day study period.

Data Analysis

Water quality parameter data—such as ammonia, nitrite, and nitrate—were collected using simple random sampling and analyzed descriptively via a quantitative approach, supported by relevant references pertaining to the study.

RESULT

The research results indicate that the addition of chitosan at varying concentrations affects water quality in terms of ammonia, nitrite, and nitrate parameters. The concentration values for ammonia, nitrite, and nitrate for each treatment are presented in Table 1.

Table 1. Ammonia, Nitrite, and Nitrate Values

Treatment	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)
A	0.05 ± 0.06	0.19 ± 0.07	27.50 ± 16.58
B	0.02 ± 0.02	0.12 ± 0.10	16.25 ± 10.31
C	0.01 ± 0.01	0.11 ± 0.10	17.50 ± 8.66

Note: A: Control, B: Addition of 30 mg/L chitosan, C: Addition of 50 mg/L chitosan

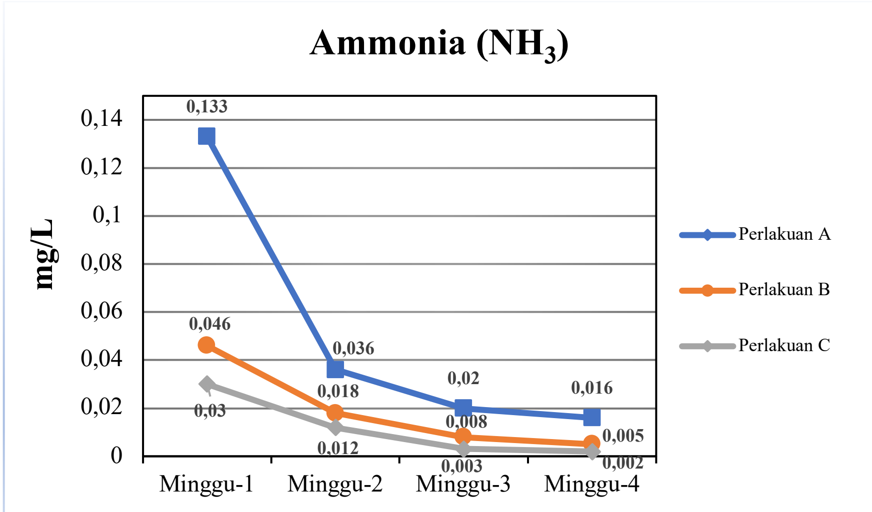

Figure 1. Average Weekly Ammonia Concentration

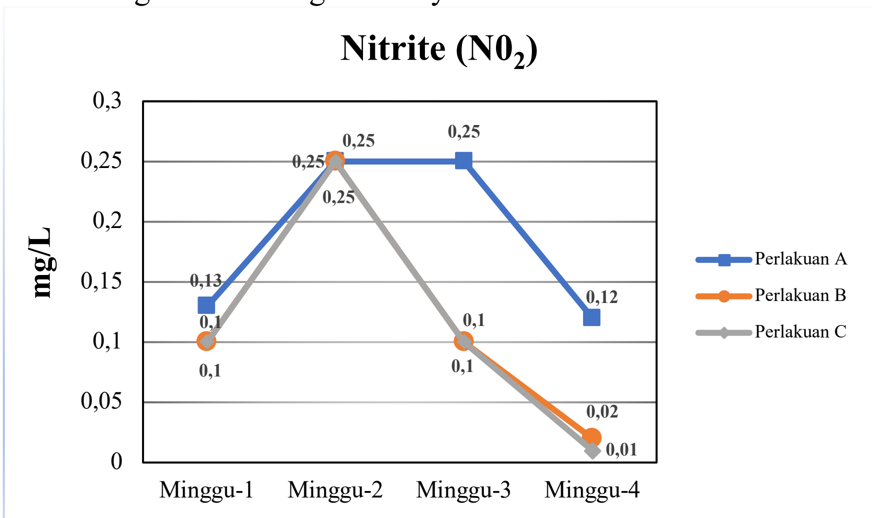

Figure 2. Average Weekly Nitrite Concentration

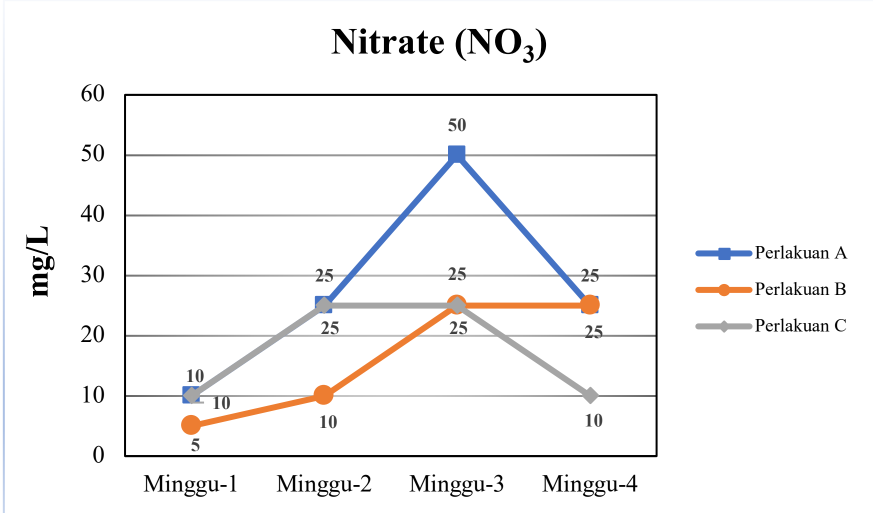

Figure 3. Average Weekly Nitrate Concentration

Ammonia concentrations (Figure 1) across all treatments varied on a weekly basis throughout the study. The average ammonia concentrations for all treatments ranged from 0.002 to 0.133 mg/L. According to the SNI 7550:2009 standard, the optimal ammonia concentration for aquaponic aquaculture systems is less than 0.02 mg/L (Pramleonita, 2018). Treatment A (control) exhibited the highest average ammonia concentration in Week 1 (0.133 mg/L) compared to Treatment B (addition of 30 mg/L chitosan) and Treatment C (addition of 50 mg/L chitosan), whereas the lowest average ammonia concentration was observed in Treatment C during Week 4 (0.002 mg/L).

Nitrite concentrations (Figure 2) throughout the study ranged from 0.01 mg/L to 0.25 mg/L across all treatments. The safe limit for nitrite concentration in aquaponic systems is <1 mg/L (Rakocy et al., 2006). The graph shows an increase in nitrite concentration for all treatments in Week 2; however, nitrite levels began to decrease in Week 3 for Treatment B (addition of 30 mg/L chitosan) and Treatment C (addition of 50 mg/L chitosan), while the nitrite concentration in Treatment A (control) remained relatively stable during that week. The lowest average nitrite concentration was recorded in Treatment C (addition of 50 mg/L chitosan) during Week 4, at 0.01 mg/L. Throughout the study, average nitrate concentrations across all treatments ranged from 5 mg/L to 50 mg/L. Nitrate concentrations in aquaponic systems should ideally not exceed 200 mg/L (Rakocy et al., 2006). The average nitrate concentration in Treatment A (control) fluctuated weekly, whereas Treatment B (addition of 30 mg/L chitosan) remained more stable during weeks 3 and 4, maintaining a level of 25 mg/L. The highest average nitrate concentration was observed in Treatment A (control) during week 3 (50 mg/L), while the lowest average concentration was recorded in Treatment B (addition of 30 mg/L chitosan) during week 1 (5 mg/L).

DISCUSSION

The research results indicate that the best outcome was achieved with treatment C (addition of 50 mg/L chitosan), as it yielded a significant reduction in ammonia concentration throughout the observation period compared to treatment A (control) and treatment B (addition of 30 mg/L chitosan). This was facilitated by an appropriate filtration system involving the addition of a chitosan solution to the physical filtration medium. Chitosan influences ammonia concentration reduction in aquaponic systems by acting as both a coagulant and a flocculant. As a cationic compound, chitosan functions as a coagulant and flocculant capable of neutralizing the charge of colloidal particles in water; this destabilizes the particles and initiates the formation of micro-flocs, which subsequently aggregate into larger clumps (flocs) through the process of flocculation (Bhalkaran, 2016). This aligns with the findings of Zaman et al. (2021), who stated that coagulants are natural substances capable of binding organic particles dissolved in water, while flocculants are natural compounds that aggregate these bound organic particles into larger, easily settleable clumps (flocs). The aggregation of organic matter in the water reduces the substrate available for heterotrophic bacteria to carry out ammonification, thereby slowing the rate at which organic nitrogen is converted into ammonia (Taslihan et al., 2021). The limited availability of organic matter for heterotrophic bacteria to utilize during ammonification results in a gradual decrease in water ammonia concentration. Fish metabolic waste (feces) and uneaten feed are the primary precursors for ammonia formation; heterotrophic bacteria subsequently break these down into amino acids through the process of ammonification (Setiawan et al., 2025).

The increase in nitrite concentration by 0.25 mg/L observed in the second week across all treatments indicates that nitrification had occurred. The nitrification process involves two reaction stages: the oxidation of ammonium ($NH3$) to nitrite ($NO2-$) by *Nitrosomonas* bacteria, followed by the oxidation of nitrite to nitrate ($NO3-$) by *Nitrobacter* (Hastuti, 2011; Septriono et al., 2023). During the oxidation of ammonia ($NH3$) to nitrite ($NO2-$) by *Nitrosomonas*, nitrite formation occurs more rapidly than its conversion to nitrate ($NO3-$); however, once the *Nitrobacter* population develops, nitrite concentrations decrease as the nitrite is converted into nitrate (Sri & Arbi, 2020). Factors influencing the success of the nitrification process include water temperature, pH, and dissolved oxygen (DO) concentration (Martini, 2024). Measurements taken during this study showed average temperature values ranging from 26.73°C to 27.30°C, average pH values between 7.23 and 8.03, and average dissolved oxygen (DO) levels between 7.5 mg/L and 8.33 mg/L. The optimal temperature range for nitrification is 25–32°C, the optimal pH range is 7.0–8.5, and the optimal dissolved oxygen (DO) level is no less than 3 mg/L (Wang et al., 2023). The addition of chitosan as a filter medium did not significantly affect temperature, pH, or dissolved oxygen (DO) parameters, and these values remained within safe limits for supporting the nitrification process. Parameters such as temperature, pH, and dissolved oxygen (DO) in culture water fluctuate and are subject to change due to factors including sunlight intensity, weather, and rainfall (Liling et al., 2026).

Nitrate is a more stable nitrogen compound than nitrite because the nitrogen exists in its highest oxidation state, rendering it less reactive (Marsidi and Herlambang, 2002). Nitrate concentrations in each treatment increased from the first to the third week but subsequently showed a significant decline in the fourth week, particularly in Treatment A (control) and Treatment C (addition of 50 mg/L chitosan). The decrease in nitrate concentrations across the treatments indicates the uptake of nitrate compounds by the plants. According to Martini (2024), plant roots absorb dissolved nutrients like nitrate through transpiration; these nutrients are then transported to plant tissues and utilized for growth and development. Yudiana et al. (2022) also state that plants can function as biofilters, absorbing inorganic nitrogenous wastes—such as ammonia, nitrite, and nitrate—and utilizing them as nutrient sources for plant growth.

CONCLUSION

An aquaponic system incorporating chitosan as a filter medium is more effective at reducing ammonia, nitrite, and nitrate concentrations in the water compared to a system without it. The most effective system for improving water quality parameters—specifically ammonia, nitrite, and nitrate levels—was the one utilizing 50 mg/L of chitosan (Treatment C) as the filter medium. The addition of chitosan as a physical filter medium enables the removal of suspended solids through coagulation and flocculation, thereby allowing the nitrification process to proceed more optimally.

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