Current Science International
Volume: 13 | Issue: 04| Oct. – Dec.| 2024

EISSN:2706-7920 ISSN: 2077-4435
DOI: 10.36632/csi/2024.13.4.50
Journal homepage: www.curresweb.com
Pages: 594-606

Effect of Nisin and Gum Arabic as Edible Coating on the Quality Properties and Extend Shelf Life Period of Fresh Strawberry fruits

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Received: 10 Oct. 2024 **Accepted:** 30 Nov. 2024 **Published:** 10 Dec. 2024

ABSTRACT

The biggest challenge worldwide is maintaining the quality of fruits and vegetables after harvest. The edible coating is one of the methods preserving fresh fruit and vegetables' quality and extending their shelf life. This study aimed to assess the effect of edible coatings such as 2% nisin, 2% gum arabic and combination of nisin and gum arabic (1:1) to extend the harvest shelf life and preserve the quality of strawberry sored at 4°C for 12 days. The effect of application these coating to fresh strawberry were assessed by physicochemical, phytochemical, weight loss, firmness, microbial test and sensory evaluation. The results showed that coated treatments maintained a higher firmness value than control treatment. As for organoleptic properties, it proved that 2% nisin was the most effective way extend the shelf life of strawberry fruit followed by mixture and 2% gum arabic recorded the lowest effect.

Keywords: strawberry, nisin**,** gum arabic, edible coating, shelf life**.**

1. Introduction

Strawberry is a widely distributed crop around the world. People appreciate strawberries (*Fragaria ananassa*, wild *F. virginiana*) for their sweet taste, attractive aroma, red color, and silky texture. Strawberry's distinct, fragrant flavor and taste are popular among many people; hence, it is frequently cultivated for fresh fruit consumption (Schwieterman *et al*., 2014).

According to Rahimi *et al.* (2019), it can alter the metabolism of fruit towels by altering respiration rate, reducing humidity and firmness loss, preserving color, delivering antioxidants, antimicrobials, and other preservatives, regulating microbial development, and extending the shelf life of fruit. According to Khodaei *et al.* (2019), edible coatings can be used to carry a variety of supplements, including probiotics, vitamins, minerals, colorings, and antimicrobials. Numerous studies have shown the value of edible coatings for different sources to increase strawberries' shelf life. (Nadim *et al.,* 2015, Valenzuela *et al.,* 2015, Sogvar *et al.,* 2016, Bose *et al.,* 2019).

Strawberry fruit is distributed crop around the world and it belong to Rosaceae family, is highly valued by consumers and is a highly significant plant in terms of economics. Due to its organoleptic qualities and particularly its nutritional content (Garriga *et al.,* 2014; Liu *et al.,* 2016). It's used for foods like jam, jelly, ice- cream, soft drinks, chocolates, etc. (Kumar *et al.,* 2017). A popular fruit with unique flavor, color, and nutritional value is the strawberry. With high levels of anthocyanins, phenolic compounds, flavonoids, nitrogenous compounds, tocopherols, carotenoids, and ascorbic acid, it is rich of vitamins A, B, and C, minerals K, Ca, Mg, Fe, and S, fiber, and one of the best natural sources of antioxidants (Abozaid and Eldeeb, 2019; Khodaei, 2019). However, strawberries have a very short shelf life (4–5 days at 4 ◦ C), mainly due to the delicate tissue, fungal activities, and physiological disorders (Pinzon *et al.,* 2020).

The strawberry crop is considered one of the most promising non-traditional export crops in Egypt, as it represents 3.2% of the total area of cultivated vegetables and 4.4% of the total vegetable production. The number of strawberry exports has increased from 3.05 thousand tons in 2005 at a

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value of $1.739 million, to about 57.8 thousand tons in the year 2021, with a value of $6.33 million (Abu Al-Yazid *and* and Hassan 2023).

Edible coatings are innovative technique to improve the quality and shelf-life of fruit and fresh-cut products (Han *et al.,* 2018). Water vapor and feasts can be prevented by using edible coatings as a semipermeable barrier. According to Sharma *et al.*, (2018), the edible coatings act as a barrier to prevent the transfer of volatile chemicals, oxygen, carbon dioxide, moisture, and scent from fruits while they are being stored.

A representative substance with a variety of uses in the food industry, nisin is a water-soluble, non-toxic polypeptide made up of 34 amino acid compounds. Nowadays, assigned to E234 (Tryfon *et al.,* 2023). Nisin is an antibiotic-family antimicrobial peptide produced by specific strains of *Lactococcus lactis* subs. Lactis, has been used for many years as a food preservative in food assiduity because of its strong antibacterial activity and low toxicity to humans. Nisin does not cause resistance or antipathetic reactions; instead, it is digested into amino acids by a protease in the digestive tract after ingestion (Mok *et al.,* 2020).

Inhibiting the biosynthesis of the cell wall causes ATP hydrolysis and ion leakage, membrane severance conformation, dislocation of the pH equilibrium and the proton motive force, and ultimately cell death. These are some of the bactericidal mechanisms of nisin (Ma *et al.,* 2020 a; Mok *et al.,* 2020). Nisin being as a GRAS (generally recognized as safe), therefore, nisin is widely used as a food preservative in many countries for a variety of food products due to its safety and effectiveness (Costello *et al.,* 2021).

Gum Arabic, also known as acacia gum (E 414), is an air-dried substance extracted from the stem and branches of Acacia seyal and Acacia Senegal (Tahir *et al.,* 2019). It is widely used as a stabilizer, thickener, emulsifier, gelling agent, and edible coating in food and pharmaceutical products (Sulieman, 2018). The branches from which the exudate is extracted or found naturally are removed, and it is allowed to solidify in the atmosphere. GA is primarily found in Nigeria, Sudan, and Chad. GA is an arabinogalactan–protein combination in terms of structure. The potassium, calcium, and magnesium salts of arabic acid make up this complex. The structure of Arabic acid is composed of 1-3 linked β-D-galactopyranosyl units and branches with two to five β-D-galactopyranosyl residues joined by 1,3-ether linkages and joined to the basic β-D-galactopyranosyl chain by 1,6-linkages (Al-Jubori *et al.,* 2023).

Therefore, this study was carried out to evaluate the effect of edible coating using nisin, gum arabic and mix together to increase the shelf life during storage as well as its reduce water loss, microbiological contamination, reduce respiration in addition to prevent degradation and maintain the quality of bioactive compounds.

2. Materials and Method

2.1 Materials

Fresh strawberry fruits (*Fragaria ananassa sensation*) of the cultivar "Sensation" were purchased from a farm in Al-Zahwiyin village, Qalyubiyya Governorate**,** Egypt. The fruits were harvested when bright red color (3/4) of surface showing red at the same ripening stage. The fruits were selected based on the uniform color, same size and free of pests, represent blemishes or disease, and physical damage.

Gum Arabic powder (E414) (which satisfies Egyptian standard specifications 2022/1378), which was provided by Imtenan Health Shop, Industrial Area, Obour City, Egypt, was one of the food-grade materials used for the coating in this study, Nisin (food grade, E 234) was purchased from Sigma chemicals (St. Louist, MO, U.S.A), Cassava Starch, obtained from Food Technology Research Institute (ARC. Egypt) The analytical-grade chemicals used in this investigation were acquired from El-Gomhoria Co. for Chemicals and Drugs, Egypt.

2.2. Sample preparation and treatment procedures.

2.2.1. Nisin solution

Nisin solution was prepared using aqueous solution containing 2% of cassava starch and 2% of nisin. The solution was heated under constant agitation until it reached to 70°C, which is the gelatinization temperature of the cassava starch, and then cooled to ambient temperature (23±2°C) (Belay *et al.,* 2023).

2.2.2. Gum arabic solution

Gum arabic solution at concentrations of 2% was prepared by dissolving 2 g of gum arabic in 100 ml distilled water (w/v). The solution was stirred at low heat (40°C) for 60 mins on a magnetic stirrer/hot plate (Model: HTS-1003), then filtered under vacuum to remove any undissolved impurities. To increase the coating solutions' strength and flexibility, (1.0%) glycerol monostearate was added as a plasticizer once they had cooled to 20°C. NaoH (1N) was used to bring the pH of the solutions down to 5.6. Gum Arabic films were made using the process outlined by Ghulam *et al.* (2015).

2.2.3. Mix Nisin and Gum Arabic solution

Prepared with addition nisin solution to gum Arabic solution 1:1 (vol:vol) and mix them together.

2.3. Technological Method

Fresh strawberry fruits were washed for two minutes with 0.01% sodium hypochlorite (NaOCl) water solution, then the fruits were air dried for an hour at room temperature. The strawberries were split into four sections at random:
Part 1: Uncoated (Control)
Part 2: Coated with Nisin (N)
Part 3: Coated with Gum Arabic (G)
Part 4: Coated with mix Nisin and Gum Arabic (N+G)

The last three treatments of strawberry fruits were immersed in different solutions for three minutes: nisin (2% N), gum arabic (2% G), or a combination of nisin and gum arabic (1% N + 1% G). The control strawberries were left untreated. Following that, all treatments were allowed to dry, then it was packed in perforated polyethylene bags. The samples were stored at 4±2 °C until they spoiled, with periodic analyses conducted every three days.

2.4. Analytical methods

2.4.1. Physico-chemical analyses

Total soluble solids (TSS), pH value and total acidity (as citric acid) were determined according to (AOAC, 2019). Total phenolic compounds were determined using the Folin Ciocalteu method, according to Kupina *et al.* (2019). Total flavonoid was determined according to the method described by Matic *et al.* (2017). Anthocyanin content was determined by the method of Holzwarth *et al.* (2012).

2.4.2. Physical properties

2.4.2.1. Weight loss

The weight changes of the fruit during storage periods were tracked using an analytical balance to determine weight loss (Han *et al.*, 2004). applying the equation that follows:

$$\text{Weight loss\%} = [(\text{initial weight} - \text{final weight}) \times 100] / \text{initial weight}$$

2.4.2.2. Firmness

A computer-connected Instron Universal Testing Machine (Model 5543 P5995 USA) was used to measure fruit firmness. It was measured how much force was needed to get 10 mm inside the fruit with a 6 mm probe diameter. The machine was set to run at 20 mm min−1 in compression mode. On three different parts of the entire fruit, readings were taken (Zapata *et al.,* 2008).

2.4.2.3. Color measurement

Using a Minolta color reader CR-400 (Minolta Co. Ltd., Osaka, Japan), three measurements were made on the pod skin to ascertain the samples' color. The Hunter scale was used to assess lightness (L*), green to red (a*), and blue to yellow (b*) (Kumar *et al.,* 2014).

2.4.3. Microbial quality

Microbiological analyses were carried out as shown by APHA, (2015). For the microbial counts, samples were serially diluted and plated in total count agar (PCA) for total viable bacteria plate (aerobic) counts, MacConkey sorbitol agar was used to enumerate *E. coli* counts in each sample, and in acidified potato dextrose agar (PDA) for molds and yeast counts. The plate count agar plates were incubated at 37°C for up to 48 h to determine total aerobic bacterial clusters, at 37°C for 24 h for *E. coli* counts and at 25°C for 5 days to determine plate counts for Yeasts and molds. The findings were expressed as log colony-forming units (CFU/g).

2.4.4. Sensory evaluation:

Different uncoated and coated strawberries during storage were organoleptically evaluated. The sample was assessed by ten members (ten panelists) of staff at the Department of Horticultural Crops Technology Research, Food Technology Research Institute, Agricultural Research Center, Egypt. The sensory characteristics of color, odor, taste, Texture and overall palatability were evaluated based on a 9-point hedonic rating scale with a maximum score considered the best (Wichchukit and O'Mahony, 2014).

2.5. Statistical analyses

Statistical Analysis System (SAS, version 9.1) software was used to analyze variance (ANOVA). Significant differences were assessed at the level of P > 0.05.

3. Results and Discussion

3.1. Effect of different coatings on physicochemical properties of strawberry fruit during storage periods

Table (1) records the changes in pH, TA, and TSS over time at 4°C, and the results appeared that pH value was increased while TA and TSS decreased significantly ($p \leq 0.05$) during the storage period for all treatments. Data shows that the uncoated sample (control) had the highest increase in pH (4.13) after 9 days.

Table 1: Effect of different coating on physicochemical Properties of strawberry during storage periods

Treatments	Storage period (days)				
	0	3	6	9	12
			pH		
Control	3.79^{Ac}	3.85^{Ac}	3.98^{Ab}	4.13^{Aa}	0.00^{Cd}
N	3.81^{Ab}	3.82^{Ab}	3.85^{Bab}	3.88^{Ba}	3.90^{Ba}
G	3.80^{Ac}	$3.87A^{bc}$	3.93^{ABabc}	3.98^{Bab}	4.03^{Aa}
N+G	3.81^{Ab}	3.80^{Ab}	3.82^{Bb}	3.91^{Ba}	3.94^{Ba}
			TA (%)		
Control	0.92^{Aa}	0.87^{Aa}	0.75^{Bb}	0.71^{Ab}	0.00^{Dc}
N	0.90^{Aa}	0.88^{Aa}	0.78^{ABb}	0.75^{Ab}	0.71^{Bc}
G	0.91^{Aa}	0.83^{Babc}	0.86^{Aab}	0.80^{Abc}	0.77^{Ac}
N+G	0.89^{Aa}	0.85^{ABa}	0.81^{ABa}	0.73^{Ab}	0.68^{BCb}
			TSS (%)		
Control	9.69^{Aa}	8.64^{Ab}	7.50^{Bc}	6.14^{Cd}	0.00^{De}
N	9.72^{Aa}	8.67^{Ab}	8.45^{Ac}	8.24^{Ac}	8.10^{Ad}
G	9.74^{Aa}	8.72^{Ab}	8.51^{Ac}	7.63^{Bd}	6.13^{Ce}
N+G	9.68^{Aa}	8.62^{Ab}	8.40^{Ac}	8.09^{Ad}	7.89^{Be}

There is no significant difference ($P \leq 0.05$) between the means in a column that has the same letters (A, B, and C). There is no significant difference ($P \leq 0.05$) between the means in a row that has the same letters (a, b, and c). Control: fresh strawberry, N: coated with Nisin (2%), G: coated with Gum Arabic (2%), mix N+G coated with Nisin and Gum Arabic (1:1%).

In contrast, the N and N+G coatings displayed the lowest pH values (3.90 and 3.94) after 12-day storage, suggesting that their application slows down pH value changes. There is a significant difference between the control and all treatments during the storage period in pH and TA. However, when compared to the control, the results in Table (1) showed that coatings (N, G, and N+G) decreased changes in TA over the course for 12 days of storage. Petriccione *et al.* (2015) showed that TA decreased as strawberries storage time increased, and these results are consistent with their findings.

Due to the utilization of organic acids as respiration substrates, a reduction in titratable acidity was anticipated in postharvest fruit (Lan *et al.* (2019) and Ktenioudaki *et al.* (2019). Also, an increase in pH value and decrease of TA may be cause fruit senescence and enzymatic reaction according to Do Nascimento *et al.* (2023).

Furthermore, the fruits started to deteriorate as the amount of organic acids decreased. This development in organic acids was responsible for changes in total acidity, which is very high in the rapid growth phase of the fruit. According to Gol *et al.* (2013), coatings can decrease respiration rate, which may lead to a decrease in the use of organic acids and the retention of TA in coated fruits. As indicated in Table (1), the decrease of TSS% in coated samples (N, G, and N+G) was significantly delayed at the end of the storage time (12 days) at 4°C ($p \leq 0.05$). The high decrement in TSS% for control sample at 6 and 9 days of storage being 26.60% and 36.64%, respectively indicated a significant reduction in the shelf life of control samples. Atress *et al.* (2010) found that coatings on the strawberry's surface decreased respiration rate, which in turn decreased TSS loss. These results are consistent with those of their study.

3.2. Effect of different coatings on firmness and weight loss of strawberry during storage periods

According to Sharma *et al.* (2018), one of the most crucial quality parameters for strawberry fruit acceptance is the firmness. The firmness of the fruits was presented in table 2. The results appeared that all strawberry fruits treatments showed significantly reduction in firmness during the storage period. Meanwhile, the coated treatments maintained a higher firmness value than the control treatment after storage for 9 days; also, these values remained high in the coating treatments after 12 days of storage compared to the control, which expired after 9 days of storage. At the extended storage periods, no significant differences between N and N+G treatments followed by G treatments which had low value. The loss of firmness occurs within the cell wall structure, where pectin degrades due to pectinase activity, resulting in protopectin (Sharma *et al.,* 2018).

Table 2: Effect of different coating on firmness and weight loss (%) of strawberry during storage periods

Storage period (days)	Treatments							
	Control	N	G	N+G	Control	N	G	N+G
	Firmness (N)				Weight Loss (%)			
0	5.48^{Aa}	5.58^{Aa}	5.69^{Aa}	5.53^{Aa}	-	-	-	-
3	4.57^{Ba}	5.37^{ABa}	5.25^{ABa}	5.30^{Aa}	7.89^{Ca}	3.61^{Db}	3.55^{Db}	3.34^{Cb}
6	3.96^{Ca}	5.01^{Ba}	4.88^{Ba}	4.70^{Ba}	9.80^{Ba}	4.80^{Cb}	4.57^{Cc}	4.51^{Bd}
9	2.66^{Db}	4.30^{Ca}	4.24^{Ca}	4.28^{BCa}	13.3^{Aa}	7.13^{Bb}	7.59^{Bb}	7.36^{Ab}
12	0.00^{Ec}	3.87^{Ca}	3.47^{Db}	3.78^{Ca}	0^{D}	8.29^{Aa}	8.68^{Aa}	8.41^{Aa}

There is no significant difference ($P \leq 0.05$) between the means in a column that has the same letters (A, B, and C) during storage periods. There is no significant difference ($P \leq 0.05$) between the means in a row that has the same letters (a, b, and c) for treatments. Control: fresh strawberry, N: coated with Nisin (2%), G: coated with Gum Arabic (2%), mix N+G coated with Nisin and Gum Arabic (1:1%).

The findings concur with those who stated that Petriccione *et al.* (2015) and Paniagua *et al.* (2013) edible coating films prevent the deterioration of fruit cell walls firmness during storage, and edible coatings reduced water vapor loss and ease up the softening of fruit by furnishing a hedge subcaste girding the fruit to decrease senescence, cellular breakdown, and pectin hydrolyzation.

Also, in Table 2, the weight loss percentage in the control was the highest compared to other samples with different storage periods, but the weight loss percentage in the N coating sample was the lowest at the end of storage (8.29%). In addition, the percentage of weight loss in all samples increased significantly after 9 days, but the percentage of weight loss of coating samples decreased compared with the control sample. According to Ali *et al.* (2010), fresh produce frequently loses weight as a result of respiration and vapor pressure gradients between the fruit and the environment. This causes wilting and, as a result, low consumer acceptance. So, the coating solutions can maintain firmness and prevent weight loss as well as reduce the respiration rate and loss of water vapor of fresh strawberry fruit.

3.3. Effect of different coating on color of strawberry fruit during storage periods

The quality and degree of ripening of fruits are typically assessed using the color parameter; the results in table (3) demonstrate color changes that are estimated by the L*, a* and b* throughout storage. The lightness (L*) of both coated and untreated strawberries steadily declined during storage.

Also, the results in table (3), show that mostly there was no significant difference in (L*, a* and b*) between the control and all coating treatments (N, G, and N+G) from zero time to 9 days of storage. The lightness (L*) of strawberry fruit (control) was decreased significantly during storage, more than coated treatments may be due to microbial growth (Khodaei *et al.* 2021). Additionally, L* slightly decreased in N followed by N+G and G, respectively, at the end of storage (12 days). In this context, the application of coating leads to decreased discoloration and maintains color quality.

Table 3: Effect of different coating on color of strawberry during storage periods

Treatments	Storage period (days)				
	0	**3**	**6**	**9**	**12**
			L*		
Control	33.57^{Aa}	29.13^{Ab}	25.82^{Ac}	23.22^{Ac}	0.00^{Bd}
N	31.07^{Aa}	30.31^{Aa}	28.06^{Aab}	26.35^{Aab}	24.11^{Ab}
G	32.52^{Aa}	29.48^{Aa}	25.24^{Ab}	21.52^{Ac}	20.90^{Ac}
N+G	33.27^{Aa}	31.47^{Aab}	27.02^{Abc}	25.50^{Ac}	23.04^{Ac}
			a*		
Control	25.78^{Aa}	22.13^{Bb}	20.47^{Bb}	18.05^{Cc}	0.00^{Cd}
N	26.56^{Aa}	26.50^{Aa}	25.20^{Aa}	24.58^{Aa}	23.78^{Aa}
G	26.44^{Aa}	24.34^{ABab}	21.70^{Bbc}	21.40^{Bbc}	18.34^{Bc}
N+G	25.36^{Aa}	24.52^{Aba}	22.09^{Bb}	21.19^{Bb}	21.13^{ABb}
			b*		
Control	17.99^{Aa}	16.31^{Ab}	10.56^{Cc}	9.48^{Dc}	0.00^{Dd}
N	18.58^{Aa}	17.75^{Aa}	17.13^{Aa}	16.97^{Aa}	17.08^{Aa}
G	18.13^{Aa}	16.81^{Ab}	12.82^{Bc}	12.39^{Cc}	12.15^{Cc}
N+G	18.11^{Aa}	16.99^{Ab}	16.41^{Ab}	15.30^{Bc}	14.31^{Bc}

There is no significant difference (P≤ 0.05) between the means in a column that has the same letters (A, B, and C). There is no significant difference (P≤ 0.05) between the means in a row that has the same letters (a, b, and c). Control: fresh strawberry, N: coated with Nisin (2%), G: coated with Gum Arabic (2%), mix N+G coated with Nisin and Gum Arabic (1:1%). lightness (L*), green to red (a*), and blue to yellow (b*)

As for, the a* value, which indicates the red color measured to fruit during storage periods, the presented data showed (Table 3) that the a* value decreased in the control sample more than coated treatments during 9 days of storage. In contrast, the coated strawberry (N) maintained stability until 12 days of storage. While N+G and G treatments showed a slightly decrement pattern.

Control sample showed a gradually significant decrease in color b* value during storage time and recorded the lowest b* value. Nisin coated sample (N) appeared no significant change in b* value during storage time (12 days). The decline in yellow color revealed a change to blue color (Kumar *et al.,* 2014).

Strawberries coated either with G or N+G exhibited a significant decrement in b* values till the third day of storage. There after the aforementioned samples (G and N+G) showed a steady non-s

ignificant changes in b* value after three days of storage and until the end of storage (12 days). Compering the estimated color characters' values of the control and all coated treatments, the results reveal that N treatment followed by N+G showed minimally significant changes. The coated fruits' showed slower color change compared to the uncoated fruits, that may have resulted from delayed ripening and senescence processes (Tahir *et al.,* 2020 and Shafique *et al.,* 2023). Also, coatings process protects fruits from advanced atmospheric dehumidification and accordingly delay their anility (Velickova *et al.,* 2013). The color deteriorate may be caused by the polyphenol composites' oxidation responses, which revealed to anthocyanin levels, whereas the color increase may be the result of the co-pigmentation phenomenon, which encouraged the synthesis of anthocyanins and the formation of polymers during ripening (Forney, 2008).

3.4. Effect of different coating on phytochemical of strawberry fruit during storage periods

The Data of total anthocyanin, total phenolic and total flavonoid compounds content of uncoated and coated strawberry fruit are presented in table (4). The most significant characteristic that characterizes the overall quality of the fruit is its color. Anthocyanins, a type of flavonoid, are the pigments that give strawberry their characteristic red color. The results in table (4) indicated that significant decrement were recorded in anthocyanin contents between control and coated strawberry during different storage periods. In general, it could be noticed that total anthocyanin content decreased in all treatments during storage. Meanwhile, non-significant differences between coated treatments after three days. During the course of storage time till the end of storage periods coated strawberries with N exhibited higher content of anthocyanin than other samples. According to Khodaei *et al.* (2021), the total anthocyanins content of strawberries is crucial to their appearance and indicates their maturity; a decrease in this content during storage may be the consequence of senescence and a halt in the synthesis of anthocyanins. The loss of anthocyanin enzyme-induced degradation is attributed to the dissolution of vacuoles, which causes anthocyanin degradation (Ali *et al.,* 2019).

Results in table (4) appeared, that the initial total phenolic compounds (TPC) of the strawberry samples at zero time was 336.69, 334.21, 314.27 and 322.97 mg/100g for control, coating N, G, and N+G, respectively. The TPC of control and coating strawberry samples decreased throughout the storage period and there was a significant difference between all samples during storage period.

Table 4: Effect of different coating on phytochemical of strawberry during storage periods

Treatments	**Storage period days**				
	0	3	6	9	12
			Anthocyanin (mg/100g)		
Control	29.51^{Aa}	27.79^{Bb}	24.55^{Cc}	22.46^{Dd}	0.00^{Ce}
N	29.87^{Aa}	29.25^{Ab}	27.45^{Ac}	26.24^{Ad}	25.41^{Ae}
G	29.74^{Aa}	28.86^{Ab}	25.84^{Bc}	23.85^{Cd}	23.01^{Be}
N+G	29.80^{Aa}	29.18^{Ab}	26.35^{Bc}	14.26^{Bd}	23.55^{Be}
			Phenolic compounds (mg/100g as Gallic acid)		
Control	336.69^{Aa}	235.22^{Cb}	192.86^{Dc}	151.22^{Dd}	0.00^{De}
N	334.21^{Ba}	283.04^{Ab}	233.46^{Ac}	180.27^{Ad}	159.08^{Ae}
G	314.27^{Da}	235.28^{Cb}	208.47^{Cc}	156.18^{Cd}	136.20^{Ce}
N+G	322.97^{Ca}	252.88^{Bb}	221.86^{Bc}	173.98^{Bd}	151.84^{Be}
			Flavonoids compounds (mg/100g as Quercetin)		
Control	160.39^{Aa}	115.07^{Db}	97.33^{Dc}	68.19^{Dd}	0.00^{De}
N	170.30^{Aa}	156.63^{Ab}	143.74^{Ac}	131.17^{Ad}	117.91^{Ae}
G	164.44^{Ca}	121.59^{Cb}	107.34^{Cc}	91.92^{Cd}	75.65^{Ce}
N+G	167.33^{Ba}	139.43^{Bb}	115.61^{Bc}	98.11^{Bd}	82.26^{Be}

The means in the same parameters inside a column that shows the same letters (A, B, and C) do not differ significantly ($P\leq 0.05$). The means in the same parameters inside a raw that shows the same letters (a, b, and c) do not differ significantly ($P\leq 0.05$). Control: fresh strawberry, N: coated with Nisin (2%), G: coated with Gum Arabic (2%), mix N+G coated with Nisin and Gum Arabic (1:1%).

The highest TPC reduction was observed in the control sample, followed by coating G and N+G, respectively, while coating N showed the highest TPC until the end of storage period. The losses of phenolic compounds in fruit during storage may be due to the degradation of cellular structure during the senescence. So, to maintain and protect the fruit against the oxidation of phenolic compounds, an effective strategy is to use edible coatings. These coating create a barrier around the fruit, helping to preserve its quality and extend its shelf-life.

One possible explanation for the decline in TPC during storage is the anthocyanins' losses (Ventura-Aguilar *et al.,* 2018). It appears that the use of various coatings (N, G, and N+G) has reduced the oxidation of total phenols, which may be the primary cause of TPC decrease (Ali *et al.,* 2019).

In addition, as table (4) illustrates, the change in total flavonoid compounds (TFC) followed a similar pattern to that of TPC, with a decrease in TFC content in both the coating and control samples throughout the course of storage; however, the control sample's decrease was higher than the coated sample's. Additionally, a significant decrease in TFC was observed at any time during the course of storage period in all sample (control and coated). This could be due to higher rate of fruit respiration, which led to a greater loss of TFC because flavonoid compounds degraded and were reduced and broken down. Thus, there was more significant evident in the control compared to the coated samples. It was cleared that strawberry which coating with nisin recorded the highest scores in the bioactive component comparing to the others, followed by that was coating with a mix from nisin and gum arabic then strawberry which coating with gum arabic a lone, while the control strawberry recorded the lowest scores comparing to all samples.

3.5. Effect of coatings on total bacteria count, yeast & molds and *E. coli* (log CFU/ g) of strawberry during storage periods

Microbial spoilage is the primary cause of perishable food quality degradation during storage. The demands of consumers for premium foods with guaranteed safety and a long shelf life. The effect of different coating treatments (N, G and N+G) for strawberry fruit on microbiological quality of strawberry fruit during storage period at 4°C is shown in and table (5).

Table 5: Effect of different coating on total bacteria count, yeast, molds and *E. coli* (log CFU/ g) of strawberry during storage periods

Treatments	Storage period (days)				
	0	3	6	9	12
			Total count		
control	1.78^{Ac}	1.98^{Ab}	1.99^{Ab}	2.03^{Aa}	-
N	ND^{Dc}	ND^{Dc}	1.03^{Cb}	1.04^{Db}	1.07^{Ca}
G	1.54^{Bc}	1.57^{Bb}	1.98^{Aa}	1.98^{Ba}	1.99^{Aa}
N+G	1.43^{Cc}	1.49^{Cb}	1.54^{Ba}	1.56^{Ca}	1.57^{Ba}
			Molds and yeast		
control	1.74^{Ac}	1.90^{Ac}	2.20^{Ab}	3.78^{Aa}	-
N	1.35^{Cd}	1.51^{Bc}	1.74^{Bb}	1.96^{Ca}	2.01^{Ca}
G	1.50^{BCe}	1.86^{Ad}	2.14^{Ac}	2.47^{Bb}	2.80^{Aa}
N+G	1.60^{ABe}	1.80^{Ad}	2.00^{Ac}	2.39^{Bb}	2.59^{Ba}
			E- coli		
control	Nil	Nil	Nil	Nil	-
N	Nil	Nil	Nil	Nil	Nil
G	Nil	Nil	Nil	Nil	Nil
N+G	Nil	Nil	Nil	Nil	Nil

The means in the same parameters inside a column that shows the same letters (A, B, and C) do not differ significantly (P≤ 0.05). The means in the same parameters inside a raw that shows the same letters (a, b, and c) do not differ significantly (P≤ 0.05). Control: fresh strawberry, N: coated with Nisin (2%), G: coated with Gum Arabic (2%), mix N+G coated with Nisin and Gum Arabic (1:1%).

The results appeared that the microbial count of uncoated strawberry (control) increased significantly ($p \leq 0.05$) through storage period which reached to 2.03 and 3.78 log UFC/g for TCB and Y&M respectively, after 9 days of storage. Meanwhile, coated strawberry with nisin gave the lowest count followed by combined N+G then strawberry coating with G solely. On the other hand, the results of counts of *E. coli* were not detected in the all samples of strawberry (control and coating samples). Nisin is used as an antimicrobial agent to inhibit microbial growth in packaging materials. (De Arauz *et al.,*2009). Nisin's effect on the target bacteria is caused by its inhibition of membrane severance conformation and disruption of cell wall biosynthesis. It is also, affects pH equilibrium and proton motive force, which ultimately results in ATP hydrolysis, ion leakage, and cell death (Ma *et al.,* 2020 b, and Mok *et al.,* 2020).

Previous results showed that the total count of bacteria, mold and yeast for all coating strawberry below the permissible limits set by FDA (2013). These findings declare that all coated strawberry samples in this study are highly safe for consumption, posing no infection, risks, or health concerns for consumers.

3.6. The impact of various coatings on strawberries' sensory evaluation over storage periods

According to Moskwitz *et al.* (2012), sensory evaluation is crucial when deciding whether to accept or reject a food product. Numerous physiological alterations during ripening and after harvest contribute to the decline in fruit quality. These alterations fall under categories like enzymatic reactions, respiration, ethylene production, and maturity. The characterized qualities of the strawberries fruit were evaluated during shelf life at 4°C (Table, 6).

Table 6: Effect of different coating on sensory evaluation of strawberry during storage periods.

Treatments	**Storage period (days)**				
	0	**3**	**6**	**9**	**12**
			Color		
Control	8.83^{Aa}	8.54^{Aa}	7.92^{Ba}	5.70^{Bb}	0.00^{Cc}
N	9.12^{Aa}	9.14^{Aa}	9.26^{Aa}	8.16^{Ab}	7.06^{Ac}
G	8.45^{Aa}	8.32^{Aa}	$8.47A^{Ba}$	7.49^{Ab}	6.24^{Bc}
N+G	9.07^{Aa}	$8.51A^{ab}$	$8.46A^{Bab}$	7.99^{Ab}	$6.64A^{Bc}$
			Taste		
Control	9.10^{Aa}	9.31^{Aa}	7.80^{Bb}	4.81^{Cc}	0.00^{Cd}
N	9.01^{Aa}	9.18^{Aa}	8.90^{Aa}	8.30^{Ab}	6.49^{Ac}
G	9.03^{Aa}	8.86^{Aa}	7.85^{Bb}	7.37^{Bc}	5.44^{Bd}
N+G	8.68^{Aab}	9.08^{Aa}	8.11^{Bb}	8.08^{Ab}	6.29^{Ac}
			Odor		
Control	9.25^{Aa}	7.90^{Ab}	7.75^{BCb}	4.90^{Cc}	0.00^{Dd}
N	9.00^{Aa}	8.54^{Aa}	8.86^{Aa}	8.71^{Aa}	7.82^{Ab}
G	8.60^{Aa}	7.56^{Ab}	7.31^{Cb}	7.76^{Bab}	6.26^{Cc}
N+G	8.77^{Aa}	8.36^{Aa}	8.44^{ABa}	8.05^{Ba}	7.09^{Bb}
			Texture		
Control	9.80^{Aa}	9.01^{Ab}	7.57^{Cc}	4.70^{Dd}	0.00^{De}
N	9.87^{Aa}	9.56^{Aab}	9.32^{Ab}	8.84^{Ac}	8.20^{Ad}
G	9.51^{Aa}	7.17^{Bb}	7.88^{BCb}	7.37^{Cb}	5.82^{Cc}
N+G	9.82^{Aa}	7.87^{Bb}	8.62^{ABb}	8.19^{Bb}	6.31^{Bc}
			Overall palatability		
Control	9.25^{Aa}	8.69^{ABb}	7.76^{Cc}	5.03^{Dd}	0.00^{De}
N	9.25^{Aa}	9.11^{Aa}	9.09^{Aa}	8.50^{Ab}	7.39^{Ac}
G	8.90^{Aa}	7.98^{Cb}	7.88^{Cbc}	7.49^{Cc}	5.94^{Cd}
N+G	9.09^{Aa}	8.45^{Bb}	8.41^{Bb}	8.08^{Bb}	6.58^{Bc}

The means in the same parameters inside a column that shows the same letters (A, B, and C) do not differ significantly ($P \leq 0.05$). The means in the same parameters inside a raw that shows the same letters (a, b, and c) do not differ significantly ($P \leq 0.05$). Control: fresh strawberry, N: coated with Nisin (2%), G: coated with Gum Arabic (2%), mix N+G coated with Nisin and Gum Arabic (1:1%).

Generally, all samples rated are high scores for all parameters at zero time. Meanwhile, after three days, no significant differences were observed in color, taste and odor for uncoated and coated fruits. On the contrary, no significant differences were regarded in texture and overall palatability for the control and coated sample with Nisin after three days of storage.

The control samples became deteriorated and unacceptable for consumption after 9 days, on the other hand, all coating treatments decreased at the end of storage, but they are still acceptable. Weight loss, oxidation, and fruit softening can cause all changes in sensory qualities that impact nutritional value. These findings suggest that various coatings (N, G, and N+G) can be effectively applied as edible coatings to enhance strawberry fruit quality and extend its shelf life while being stored for 12 days at 4°C. The degradation rate of coated strawberries was significantly lower than that of uncoated strawberries of the same cultivar when they were stored at 2 °C (Petriccione *et al.,* 2015).

At the end of shelf life (12 days), the data in table (6) revealed that coated samples with (2% N) achieved high scores for all quality attributes. Whereas there are no significant differences in color and taste parameters for N and N+G treatments at the end of storage periods. The obtained results, shown in Table (6), demonstrated that significant differences in odor, texture, and overall palatability were found between the N-coated sample and the N+G and G treatments at the end of shelf life (12 days) ($P \leq 0.05$). Finally, it could be observed that coated strawberries with nisin had the highest scores for all parameters, due to the efficiency of nisin to delay the deterioration of fruit in all physiochemical characteristics and quality parameters, especially microbiological, and the incorporation of nisin with gum Arabic enhanced the potential effect more than gum arabic solely.

4. Conclusions

This study demonstrates that coating strawberries with nisin (2% N), gum arabic (2% G), or a combination of nisin and gum arabic (1:1% N+G) can effectively preserve strawberries for 12 days by inhibiting microbial development. In terms of physicochemical, firmness, color, phytochemical, and sensory attributes, the coated strawberries continuously performed better than the control sample. To extend the shelf-life of strawberries after 12 days of storage at 4 °C, coating them with (2%) nisin was the most preferred method. This was followed by coatings with a mixture of (1:1%) nisin and gum arabic and (2%) gum arabic respectively. These findings support the notion that using the aforementioned coatings improves and extends the shelf-life of strawberries. So, the observed maintenance of these parameters has pointed to the effectiveness of coated treatments in maintaining the quality of strawberry fruits.

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