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Effect of edible coating formulation from Raja Bulu Banana starch (Musa paradisiaca L.) on inhibiting chilling injury symptoms in Siam Orange (Citrus tangerina)

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ABSTRACT

Edible Coating has the ability to protect fruits and vegetables from biological, microbiological and chemical damage, so that shelf life can be extended. This study used variations in CMC and storage time. The purpose of this study was to determine the effect of using Raja Bulu banana starch (*Musa paradisiaca* L.) in making edible coating. To determine the effect of using CMC in making edible coating from Raja Bulu banana starch (*Musa paradisiaca* L.). To determine the effect of edible coating on shelf life and physical quality of Siamese oranges (*Citrus tangerina*). Sampling was carried out in an orange orchard, Jl. Ginting Suka Museum, Tiga Panah District, Karo Regency, North Sumatra. This study was conducted at the Agricultural Product Technology Laboratory, Faculty of Agriculture, Muhammadiyah University of North Sumatra. This study used a factorial Completely Randomized Design (CRD) with two (2) replications. Factor I is CMC, given the symbol (S) which consists of 4 levels, namely, S0 = 0%, S1 = 1%, S2 = 2% and S3 = 3%. Factor II is storage time, symbolized (W) consisting of 4 levels, namely, W1 = day 3, W2 = day 6, W3 = day 9 and W4 = day 12. The parameters observed include weight loss, total soluble solids (TPT), organoleptic taste, texture, color (L *, a * and b *) and vitamin C. The results of the study obtained were that the addition of CMC had a very significant effect at the p <0.01 level on the parameters of weight loss, total soluble solids, organoleptic taste, texture, color L*, color a*, color b* and vitamin C. Storage time had a very significant effect at the p <0.01 level on the parameters of weight loss, total soluble solids, organoleptic taste, texture, color L*, color a*, color b* and vitamin C.

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1. INTRODUCTION

This edible coating will be made using starch because it has the benefit of extending shelf life and maintaining the quality of food products. This is consistent with Sembara et al. (2021), who stated that the application of starch edible coating can prevent dehydration, fat oxidation, and browning on the surface, as well as reduce respiration rates by controlling the composition of CO2 and O2 gases in the atmosphere. Other advantages of polysaccharide-based edible coatings

include improved flavor, texture, and color, increased stability during sales and storage, improved appearance, and reduced spoilage rates in tangerines (Novita et al. 2004).

Unripe banana flesh contains more starch. Carbohydrates make up approximately 22-23% of the weight of banana flesh. Banana flesh is also rich in minerals, especially potassium, magnesium, phosphorus, and folate, as well as vitamins A, B6, and C (Maulana et al., 2024). Therefore, this study will use starch from the Raja Bulu banana in the production of edible coating.

Oranges are a fruit well-suited to subtropical climates and are also very easy to cultivate. Increased production is also related to their flavor and the health benefits they offer. 100 grams of oranges contain 27-49 mg of vitamin C, 0.9g of protein, 11.8g of carbohydrates, 9.4g of sugar, 2.4g of fiber, and 0.1g of fat. Oranges also offer benefits such as preventing premature aging, preventing cancer, boosting immunity, and more. However, to obtain maximum benefits, oranges of good physical quality are required (Lapendy et al., 2024).

The characteristics of the Siamese orange include a yellowish-green color, a shiny, smooth surface, and a peel thickness of approximately 2mm. The fruit weighs approximately 75.6g. The tip of the fruit is shallowly indented. The flesh is soft and juicy, with a refreshing, sweet flavor (Rochilah, 2023).

Post-harvest oranges undergo several physiological, enzymatic, and chemical processes. These processes contribute to quality changes. Generally, oranges are sold outdoors, which facilitates water evaporation, resulting in a decline in quality. Furthermore, a factor influencing the rate of decline in quality during storage is the fruit's ripeness. Numerous studies have shown that as tropical fruits mature, their water content, total soluble solids content, color, and aroma also increase. However, vitamin C content decreases. Therefore, proper citrus storage techniques are essential (Sundari and Sumiasih, 2023).

Oranges are a fresh horticultural commodity that is easily damaged post-harvest due to their high water content. Oranges also undergo metabolic processes after harvest, including transpiration and respiration. Therefore, proper post-harvest management is necessary to extend the product's shelf life and prevent quality degradation, such as weight loss, rotting, and decreased nutritional value and quality (Jannah, 2024; Novita et al. 2025).

Therefore, an alternative method for maintaining the quality of tangerines is the application of edible coating. According to Saupiana et al. (2024), edible coating is a method of applying a thin layer as a barrier to the surface of fruit or vegetables. This layer functions as a moisture barrier and prevents the escape of gases and water vapor, as well as contact with oxygen, thereby extending the shelf life of the commodity.

2. METHOD

2.1 Place and Time

This research was conducted in an orange orchard, Jl. Museum Ginting Suka, Tiga Panah District, Karo Regency, North Sumatra, and carried out in the Agricultural Product Technology Laboratory, Faculty of Agriculture, University of Muhammadiyah North Sumatra. It was conducted from January 2025 until completion.

2.2 Research Materials

The materials required for this study were Siamese oranges (Citrus tangerina), king bananas (Musa paradisiaca L.), 1000 ppm sodium bisulphite, distilled water, glycerol, CMC (Carboxymethyl Cellulose), stearic acid, red galangal juice, and ascorbic acid.

2.3 Research Tools

The equipment used in this research included beaker glasses, measuring cups, stirring rods, Erlenmeyer flasks, pestles and mortars, filter cloths, droppers, filter paper, knives, blenders, 80 mesh sieves, basins, cutting boards, gloves, funnels, spatulas, colorimeters, analytical scales, refractometers, penetrometers, hotplates, spectrophotometers, magnets, and cuvettes.

2.4 Research Method

This research method was conducted using a Complete Randomised Design (CRD) Factorial consisting of 2 factors, namely: Factor I: CMC (Carboxymethyl Cellulose) (S) S0 = 0%; S2= 2%; S1 = 1% S3 = 3%. Factor II: Storage time (W): W1 = day 3 W3 = day 9; W2 = day 6 W4 = day 12. The number of treatment combinations (TC) was 4 x 4 = 16.

2.5 Research parameters

The parameters observed in this study included: weight loss, total dissolved solids, organoleptic taste, texture, colour (L* (dark to light), a* (red to green), b* (yellow to blue), vitamin C test.

3. RESULTS AND DISCUSSION

3.1 Result

Based on the research conducted, statistical test results indicate that the addition of CMC in edible coating production affects the observed parameters. The average CMC effect values are shown in Tables 1 and 2 below.

Table 1. Effect of CMC on Observed Parameters

CMC (%)	Weight Loss (%)	TPT (^{0}Brix)	Organoleptic Taste	Texture (kgf)
S_0= 0%	44,038	8,075	2,000	3,165
S_1= 1%	38,350	11,813	2,888	5,770
S_2= 2%	36,338	13,288	3,019	9,885
S_3= 3%	28,750	16,838	3,525	12,153

Table 2. Effect of CMC on Observed Parameters

CMC (%)	Color			Vitamin C (%)
	L*	a*	b*	
S_0= 0%	61,531	4,513	2,704	7,288
S_1= 1%	55,685	8,691	3,503	8,859
S_2= 2%	52,821	10,563	3,780	11,479
S_3= 3%	47,684	13,509	4,306	13,120

Based on Tables 1 and 2, it can be seen that the effect of adding CMC has a very significant effect on each of these parameters. Based on these results, there is an increase in the average value from S0 to S3 on the TPT test parameters, organoleptic taste, texture, color a*, color b* and vitamin C. while there is a decrease in the average value on the weight loss and color L* test parameters.

Based on the research conducted, statistical test results indicate that storage time influences the observed parameters in edible coating production. The average values for the effect of storage time are shown in Tables 3 and 4 below.

Table 3. Effect of Storage Time on Observed Parameters

Storage Time (Day)	Weight Loss (%)	TPT (^{0}Brix)	Organoleptic Taste	Texture (kgf)
W_1= 3 Days	40,938	10,713	3,263	9,450
W_2= 6 Days	37,575	12,238	2,938	8,268
W_3= 9 Days	35,825	13,063	2,769	7,193
W_4= 12 Days	33,138	14,000	2,463	6,823

Table 4. Effect of Storage Time on Observed Parameters

Storage Time (Day)	Color			Vitamin C (%)
	L*	b*	b*	
W_1= 3 Days	57,590	8,673	3,353	11,645
W_2= 6 Days	55,076	9,263	3,471	10,734
W_3= 9 Days	53,749	9,598	3,671	9,773
W_4= 12 Days	51,590	9,861	3,798	9,223

Based on Tables 3 and 4, it can be seen that the effect of storage time has a very significant effect on each of these parameters. Based on these results, there is an increase in the average value from W1 to W4 for the TPT test parameters, color a* and color b*. Meanwhile, there is a decrease in the average value for the test parameters of weight loss, organoleptic taste, texture, color L* and vitamin C.

3.1 Interaction Between CMC and Storage Time on Weight Loss Parameters

Based on the analysis of variance, it was found that the interaction between CMC and storage time had a significant effect ($p<0.05$) on weight loss parameters. The level of this difference was tested using a mean difference test and can be seen in Table 5.

Table 5. Results of the Mean Difference Test of CMC and Storage Time on Weight Loss Parameters

Treatment	Average Distance		LSR		Notation	
			0,05	0,01	0,05	0,01
S0W1	48,80	-	-	-	a	A
S0W2	44,80	2	0,750	1,033	b	B
S0W3	42,80	3	0,788	1,085	c	C
S0W4	39,75	4	0,808	1,113	d	D
S1W1	42,55	5	0,825	1,135	c	C
S1W2	39,35	6	0,835	1,150	d	D
S1W3	37,30	7	0,843	1,168	e	E
S1W4	34,20	8	0,848	1,180	f	F
S2W1	39,55	9	0,853	1,190	d	D
S2W2	36,75	10	0,858	1,198	e	E
S2W3	35,70	11	0,858	1,205	e	E
S2W4	33,35	12	0,860	1,210	f	F
S3W1	32,85	13	0,860	1,215	f	F
S3W2	29,40	14	0,863	1,220	g	G
S3W3	27,50	15	0,863	1,225	h	H
S3W4	25,25	16	0,865	1,228	i	I

Description: Different letters in the notation column indicate a significantly different effect at the p<0.05 level and a very significantly different effect at the p<0.01 level.

Based on Table 5, it can be seen that the highest average value was found in S0W1, namely 48.80, and the lowest value was in the S3W4 treatment with an average of 25.25. For more clarity, see Figure 1.

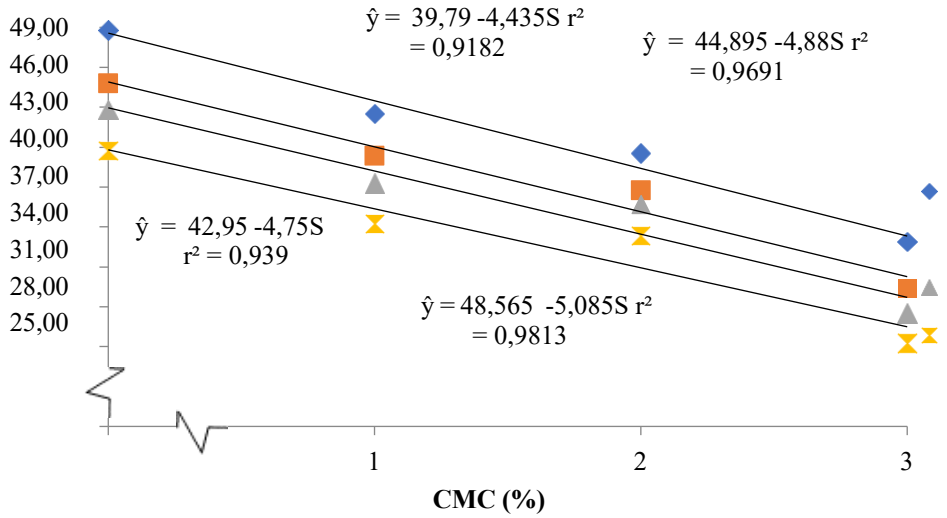

Figure 1. Relationship between the Interaction Effect between CMC and Storage Time on Weight Loss Parameters

Based on Figure 1 shows the relationship between CMC and storage time on weight loss parameters. From the graph it can be seen that the combination of adding CMC to edible coating of banana starch with storage time can consistently retain water, maintain and suppress the rate of weight loss in Siamese oranges so that it can maintain the physical quality of Siamese oranges. This is in accordance with Ababiel et al., (2023) who stated that the value of weight loss in fruits and vegetables coated with edible coating tends to be lower when compared to fruits and vegetables that are not coated with edible coating is able to prevent the loss of water content in fruits and vegetables and is able to control the rate of respiration in post-harvest fruits and vegetables.

3.2 Interaction Between CMC and Storage Time on Total Dissolved Solids

Analysis of variance (ANOVA) revealed that the interaction between CMC and storage time had a highly significant effect (p>0.01) on total dissolved solids. The level of this difference was tested using a mean difference test and is shown in Table 6.

Table 6. Results of the Mean Difference Test of CMC and Storage Time on Total Dissolved Solids

Treatment	Average.	Distance	LSR		Notation	
			0,05	0,01	0,05	0,01
S0W1	6,40	-	-	-	k	K
S0W2	7,65	2	0,392	0,539	j	J
S0W3	8,40	3	0,411	0,566	i	I
S0W4	9,85	4	0,422	0,581	h	H
S1W1	10,05	5	0,431	0,592	h	H
S1W2	11,45	6	0,436	0,600	g	G
S1W3	12,30	7	0,440	0,609	f	F
S1W4	13,45	8	0,442	0,616	e	E
S2W1	11,45	9	0,445	0,621	g	G
S2W2	13,15	10	0,448	0,625	e	E
S2W3	13,95	11	0,448	0,629	e	E
S2W4	14,60	12	0,449	0,632	d	D
S3W1	14,95	13	0,449	0,634	d	D
S3W2	16,70	14	0,450	0,637	b	B
S3W3	17,60	15	0,450	0,639	a	A
S3W4	18,10	16	0,452	0,641	a	A

Description: Different letters in the notation column indicate a significantly different effect at the p<0.05 level and a very significantly different effect at the p<0.01 level.

Based on Table 6, it can be seen that the highest average value is found in S3W3, namely 17.60°Brix and S3W4, namely 18.10°Brix. The lowest value is in the S0W1 treatment with an average of 6.40°Brix. For more details, see Figure 2.

Based on Figure 2 shows the relationship between CMC and storage time on the total soluble solids parameter. The increase in total soluble solids from S0W1 6.40°Brix and S3W4 18.10°Brix. TPT indicates the total sugar roughly and greatly determines the level of sweetness of Siamese oranges, the level of sweetness in oranges is also influenced by the level of fruit ripeness. This is in accordance with Manurung et al., (2024) who stated that the increase in TPT due to increased ripeness of oranges is due to the breakdown of water-insoluble polysaccharide components such as cellulose and pectin which are the main components of cell walls into water-soluble saccharides such as glucose, sucrose and fructose.

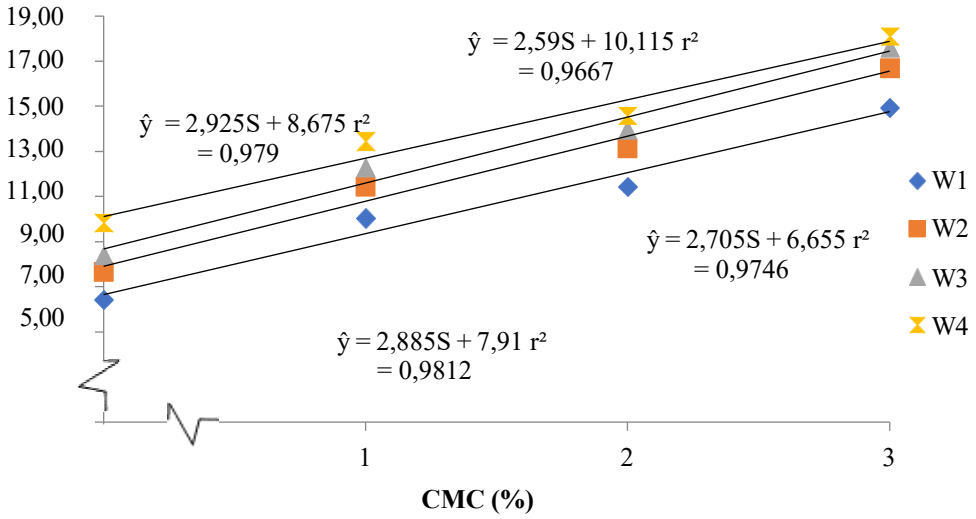

Figure 2. Relationship between the Effect of Interaction between CMC and Storage Time on Total Dissolved Solids Parameters

3.3 Interaction Between CMC and Storage Time on Vitamin C Parameters

Analysis of variance revealed that the interaction between CMC and storage time significantly (p<0.05) affected vitamin C parameters. The level of this difference was tested using a mean difference test and is shown in Table 7.

Table 7. Results of the Mean Difference Test of CMC and Storage Time on Vitamin C Parameters

Treatment	Average.	Distance	LSR		Notation	
			0,05	0,01	0,05	0,01
S0W1	8,78	-	-	-	h	H
S0W2	7,79	2	0,227	0,313	i	I
S0W3	6,87	3	0,238	0,329	k	K
S0W4	5,82	4	0,245	0,337	l	L

S1W1	10,22	5	0,250	0,344	f	F
S1W2	9,40	6	0,253	0,348	g	G
S1W3	8,57	7	0,255	0,354	h	H
S1W4	7,26	8	0,257	0,357	j	J
S2W1	13,10	9	0,258	0,360	c	C
S2W2	12,01	10	0,260	0,363	d	D
S2W3	10,90	11	0,260	0,365	e	E
S2W4	9,91	12	0,260	0,366	f	F
S3W1	14,49	13	0,260	0,368	a	A
S3W2	13,84	14	0,261	0,369	b	B
S3W3	12,76	15	0,261	0,371	c	C
S3W4	11,40	16	0,262	0,372	e	E

Description: Different letters in the notation column indicate a significantly different effect at the p<0.05 level and a very significantly different effect at the p<0.01 level

Table 7 shows that the highest average value was found in S3W1, at 14.49%, and the lowest value was found in S0W4, at 5.82%. For more clarity, see Figure 3.

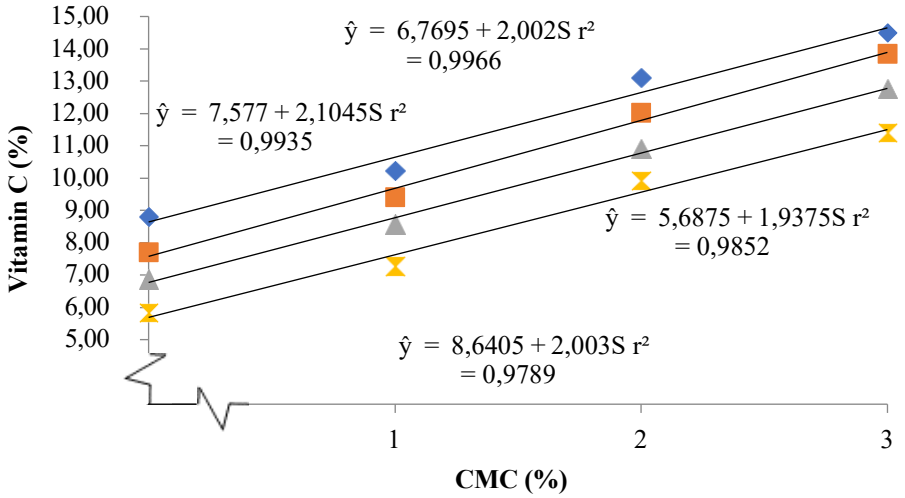

Figure 3. Relationship between the Interaction Effect of CMC and Storage Time on Vitamin C Parameters

Based on Figure 3, it shows the relationship between CMC and storage time on vitamin C parameters, the best results were found in the S3W1 treatment with a vitamin C content of 14.49%. This is because the addition of 3% CMC in the manufacture of edible coating of Raja Bulu banana starch has a significant effect on maintaining the quality of the vitamin C content of Siamese oranges. This is in accordance with Mutia and Darmawan (2024) who stated that using edible coating can maintain vitamin C levels even though there is a decrease, the level of decrease tends to be low. This is because the edible coating with the addition of CMC allows it to form a layer that is good enough to inhibit the respiration and transpiration processes so that the decrease in vitamin C content can be inhibited.

3.4 Interaction Between CMC and Storage Time on Texture Parameters

Analysis of variance revealed that the interaction between CMC and storage time significantly (p<0.05) affected texture parameters. The level of this difference was tested using a mean difference test and is shown in Table 8.

Table 8. Results of the Mean Difference Test of CMC and Storage Time on Texture Parameters

Treatment	Average Distance		LSR		Notation	
			0,05	0,01	0,05	0,01
S0W1	4,96	-	-	-	g	G
S0W2	3,78	2	0,292	0,402	h	H
S0W3	2,54	3	0,307	0,423	i	I
S0W4	1,38	4	0,315	0,434	j	J
S1W1	7,64	5	0,322	0,442	e	E
S1W2	6,22	6	0,325	0,448	f	F
S1W3	5,08	7	0,328	0,455	g	G
S1W4	4,15	8	0,330	0,460	h	H
S2W1	11,29	9	0,332	0,464	c	C
S2W2	10,31	10	0,334	0,467	d	D
S2W3	9,61	11	0,334	0,470	d	D
S2W4	8,34	12	0,335	0,472	e	E
S3W1	13,91	13	0,335	0,474	a	A

S3W2	12,77	14	0,336	0,475	b	B
S3W3	11,55	15	0,336	0,477	c	C
S3W4	10,38	16	0,337	0,478	d	D

Description: Different letters in the notation column indicate a significantly different effect at the p<0.05 level and a very significantly different effect at the p<0.01 level.

Based on Table 8, it can be seen that the highest average value was found in S3W1, namely 13.91 kgf, and the lowest value was in the S0W4 treatment with an average of 1.38 kgf. For more clarity, see Figure 4.

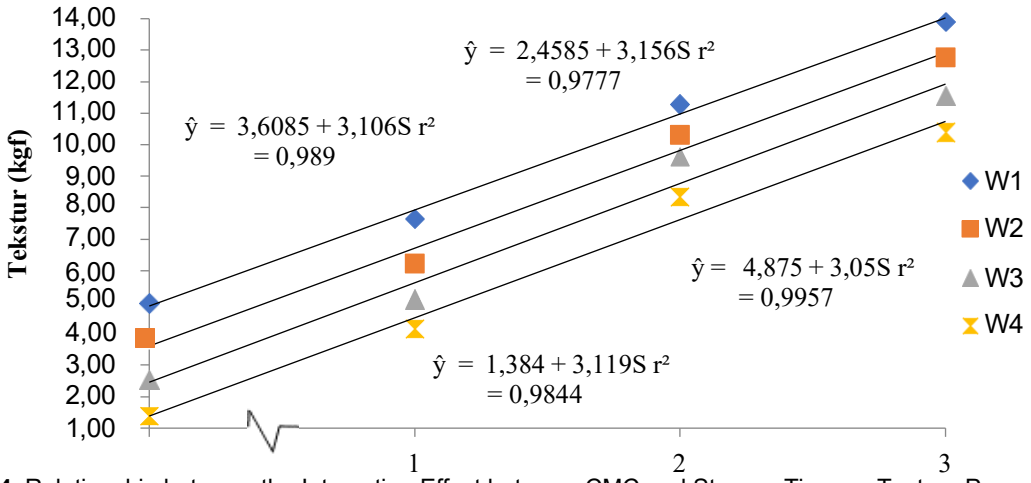

Figure 4. Relationship between the Interaction Effect between CMC and Storage Time on Texture Parameters

Based on Figure 4, the relationship between CMC and storage time on texture parameters is shown. The best results were obtained with a 3% CMC addition. This is due to the effect of the 3% CMC addition on maintaining the hardness of the tangerine. This is in accordance with Agustin and Cahyanto (2024) who stated that during the fruit ripening process, there is an increase in pectin-esterase and polygalacturonase activity, causing the dissolution of pectate compounds. Coating the fruit with edible coating will create low oxygen and high carbon dioxide conditions that will reduce the activity of these two enzymes, so that the fruit texture is better maintained during storage.

3.5 Interaction Between CMC and Storage Time on Color Parameter b*

Based on the analysis of variance, it was found that the interaction between CMC and storage time had a highly significant effect (p<0.01) on color parameter b. The level of this difference was tested using a mean difference test and can be seen in Table 9.

Table 9. Results of the Mean Difference Test of CMC and Storage Time on Color Parameter b*

Treatment	Average Distance		LSR		Notation	
			0,05	0,01	0,05	0,01
S0W1	2,55	-	-	-	c	C
S0W2	2,60	2	0,141	0,194	c	C
S0W3	2,80	3	0,148	0,204	c	C
S0W4	2,88	4	0,152	0,209	c	C
S1W1	3,10	5	0,155	0,213	b	B
S1W2	3,39	6	0,157	0,216	a	A
S1W3	3,60	7	0,158	0,219	a	A
S1W4	3,93	8	0,159	0,222	a	A
S2W1	3,65	9	0,160	0,223	a	A
S2W2	3,67	10	0,161	0,225	a	A
S2W3	3,88	11	0,161	0,226	a	A
S2W4	3,93	12	0,161	0,227	a	A
S3W1	4,12	13	0,161	0,228	a	A
S3W2	4,24	14	0,162	0,229	a	A
S3W3	4,41	15	0,162	0,230	a	A
S3W4	4,47	16	0,162	0,230	a	A

Note: Different letters in the notation column indicate a significantly different effect at the p<0.05 level and a highly significant difference at the p<0.01 level

Table 9 shows that the highest average value was found in S3W4, at 4.47, and the lowest value was found in S0W1, at 2.55. For more clarity, see Figure 5.

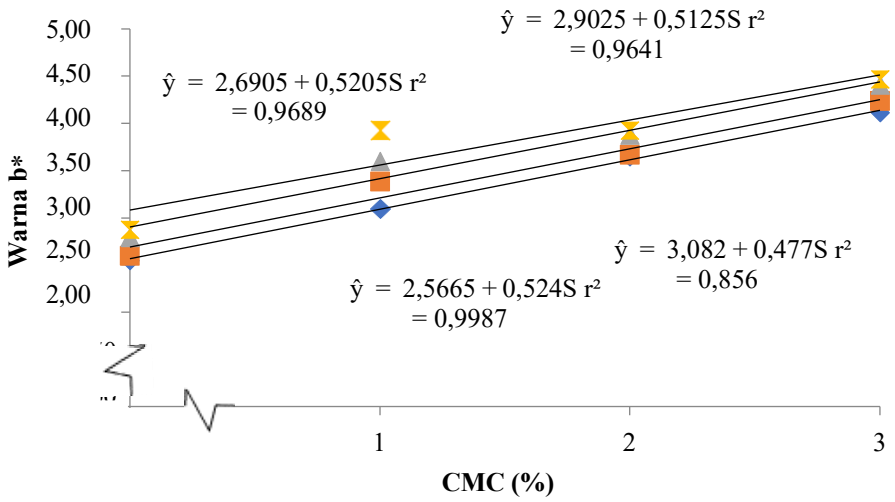

Figure 5. Relationship between CMC and Storage Time on the Color Parameter b*

Figure 5 shows the relationship between CMC and storage time on the color parameter b*. The best results were found in the S3W4 treatment with a value of 4.47. This is because the b* color value increases due to increased degradation of natural compounds such as anthocyanins and the formation of yellowish compounds such as chalcones, or storage that accelerates the color degradation reaction. An increase in b* color indicates the degree of yellowness in the sample (Sahupala, 2020).

4. CONCLUSION

The addition of CMC had a highly significant effect at the p<0.01 level on the parameters of weight loss, total soluble solids, organoleptic taste, texture, L* color, a* color, b* color, and vitamin C. Storage time had a highly significant effect at the p<0.01 level on the parameters of weight loss, total soluble solids, organoleptic taste, texture, L* color, a* color, b* color, and vitamin C. The interaction between the addition of CMC and storage time had a highly significant effect at the p<0.01 level on the parameters of weight loss and b* color. While the parameters of total soluble solids, texture, and vitamin C had a significant effect at the p<0.05 level, and there was no significant difference in the organoleptic parameters of taste, L* color, and a* color. The best treatment in this study was S3W1 because it contains vitamin C because edible coating can inhibit respiration in citrus fruit.

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