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Microbiological and Physicochemical Properties of Grapes (Vitis vinifera) Treated with Chitosan Incorporated with Citronella Oil

Syarah Syahindah Abdullah[1], Munira Zainal Abidin[1*]

[1] *UTHM Kampus Cawangan Pagoh, Hab Pendidikan Tinggi Pagoh, KM 1, Jalan Panchor, 84600 Pagoh, Muar, Johor, MALAYSIA.*

*Corresponding Author: muniraza@uthm.edu.my
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Abstract

Grapes are a fruit valued in the food sector for their high quantity of bioactive substances. However, it is a highly perishable fruit that is frequently attacked by phytopathogenic issues, reducing its shelf life. Typically, chitosan coatings incorporating organic products such as essential oil are utilized to reduce losses caused by pathogenic bacteria. Chitosan is one of the most researched antimicrobial agents due to its ability for food packaging to form films and coatings. It also exhibits antimicrobial activity against a variety of fungus, yeasts, and bacteria that are found in food, with greater efficacy against yeast that causes fungal development in grapes (*Vitis vinifera*) during post-harvest storage. The research aimed to develop chitosan incorporated with citronella oil coating spray and to assess the microbiological and physicochemical properties of grapes coated with chitosan incorporated with three different concentration of citronella oil (0.5%, 1.0%, 1.5%) by spraying technique. In this study, the treated grapes were stored at 4°C for 15 days. The physicochemical properties (pH, visual observation, firmness and moisture content) of the grapes treated with chitosan incorporated with citronella oil were analysed using pH meter, Texture Analyzer and laboratory drying oven. The result showed that the highest concentration of citronella essential oil with 1.5% (T4) showed to be the most successful as a coating since it has the lowest pH value (3.56 to 3.61), excellent visual qualities, higher skin strength (83.57 ± 2.72 to 109.28 ± 7.55), enhanced elasticity (18.19 ± 3.45 to 24.13 ± 0.43), and preserved moisture content (80.07 ± 0.70 to 82.57 ± 2.13). Meanwhile, for the microbiological analysis, mold and yeast counts were lowest (3.36 Log CFU/g) in the T4 coating treatment. The findings indicated that adding essential oil to chitosan can extend its shelf life.

1. Introduction

Grapes, also known as Vitis vinifera, produced specifically for fresh consumption are grown in a way that improves their aesthetic appeal, and they are highly valued by consumers for their delightful sensory features as well as their usefulness as a rich source of nutrients and beneficial compounds. Like other fruits and vegetables, grapes are most susceptible to post-harvest decline due to fungal decomposition, among other things [15]. This fungus spreads quickly through the fruit clusters and also develops at low temperatures (0°C), making its

management crucial during chilled storage. Botrytis cinerea is the primary biological element produce post-harvest problems since it is responsible for the growth of grey mold [5]

Grey mold is one of the world's harmful and economically significant grape diseases. It can be potentially risky in dormant or semi-dormant saprophytic forms in necrotic floral tissues, and it can affect the tissues of flowers and growing berries. Grey mold is a dangerous grapevine disease that affects grapevines all over the world, mostly in temperate climates like South Italy, and has a considerable negative economic impact on wine and grape production [18]. Due to the prevalence of dangerous microorganisms such as grey mold on grapes, chitosan edible coating can be an excellent substitute for natural coating. This is particularly relevant when the coating incorporates essential oil to prevent the growth of spoilage microorganisms [24].

Chitosan has been recognized as a material with high potential for transporting active compounds, inherent antimicrobial and antioxidant elements, as well as strong film-forming capabilities [11]. Chitosan, a deacetylated chitin, is soluble in water and possess wide range of application in different areas of food technology [8]. The general applications of antimicrobial packaging in food products have expanded because of edible coatings and film containing essential oils [10] [14]. Natural essential oils can be used as antimicrobial agents to successfully prevent the growth of spoilage and harmful bacteria [13]. This study is to develop chitosan incorporated with citronella oil coating spray and to analyse the microbiological and physicochemical properties of grapes treated with chitosan incorporated with citronella oil.

The study of chitosan-citronella oil coatings and their effects on the shelf life and quality of fruits and vegetables has significant implications for the food industry. The findings suggest that chitosan-citronella oil coatings could be used to extend the shelf life of grapes and other fruits, improving their quality and reducing waste [16]. This innovation could lead to major advancements in the food industry, ensuring that fruits and vegetables remain fresh and nutritious for a longer period. Furthermore, the use of chitosan-citronella oil coatings could potentially reduce the need for synthetic preservatives and chemicals, making the food more natural and healthier for consumption [23].

2. Material and Methods

2.1 Materials

The grapes were purchased from a local supplier (Johor, Malaysia) and used immediately after purchase. Chitosan powder (85% deacetylated, CAS No. J64143.18, Ward Hill, USA), glacial acetic acid (Bendosen, CAS No. 64-19-7, Malaysia), and, glycerol (R&M, CAS No. 56-81-5, Semenyih, Selangor), as a plasticizing agent, Tween-20 as an emulsifier (Sigma, Milwaukee, WI, USA), citronella essential oil (Future Food, Thailand), commercial potato dextrose agar (PDA) (HIMEDIA, India), and peptone water (HIMEDIA, India) were analytical grade.

2.2 Preparation of chitosan solution incorporated with citronella oil

Chitosan powder was gradually added to an aqueous solution containing 1% acetic acid and 0.75% glycerol (v/v) while being gently stirred to create a 1% (w/v) chitosan coating solution. After homogenizing for 120 seconds at 500 rpm, the mixture was kept overnight at 22 °C room temperature. 0.25% Tween-20 (v/v) and citronella essential oil of different concentrations (0.5%, 1.0%, and 1.5%) were mixed with the chitosan solution. Distilled water was set as a control sample. The final coating mixtures were homogenized at 500 rpm for 90 seconds [19].

2.3 Coating of chitosan solution incorporated with citronella oil

The spray technique by using a hand-sprayer was employed to coat the grapes with the chitosan solution containing citronella oil until the grapes full coated [14]. The treated samples were placed in polypropylene container (pp) and stored at 4°C for 15 days.

2.4 Physicochemical properties of grapes

In this section all the physicochemical properties which are pH, visual observation, firmness (elasticity and skin strength), and moisture content were evaluated at day 0, 3, 6, 9, 12, and 15 of storage.

2.4.1 pH analysis

On day 0, 3, 6, 9, 12, and 15, the grape samples were blended with distilled water in a Panasonic blender to determine their pH values using a pH meter. The pH meter (Apera, SX751, Shanghai, China) is calibrated using set up pH buffer solutions of pH 4, 7, and 10 in order to acquire an accurate pH value. The accuracy and consistency of the pH readings are guaranteed by this calibration procedure. First, the pH rod was cleaned with distilled water before it was immersed in samples [22].

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2.4.2 Visual observation

The visual observation of grapes was used to assess their appearance. The grapes were placed in opaque plastic containers, preserved in PP (polypropylene) containers, and refrigerated at 4°C for 15 days to preserve mature table grape postharvest quality. The physical appearance of grapes (*Vitis vinifera*) treated with chitosan and citronella oil was assessed by determining whether they were in good condition or had moldy patches on the surface and sticky liquid escaping from the fruits. To maintain consistency, the grapes were evaluated using a standardized visual evaluation technique. This could include inspecting the grapes for colour, brightness, uniformity, surface texture, and other visual characteristics.

2.4.3 Firmness analysis

The highest force necessary to break the fruit was measured using the TA.XTplus Texture Analyzer (Stable Micro Systems, Surrey, UK) with HDP/90 platform and 30 kg load cell. A 35mm P/35 probe [25] was used to immediately assess the skin strength and elasticity of the grapes. When the probe is put over the grapes, the Texture Analyzer regulates the sample with a controlled force or deformation while monitoring the resulting reaction.

2.4.4 Moisture content analysis

To assess the moisture content of grapes, they were oven dried for 7 hours at 105 °C in a laboratory drying oven (UFE-500, Memmert, Schwabach, Germany). An average sample size of 5g will be placed on an aluminium tray in automatic mode and exposed to 105°C infrared radiation [9]. The sample is then gently dried using heat by the apparatus. After a few hours, demonstrate that all of the moisture has been removed. The moisture content data of the grapes were interpreted. The moisture content was measured three times. The moisture content of the grapes was calculated using Equation 1.

$$Moisture\ content\ (\%) = \frac{Initial\ weight - Final\ weight}{Initial\ weight} \times 100 \quad (1)$$

2.5 Microbial test

2.5.1 Yeast and mold analysis

Yeast and mold analysis on potato dextrose agar (PDA) using the spread plate technique was used to evaluate the microbiological test of grapes treated with chitosan and combined with citronella oil. The steps include the preparation of plate agar, sample preparation, dilution, incubation, and counting of colonies. The microbiological evaluation for yeast and mold analysis was performed on days 0, 3, 6, 9, 12, and 15 of the storage periods.

2.5.2 Media and Sample preparation and Dilution

To make the agar, 39.0g of Potato Dextrose Agar (PDA) powder was mixed with 1000 mL of distilled water and placed in a water bath at 46 to 48°C until thoroughly dissolved. The agar solution was then placed in a glass bottle and autoclaved at 121°C for around 15 minutes. Place the medium in a disposable petri dish and let it to harden [20].

To manufacture buffered peptone water, 15g of buffered peptone water powder was diluted in 1000 mL of distilled water. Fill each universal bottle with 9 mL of buffered peptone water. The buffered peptone water was then autoclaved for roughly 15 minutes at 121°C. Each triplicate of 25 g grape sample was homogenized in 225 mL of sterile buffered peptone water and vigorously shaken at 200 rpm for 30 minutes. In an aseptic chamber under sterilized conditions, 1 mL of material was completely mixed with 9 mL of peptone water to obtain the first dilution (10-1).

Then, 1 mL of the first dilution was transferred into 9 mL of peptone water to form the second dilution (10-2) and the process was repeated by transferring 1 mL of the second dilution to make the third dilution (10-3) until the sixth dilution (10-6) was obtained. Using the spread plate method, yeast and mold counts were conducted on potato dextrose agar (PDA) after five days of incubation at 28°C ± 1°C [20]. Grape sample data were expressed as Log 10 colony-forming unit/g (Log CFU/g).

2.6 Statistical analysis

All studies were conducted three times with the identical grape batches. At different times, the identical treatment condition will be applied to each replication. To establish whether there was a significant difference, data were evaluated using two-way analysis of variance (ANOVA). There were discrepancies in the data

obtained. Tukey's test was used to calculate the difference between means at a significance level of 5%. If the value is $p \leq 0.05$, it is considered significant. The SPSS trial version was used to do ANOVA.

3. Results and Discussion

3.1 Physicochemical properties of grapes

3.1.1 pH analysis

The pH of the samples relates to the concentration of hydrogen. The pH analysis is used to determine the acidity of the grapes after treatment which can influence pH value and shelf life of fruits. This may happen due to the possibility of improper pH of grapes that stimulate mold and yeast growth. Throughout the storage period, the pH of the solutions increased. The decrease in the amount of accessible organic acids, which are used as an energy source to fuel the fruit-ripening process, was related to this behaviour. Table 1 shows the pH of the samples were increased (3.53 ± 0.02 to 3.74 ± 0.01) throughout the storage period. The increase in pH was accompanied by a decrease in titratable acidity as a result of citric acid loss (1).

Table 1 *pH value of grapes (Vitis vinifera) that treated with chitosan incorporated with citronella oil*

Sample	Mean ± SD value for overall pH					
	Storage (Day)					
	0	3	6	9	12	15
Control	3.57±0.02 ^{Da}	3.66±0.01 ^{Ca}	3.67±0.01 ^{BCa}	3.69±0.01 ^{ABa}	3.73±0.02 ^{ABa}	3.74±0.01 ^{Aa}
T1	3.53±0.02 ^{Db}	3.62±0.02 ^{Cb}	3.63±0.01 ^{BCb}	3.67±0.01 ^{ABb}	3.65±0.02 ^{ABb}	3.72±0.01 ^{Ab}
T2	3.54±0.03 ^{Db}	3.63±0.01 ^{Cb}	3.66±0.05 ^{BCb}	3.64±0.01 ^{ABb}	3.64±0.01 ^{ABb}	3.67±0.01 ^{Ab}
T3	3.56±0.03 ^{Dc}	3.57±0.02 ^{Cc}	3.62±0.01 ^{BCc}	3.63±0.02 ^{ABc}	3.63±0.02 ^{ABc}	3.63±0.01 ^{Ac}
T4	3.56±0.01 ^{Dc}	3.58±0.02 ^{Cc}	3.55±0.04 ^{BCc}	3.62±0.01 ^{ABc}	3.62±0.01 ^{ABc}	3.61±0.01 ^{Ac}

*Note: T1: 1% Chitosan, T2: 1% Chitosan + 0.5% Citronella oil, T3: 1% Chitosan + 1.0% Citronella oil, and T4: 1% Chitosan + 1.5% Citronella oil. The values displayed are measured in mean ± standard deviation. The mean values for Uppercase (A, B, C, D) is Day and lowercase letter (a, b, c, d) is concentration.

3.1.2 Visual observation

Chitosan mixed with citronella essential oil was used to coat the grapes, which were kept at 4°C for 15 days. Table 2 reveals that treatments T1 to T4 effectively protected the grapes based on the initial visual quality check. When compared to the other treatments, the control sample displayed apparent evidence of mildew degradation, including moldy patches on the surface and sticky liquid pouring from the grape on day 9. The grapes coated with chitosan alone or in combination with citronella oil have great visual properties. However, as the days continue until day 15, the colour begins to dim.

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Table 2 *Visual observation of grapes (Vitis vinifera) treated with chitosan incorporated with citronella oil*

*Note: T1: 1% Chitosan, T2: 1% Chitosan + 0.5% Citronella oil, T3: 1% Chitosan + 1.0% Citronella oil, and T4: 1% Chitosan + 1.5% Citronella oil.

DAYS / TREATMENT	VISUAL OBSERVATION					
	0	3	6	9	12	15
Control						
T1						
T2						
T3						
T4						

3.1.3 Firmness

Skin strength

The skin strength of table grapes has a direct impact on their firmness. Higher skin strength is relating to firmer grapes, which customers prefer due to their increased eating quality and longer storage capacity [16]. Skin strength is an important quality criterion since it determines the hardness and durability of table grapes. Treatments and environmental conditions have been demonstrated in studies to influence grape skin strength, hence influencing texture and overall quality [21]. Table 3 shows the average skin strength of grapes treated with chitosan and citronella oil ranged from 66.19 ± 3.31 to 109.28 ± 7.55 for all days and samples. The skin strength of grape for control, T1, T2, and T3 were decreased slightly in values from day 0 in comparison with T4, which increased in range from 87.85 ± 2.54 to 109.28 ± 7.55. The interaction of hydrocolloids and other additives such as plasticizers, water and antimicrobial substances has the greatest influence on the textural properties of edible coatings [6]. According to Li *et al.*, (2019) [12], chitosan's ability to trigger plant defence responses can be further amplified by the presence of citronella oil's bioactive compounds, leading to stronger cell walls and increased grape skin strength. Some studies have reported that the use of edible coatings on grapes preserved their firmness during 12 days of storage at room temperature [4]. Additionally, edible coatings have been found to decrease fruit weight loss and inhibit the increase of cell-wall-degrading enzyme activities, further contributing to the preservation of grape quality [3].

Table 3 *Skin strength of grapes (Vitis vinifera) that treated with chitosan incorporated with citronella oil*

Mean ± SD value for overall skin strength (g)						
Sample	Storage (Day)					
	0	3	6	9	12	15
Control	66.19±3.31 ^{Ba}	69.53±2.68 ^{Ba}	75.72±2.03 ^{Ba}	22.16±3.14 ^{Ba}	60.81±1.84 ^{Ba}	9.07±0.44 ^{Ba}
T1	90.73±3.25 ^{Aa}	68.17±3.47 ^{Aa}	85.56±3.17 ^{Aa}	97.23±4.82 ^{Aa}	84.74±3.87 ^{Aa}	68.04±3.47 ^{Aa}
T2	81.72±1.83 ^{Aa}	96.89±5.68 ^{Aa}	93.91±2.02 ^{Aa}	81.61±3.03 ^{Aa}	109.66±5.72 ^{Aa}	81.21±3.54 ^{Aa}
T3	85.91±0.84 ^{Aa}	82.68±1.40 ^{Aa}	106.65±7.56 ^{Aa}	85.81±1.61 ^{Aa}	106.20±2.53 ^{Aa}	93.06±3.28 ^{Aa}
T4	87.85±2.54 ^{Aa}	83.57±2.72 ^{Aa}	100.22±1.14^{Aa}	93.81±2.98 ^{Aa}	104.61±2.90 ^{Aa}	109.28±7.55 ^{Aa}

*Note: T1: 1% Chitosan, T2: 1% Chitosan + 0.5% Citronella oil, T3: 1% Chitosan + 1.0% Citronella oil, and T4: 1% Chitosan + 1.5% Citronella oil. The values displayed are measured in mean ± standard deviation. The mean values for Uppercase (A, B, C, D) is Day and lowercase letter (a, b, c, d) is concentration.

Elasticity

Chitosan combined with a high concentration of citronella oil can also affect grape elasticity. Chitosan-citronella oil interaction may affect the mechanical properties of grape skin, particularly elasticity [5]. Table 4 shows the average elasticity of grapes treated with chitosan and citronella oil ranged from 16.37 ± 2.29 to 24.18 ± 2.92 for all days and samples. The elasticity grape for control ranged from 19.96 ± 2.16 to 22.75 ± 2.41, for T1 from 16.37 ± 2.29 to 21.37 ± 0.65, for T2 from 17.98 ± 1.02, and for T3 from 18.24 ± 0.11 to 21.72 ± 0.52, not given differed significantly (p > 0.05) and decreased slightly in values from day 0 in comparison with T4, which increased in range from 18.19 ± 3.45 to 24.13 ± 0.43. The concentration of citronella oil used in treatment, according to study, can affect grape flexibility. Grapes with higher citronella oil content may have greater flexibility [2]. According to Pal *et al*., (2021) [17], Chitosan, a natural biopolymer, has been widely studied for its antimicrobial and antioxidant properties. When combined with citronella oil, which also possesses antimicrobial and antioxidant characteristics, the resulting composite may help in preserving the quality of grapes by reducing microbial growth and oxidative damage and enhance their flexibility. Motelica *et al*., (2020) [16] also reported that research on chitosan composite films has shown that the addition of essential oils, such as citronella oil, can improve the flexibility and mechanical properties of the films. As a result, the incorporation of citronella oil into chitosan-based films may contribute to increased elasticity, which could benefit grape preservation and storage.

Table 4 Elasticity *of grapes (Vitis vinifera) that treated with chitosan incorporated with citronella oil*

Mean ± SD value for overall elasticity (mm)						
Sample	Storage (Day)					
	0	3	6	9	12	15
Control	21.68±3.90 ^{Aa}	20.26±0.83 ^{Aa}	19.96±2.16 ^{Aa}	22.75±2.41 ^{Aa}	20.86±1.10 ^{Aa}	21.78±4.55 ^{Aa}
T1	21.32±2.55 ^{Aa}	21.37±0.65 ^{Aa}	16.89±0.34 ^{Aa}	20.15±1.23 ^{Aa}	20.81±2.39 ^{Aa}	16.37±2.29 ^{Aa}
T2	21.11±2.78 ^{Aa}	21.04±2.07 ^{Aa}	24.18±2.92 ^{Aa}	21.51±3.30 ^{Aa}	21.15±0.40 ^{Aa}	17.98±1.02 ^{Aa}
T3	19.60±0.24 ^{Aa}	21.22±0.14 ^{Aa}	21.72±0.52 ^{Aa}	20.04±0.24 ^{Aa}	19.48±0.27 ^{Aa}	18.24±0.11 ^{Aa}
T4	18.19±3.45 ^{Aa}	19.17±3.26 ^{Aa}	19.86±0.72 ^{Aa}	19.85±0.40 ^{Aa}	21.59±1.47 ^{Aa}	24.13±0.43 ^{Aa}

*Note: T1: 1% Chitosan, T2: 1% Chitosan + 0.5% Citronella oil, T3: 1% Chitosan + 1.0% Citronella oil, and T4: 1% Chitosan + 1.5% Citronella oil. The values displayed are measured in mean ± standard deviation. The mean values for Uppercase (A, B, C, D) is Day and lowercase letter (a, b, c, d) is concentration.

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3.1.4 Moisture content analysis

Because a lower moisture content indicates a longer shelf life and better preservation, this number is critical for determining grape quality and shelf life. The moisture content of grapes fluctuates depending on temperature, drying procedure, and other factors [7]. Table 5 shows the average moisture content of grapes treated with chitosan and citronella oil, as well as the interactions between them.

According to Table 5, the range obtained for moisture content from all samples was 60.90 ± 1.80 to 82.57 ± 2.13 and the data was recorded from day 1 until day 15. From the data, samples T1, T3 and T4 shown a slightly decrease in value of moisture content where sample T1 was 80.90 ± 1.49 to 75.50 ± 1.83, samples T3 was 80.53 ± 2.18 to 79.67 ± 2.28 and T4 was 81.07 ± 1.45 to 80.50 ± 1.60 at the end of the day. As for sample T2, there is a small increase in value of moisture content from 79.90 ± 1.48 to 81.67 ± 0.21 and was significant difference ($p \leq 0.05$). In comparison with control, this samples shown drastic decreasing value of moisture content from 79.17 ± 1.50 to 60.90 ± 1.80. According to the research, the concentration of citronella oil used in treatment can affect the amount of moisture in grapes where higher citronella oil concentrations may retain grape moisture content [7].

Table 5 *Moisture content of grapes (Vitis vinifera) treated with chitosan incorporated with citronella oil*

Mean ± SD value for overall moisture content (%)						
Sample	Storage (Day)					
	0	3	6	9	12	15
Control	79.17±1.50 ^{Ba}	73.00±2.82 ^{Ba}	69.83±2.70 ^{Ba}	76.00±2.96 ^{Ba}	68.50±3.30 ^{Ba}	60.90±1.80 ^{Ba}
T1	80.90±1.49 ^{Aa}	80.87±2.82 ^{Aa}	79.40±1.49 ^{Aa}	80.50±1.83 ^{Aa}	78.20±1.45 ^{Aa}	75.50±1.83 ^{Aa}
T2	79.90±1.48 ^{Aa}	80.40±1.36 ^{Aa}	81.07±1.86 ^{Aa}	79.50±3.14 ^{Aa}	80.13±2.00 ^{Aa}	81.67±0.21 ^{Aa}
T3	80.53±2.18 ^{Aa}	82.50±1.77 ^{Aa}	79.50±2.23 ^{Aa}	80.73±3.87 ^{Aa}	81.73±1.68 ^{Aa}	79.67±2.28 ^{Aa}
T4	81.07±1.45 ^{Aa}	80.07±0.70 ^{Aa}	82.57±2.13 ^{Aa}	81.97±0.80 ^{Aa}	81.13±1.93 ^{Aa}	80.50±1.60 ^{Aa}

*Note: T1: 1% Chitosan, T2: 1% Chitosan + 0.5% Citronella oil, T3: 1% Chitosan + 1.0% Citronella oil, and T4: 1% Chitosan + 1.5% Citronella oil. The values displayed are measured in mean ± standard deviation. The mean values for Uppercase (A, B, C, D) is Day and lowercase letter (a, b, c, d) is concentration.

3.2 Microbial test

3.2.1 Yeast and mold analysis

Fig. 1 depicts the influence of edible coatings on yeast and mold growth in grapes stored at 4 ± 1°C. According to the statistical analysis, there are significant differences at ($p \leq 0.05$) between storage duration and grape treatments in relation to yeast and mold characteristics. When compared to the control, the treatment considerably reduced at ($p \leq 0.05$) for the population of yeast and mold. This resulted in more effective treatments with a final population of T2: 4.25 Log CFU/g, T3: 3.82 Log CFU/g, and T4: 3.36 Log CFU/g after the addition of citronella essential oil. From day 0 until day 15, the population of yeast and mold went up by one logarithmic unit in chitosan-citronella oil treatments, compared to three logarithmic units in the control treatment and two logarithmic units in the chitosan-only treatment. Several studies have proved that chitosan and essential oil-based films and coatings improved fruit quality and shelf-life by suppressing pathogenic, food-related fungal development [9]. The goal of fruit-life research is to keep yeast and mold populations below 7 log CFU/g, which was achieved over a 15-day period using the treatments used in this study.

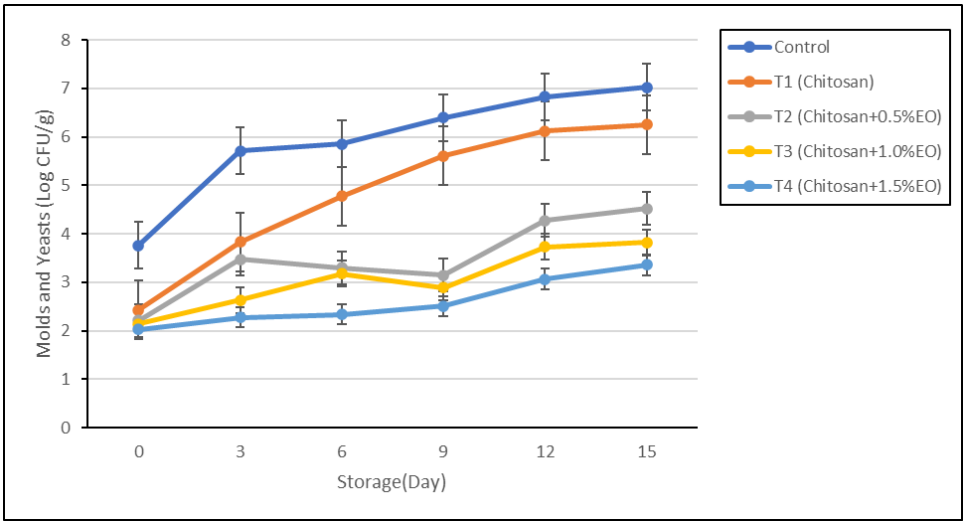

Fig. 1 *Counting of yeast and mold in grapes with chitosan and citronella oil*

4. Conclusion

In conclusion, grapes treated with chitosan incorporated with citronella oil can prevent fungal growth, preserving and improving the properties during the storage. All these data demonstrated that lowering the microbial population and extending grape shelf life had a positive effect. T4 shows the most effective therapy with the largest concentration of citronella essential oil. The result showed that the highest concentration of citronella essential oil with 1.5% (T4) showed to be the most successful as a coating since it has the lowest pH value, excellent visual qualities, higher skin strength, enhanced elasticity, and preserved moisture content. Meanwhile, for the microbiological analysis, mold and yeast counts were lowest in the T4 coating treatment. The findings indicated that adding essential oil to chitosan can extend its shelf life. However, limitations include focusing on laboratory conditions, assessing microorganism development, and addressing consumer preferences. Grape composition and properties can vary based on variety, growing conditions, and maturity stage. Further research and real-world application will enhance the effectiveness of the coating spray.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Syarah Syahindah Abdullah, Munira Zainal Abidin;* ***data collection:*** *Syarah Syahindah;* ***analysis and interpretation of results:*** *Syarah Syahindah;* ***draft manuscript preparation:*** *Syarah Syahindah, Munira Zainal Abidin. All authors reviewed the results and approved the final version of the manuscript.*

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