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The effect of cinnamon bark (*Cinnamomum burmanii*) essential oil microcapsules on vacuumed ground beef quality

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Abstract. Ground beef has a short shelf life because it is susceptible to damage due to microbial contamination and lipid oxidation. So some sort of preservation method such as refrigerated storage, vacuum packaging or natural preservative addition is needed to extend the shelf life of ground beef. A natural preservative that can be used as a food preservative is the cinnamon bark (*Cinnamomum burmanii)* essential oil microcapsules. The aim of the research was to determine the influence of a cinnamon bark essential oil microcapsules (0%;0.5% and 1% w/w of the ground beef) on the Total Plate Count (TPC), Thiobarbituric Acid (TBA), pH and color of ground beef during refrigerated storage (4±1°C). The result showed that cinnamon bark essential oil microcapsules affected the TPC, TBA, pH and color of ground beef. The addition of the cinnamon bark essential oil microcapsules on ground beef can inhibit microbial growth, inhibit lipid oxidation, inhibit discoloration and lowering pH of fresh ground beef during refrigerated storage compared to the control sample. The higher of the microcapsules were added, the higher the inhibition of microbial growth, lipid oxidation and discoloration of ground beef, indicating better preservation effects.

1. Introduction

Beef is a livestock product that is widely popular among consumers. The production of beef in Indonesia increase by 505,477 tons in 2012 with 6.76% rise each year [1]. Beef is a nutritious food. The nutritional values of beef were 18.8% protein, 14% lipid, 11 mg/g Ca, 170 mg/g phosphate, 2.8 mg/g Fe, 30 SI vitamin A and 0.08 mg/g vitamin B [2]. In addition to the form of chunks, beef is also sold in the form of ground beef. Fat and other tissue in beef were trimmed and size reduced by using a meat grinder [3,4]. Because of the size reduction, the surface of the ground beef will be wider and more susceptible to damage [5]. The deterioration of ground beef occurs due to microbial contamination and lipid oxidation. So, the shelf life of beef was 24 hours at room temperature storage and 1-4 days in refrigerated storage [6]. To extend ground beef shelf life, use of a preservation combination is a must. Preservation methods that can be used for ground beef are refrigerated storage, vacuum packaging [7] and addition of a natural preservative such as essential oil [8].

Essential oils can be extracted from Indonesian cinnamon bark (*C. burmanii*). The main component of cinnamon bark essential oil is cinnamaldehyde [9-11]. Cinnamaldehyde is an antimicrobial substance that acts against aerobic microbial (*Staphylococcus aureus)* and anaerobic facultative microbial such as *Escherichia coli*, *Bacillus cereus*, *Listeria monocytogenes*, and *Pseudomonas aeruginosa*. Those microbial are an example of spoilage flora in ground beef [6, 12, 13]. Beside the antimicrobial component, cinnamon bark essential oil also contains linalool [11] and cinnamic acid [14] as an antioxidant to prevent lipid oxidation. But essential oil has several weaknesses. There is evaporation of

volatile components, it is oxidized easily, it is poorly dispersible in dried material, and is susceptible due to high temperatures, UV light and moisture [15,16]. So, essential oil needs further treatment by microencapsulation to protect the liquid core taking a solid form [17].

The cinnamon bark essential oil microcapsules with a coating material made of maltodextrin and gum arabic (2:3) had the best physical characteristics for cinnamon oil microcapsules [18]. The active components will be protected in microcapsules form and will be released rapidly in certain application because of the water solubility of the microcapsules [19]. Cinnamon bark essential oil microcapsules can be used for ground beef preservation. The aim of the research was to determine the effect of the cinnamon bark essential oil microcapsules (0%;0.5% and 1% w/w of the ground beef) on the Total Plate Count (TPC), Thio Barbituric Acid (TBA), pH and color of ground beef during refrigerated storage (4±1°C).

2. Experimental

2.1. Cinnamon Bark Essential Oil Preparation

Cinnamon bark (*C. burmanii*) from Bubakan, Girimarto, Wonogiri (Indonesia) was sun dried for four days until the water content was 10-12%. The dried cinnamon bark was milled and sieved detained a 10 mesh. The cinnamon powder was subjected to steam distillation for four hours [11].

2.2. Cinnamon Bark Essential Oil Microcapsules Preparation

The cinnamon bark essential oil microcapsules were made from maltodextrin and gum arabic coating materials in a 2:3 ratio. The ratio of essential oil and coating materials was 1:25. Then, the formula was dissolved in distilled water with a ratio of coating material and distilled water of 1:20 [18]. All of the materials were homogenized with an "Ultra Turax® Basic® Woke" homogenizer for 15 minutes at 8000 rpm. The next process was microencapsulation by a spray dryer "SD Basic Lab Plant" with an inlet temperature of 109°C, a feed flow rate 15 - 20 ml/minute [20] and exhaust temperature of 57°C.

2.3. Application of the cinnamon bark essential oil microcapsules to ground beef

Tenderloin beef from a local slaughter house Sapto Raharjo, Surakarta, Indonesia was obtained three hours after slaughter and kept in a cool box to prevent contamination. The fat and other tissue of the beef was cut off to make it easier to grind. Beef grinding and application of microcapsules was done 4 hours after slaughtered. 70 g of beef was grinding by "Miyako BL 151" for each sample. The microcapsules (0%, 0.5 % and 1% w/w of the ground beef) were mixed with ground beef in 250 ml beaker glass and stirred with a stirrer stick. The ground beef was packed with vacuum packaging "Maksipack Automatic Vacuum Packager DZ-260/PD", using vacuum plastic packaged "Salaman" nylon material 75 micrometers thick. The vacuumed ground beef was preserved at 4±1°C in a "Samsung" refrigerator. TPC [21], TBA [22], pH [22] and the color (using Lutron Electronic RGB-1002) of the vacuum ground beef was determined on days 0, 4, 8, 12 and 16 day.

3. Results and discussion

3.1. Total Plate Count (TPC)

Table 1. Effect of Cinnamon Bark Essential Oil Microcapsules in Total Plate Count of Vacuumed Ground Beef during refrigerated storage (4±1°C).

Microcapsules	TPC (log CFU/g)				
	Day-0	Day-4	Day-8	Day-12	Day-16
0%	5.04^{aA}±0.000	5.73^{aB}±0.014	5.84^{aC}±0.044	5.92^{bD}±0.019	6.56^{cE}±0.003
0.5 %	4.99^{aA}±0.084	5.37^{aB}±0.278	5.64^{aB}±0.139	5.69^{aBC}±0.046	6.07^{bC}±0.008
1 %	4.83^{aA}±0.040	5.14^{aB}±0.055	5.54^{aC}±0.046	5.60^{aC}±0.052	5.74^{aD}±0.075

The figures follow the same large superscript letters in the same row and small superscript letters in the same column showed no significant difference at the 5% significance level.

During refrigerated storage for 16 days, the TPC of all samples increased significantly. The initial TPC of the vacuumed ground beef was around 4.83 – 5.04 log CFU/g. This is similar to the result which related to minced beef with the addition of acetic acid, CO_2 and mustard over 15 days of storage, when the initial TPC was 5.72 – 5.82 log CFU/g [23]. The TPC of the vacuumed ground beef with the addition of cinnamon bark essential oil microcapsules was significantly lower than that of the control sample. At the end of the storage (day 16), the TPC of the vacuumed ground beef with addition of 1% cinnamon bark essential oil microcapsules was still below the maximum acceptable limit 6 log CFU/g. However, the TPC of control and sample with the addition of 0.5% cinnamon bark essential oil microcapsules exceeded the standard level. This indicates that the addition of cinnamon bark essential oil microcapsules could inhibit microbial growth. A similar result found that edible coating enriched with 2% cinnamon oil could inhibit bacterial growth on beef during refrigerated storage. The TPC of treated sample was 6.03 log CFU/g while, the control sample was 7.13 log CFU/g at day 20 [24]. Previous research also reported that TPC of chilled pork samples with the addition of chitosan nanoparticles loaded with cinnamon essential oil was 6.60 – 7.61 log CFU/g at day 15, but the control sample reached 6.19 log CFU/g just after six days [25].

The TPC of the vacuumed ground beef with the addition of cinnamon bark essential oil microcapsules was significantly lower than that of the control sample because cinnamon bark essential oil microcapsules has an active component that is cinnamaldehyde [9]. Cinnamaldehyde is an antibacterial [13] and antimicrobial component [26]. The active component in the microcapsules will be released when the microcapsules dissolves in the water [19] of ground beef, which has 66% water content [2].

The mechanism of microbial inhibition by cinnamon bark essential oil's active component is because of the active component of essential oil affects the lipid bilayer cell membrane and mitochondria, disturbs the structure and leakages of the cell [27]. Bioactive compounds will react with the proteins on the wall of microbial cell membranes or in the cytoplasm and cause denaturation. The damage to the cell wall and cell membrane is caused by the weakening of the wall structure and cell membranes that become abnormal and whose cell pores are enlarged. Thus the cell wall and cell membrane cannot selectively regulate the exchange of substances from and into the cell and ultimately cell lysis occurs [28]. Cinnamaldehyde inhibits ATPase activity. Cinnamaldehyde can increase membrane permeability, leakage of cytoplasm, and interact with enzymes located on the cell wall. Interaction of cinnamaldehyde with the cell membrane may cause leakage of small ions or it can inhibit the enzymes necessary for amino acid biosynthesis [29].

3.2. Thiobarbituric Acid (TBA)

Table 2. Effect of Cinnamon Bark Essential Oil Microcapsules on Thiobarbituric Acid (TBA) of Vacuumed Ground Beef during refrigerated storage (4±1°C).

Microcapsules	TBA (mg malonaldehide/kg)				
	Day-0	Day-4	Day-8	Day-12	Day-16
0%	0.044^{bA}±0.002	0.061^{aB}±0.003	0.067^{bB}±0.001	0.094^{bC}±0.004	0.116^{aD}±0.005
0.5 %	0.046^{bA}±0.001	0.055^{aB}±0.005	0.060^{aB}±0.001	0.078^{aC}±0.004	0.111^{aD}±0.001
1 %	0.027^{aA}±0.002	0.054^{aB}±0.001	0.063^{aC}±0.002	0.083^{aD}±0.001	0.102^{aE}±0.005

The figures follow the same large superscript letters in the same row and small superscript letters in the same column showed no significant difference at the 5% significance level.

The addition of cinnamon bark essential microcapsules causes inhibition of lipid oxidation on vacuumed ground beef. This is shown by the result for the TBA value of the treatment sample with the addition of 0.5% and 1% microcapsules, which was lower than the control sample at the end of the storage (day 16). The maximum acceptable limit for the TBA value was 2 malonaldehide/kg [30]. In this research, all samples had lower TBA value than the maximum acceptable limit by the end of the storage period. Previous research found that edible coating enriched with 2% cinnamon oil could inhibit lipid oxidation and the TBA value was lower than control during 20 days of storage [24]. Another research also reported

that TBA of chilled pork samples with the addition of chitosan nanoparticles loaded with cinnamon essential oil reached 2.09 malonaldehide/kg on day 15 while the control exceeded the maximum acceptable limit on day six [25]. The TBA value of the treatment sample with the addition of 0.5% and 1% microcapsules which lower than the control happened because cinnamon bark essential oil contains cinnamaldehyde [14] and linalool [14]. Besides that, cinnamon bark extract also contains eugenol and cinnamic acid. Cinnamaldehyde, linalool, eugenol and cinnamic acid perform an antioxidant activity [31]. Antioxidants are free radical scavengers and hydrogen atom donors so can inhibit lipid oxidation [32].

3.3. pH

Table 3 Effect of Cinnamon Bark Essential Oil Microcapsules on pH of Vacuumed Ground Beef during refrigerated storage (4±1°C).

Microcapsules	pH				
	Day-0	Day-4	Day-8	Day-12	Day-16
0%	$5.8^{aC}\pm 0.1$	$5.7^{aBC}\pm 0.1$	$5.5^{aAB}\pm 0.0$	$5.5^{bAB}\pm 0.0$	$5.5^{aA}\pm 0.1$
0.5 %	$5.9^{aC}\pm 0.1$	$5.8^{aBC}\pm 0.1$	$5.8^{cBC}\pm 0.0$	$5.6^{bB}\pm 0.0$	$5.4^{aA}\pm 0.1$
1 %	$6.1^{aD}\pm 0.1$	$5.7^{aC}\pm 0.0$	$5.6^{bC}\pm 0.0$	$5.4^{aB}\pm 0.1$	$5.2^{aA}\pm 0.1$

The figures follow the same large superscript letters in the same row and small superscript letters in the same column showed no significant difference at the 5% significance level.

During refrigerated storage for 16 days, the pH of all samples decreased significantly. Previous research reported that the pH of ground beef packaged with vacuum packaging decreased from 6.04 at day 0 to 5.45 at day 14 [7]. The growth of lactic acid bacteria that produce lactic acid decreased pH of packaged meats. The pH levels of the treatment samples with the addition of cinnamon bark essential oil microcapsules were lower than that of the control sample. This happened because glucose, lactic acid and some of the amino acid in the beef will be degraded by all of microbial contaminant into alkaline metabolite. This alkaline metabolite could make the higher of pH [33]. The pH decreasing of the control sample was slower than that of the treatment samples because the alkaline metabolite in the sample control was higher than in the treatment samples so it could inhibit the decrease of pH. But in the treatment samples, the alkaline metabolite content was a little lower because of the cinnamaldehyde compound can inhibit microbial growth which can produce alkaline metabolites.

3.4. Color

Table 4 Effect of Cinnamon Bark Essential Oil Microcapsules in Color of Vacuumed Ground Beef during refrigerated storage (4±1°C).

	Microcapsules	Color				
		Day-0	Day-4	Day-8	Day-12	Day-16
Red	0%	$207.5^{aA}\pm 17.7$	$237.5^{cB}\pm 2.1$	$273.5^{cC}\pm 0.7$	$318^{bD}\pm 1.4$	$332^{bD}\pm 9,9$
	0.5 %	$182.3^{aA}\pm 17.3$	$222.5^{bB}\pm 0.7$	$231^{bB}\pm 5.7$	$226^{aB}\pm 5.7$	$225.5^{aB}\pm 7,8$
	1 %	$208.5^{aB}\pm 12.0$	$185.5^{aA}\pm 7.8$	$197.5^{aAB}\pm 9.2$	$213^{aB}\pm 7.1$	$248.5^{aC}\pm 3,5$
Green	0%	$100.5^{aA}\pm 7.8$	$121.5^{aB}\pm 0.7$	$146.5^{bC}\pm 0.7$	$164.5^{bD}\pm 0.7$	$166^{cD}\pm 2,8$
	0.5 %	$96.8^{aA}\pm 3.9$	$101.5^{aA}\pm 2.1$	$117,8^{aB}\pm 3.8$	$113.5^{aB}\pm 2.1$	$112.5^{aB}\pm 3,5$
	1 %	$103^{aA}\pm 5.7$	$107^{aA}\pm 8.5$	$113^{aAB}\pm 4.2$	$122^{aB}\pm 4.2$	$126^{bB}\pm 2,8$
Blue	0%	$84.5^{aA}\pm 7.8$	$97.5^{aB}\pm 0.7$	$124.5^{bC}\pm 3.5$	$134.5^{bC}\pm 2.1$	$134.5^{cC}\pm 0,7$
	0.5 %	$93.8^{aA}\pm 1.8$	$90^{aA}\pm 1.4$	$95,8^{aA}\pm 3.2$	$95^{aA}\pm 1.4$	$93,5^{aA}\pm 3,5$
	1 %	$87.5^{aA}\pm 4.9$	$90.5^{aAB}\pm 7.8$	$101^{aBC}\pm 2.8$	$101^{aBC}\pm 4.2$	$109.5^{bC}\pm 2,1$

The figures follow the same large superscript letters in the same row and small superscript letters in the same column showed no significant difference at the 5% significance level.

The redness of all vacuumed ground beef samples increased significantly over 16 days of refrigerated storage. The change of meat color happened because of the change of fresh ground beef pigment. Myoglobin is the main pigment associated with meat color. The oxygenated form of myoglobin is

oximyoglobin that responsible for the bright-red color, while the oxidized form of myoglobin is metmyoglobin that responsible for browning [34]. The change of redness of the samples treated with cinnamon bark essential oil microcapsules was lower than the control sample because cinnamon bark essential oil has antioxidant compounds such as cinnamaldehyde, eugenol and linalool [11,14,31]. These antioxidants inhibit the discoloration of ground beef. Previous research stated that oregano extract that contains antioxidant can inhibit the discoloration of beef patties packaged in modified atmosphere storage [35].

The greenness of all vacuumed ground beef samples increased significantly over the 16 days of refrigerated storage. The change of greenness is because of oxidation of myoglobin to metmyoglobin, which then combines with H_2S which is a product of bacteria to form sulphmyoglobin (green pigment) and the growth of *Penicillium* [36]. *Pseudomonas fluorescens* produced slime and a green pigment on meat [6]. The samples treated with cinnamon bark essential oil microcapsules had lower greenness than the control sample. Antimicrobial compound such as cinnamaldehyde in the cinnamon bark essential oil can inhibit the growth of *Penicillium* [37] and *Pseudomonas fluorescens* [14] which form green pigment.

During 16 days of refrigerated storage, the blueness of the vacuumed ground beef control sample and the samples with a 1% addition of cinnamon bark essential oil microcapsules increased significantly. The blueness of the vacuumed ground beef samples with the addition of cinnamon bark essential oil microcapsules were lower than that of the control sample. The blueness is formed by *Penicillium* which produced a blue-green pigment [36]. Cinnamaldehyde as an antimicrobial compound in cinnamon bark essential oil can inhibit the growth of *Penicillium* [37].

4. Conclusion

The addition of the cinnamon bark essential oil microcapsules on ground beef can inhibit microbial growth, inhibit lipid oxidation, inhibit discoloration and lowering pH of fresh ground beef during refrigerated storage compared to the control sample. These results because of the active components of the cinnamon bark essential oil microcapsules that are cinnamaldehyde, linalool, eugenol. The higher of the microcapsules were added, the higher the inhibition of microbial growth, lipid oxidation and discoloration of ground beef, indicating better preservation effects.

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