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EFFECT OF JOWAR, FENUGREEK SEEDS AND FLAX SEEDS POLYSACCHARIDES BASED EDIBLE COATINGS ON THE QUALITY ATTRIBUTES AND SHELF-LIFE OF BANANA DURING STORAGE

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ABSTRACT

Fruit waxing is the process of applying of a thin layer of coatings aids in preventing fruit skin dents, splits, and moisture loss, to enhance nutritional values and their shelf life. This study evaluates the effectiveness of edible polysaccharide coatings derived from flaxseed, fenugreek seed, and jowar on the preservation of bananas compared to traditional wax coatings. The polysaccharide coatings were applied to bananas and assessed for sensory attributes, nutritional quality, and microbial safety over a 9-day storage period. Results demonstrated that bananas coated with flaxseed polysaccharides exhibited superior preservation of sensory attributes, maintaining higher scores in appearance, aroma, taste, texture, and overall acceptability, with slower degradation compared to uncoated bananas and those coated with fenugreek or jowar polysaccharides. Nutritional analysis indicated effective retention of vitamin C, phenolic content, and total sugars in flaxseed-coated bananas, while microbial analysis showed low bacterial and fungal counts, underscoring the coating's role in extending shelf life and maintaining safety. This study highlights the potential of flaxseed polysaccharide coatings as an effective, healthier alternative to traditional chemical waxes for fruit preservation.

Keywords: Fruit waxing, polysaccharides edible coating, physicochemical analysis, sensory evaluation

INTRODUCTION

Fruit waxing is a technique used to apply a thin, edible layer of wax to the surface of fruits, either through manual rubbing, dipping, or automated roller brush application. This process serves to replace or augment the fruit's natural wax, which acts as a barrier to reduce moisture loss and enhance the fruit's appearance. The primary objectives of fruit waxing are to protect the fruit from dehydration, postharvest decay, bruising, and physical damage, while also delaying browning and providing a shiny surface (Michelle Chan, 2016; Melita Fernandes, 2018). Most fruit waxes are composed of a blend of natural or artificial waxes mixed with additives such as glycerols, lactic acid, or acetic acid to adjust the pH, as well as preservatives, antimicrobial agents, and texture enhancers. Morpholine, commonly found in artificial waxes, is used to ensure a thin and even coating. However, excessive consumption of morpholine and other chemicals used in waxing can pose health risks, including allergies, cancer, and damage to the liver and kidneys (Melita Fernandes, 2018).

In recent years, there has been growing interest in edible coatings derived from polysaccharides due to their biodegradability, biocompatibility, and non-toxicity. Polysaccharides such as chitosan, alginate, cellulose, starch, and pectin offer numerous benefits as fruit coatings. They can reduce respiration rates, maintain firmness, protect sensitive compounds, inhibit microbial growth, and delay oxidative damage. These polysaccharide-based coatings have been shown to decrease weight loss, maintain sensory properties, and offer protective effects against chill injury and disease severity (Rosy G. Cruz-Monterrosa, 2023).

Among the polysaccharides of interest are those derived from jowar, flax seeds, and fenugreek seeds. Amylopectin from jowar, composed of alpha-(1-4) glucose units with branching alpha-(1-6) bonds, can provide structural benefits due to its high molecular weight and branching complexity (Siva Sai Kumar, R, 2008). Flaxseed hull polysaccharides are noted for their strong antioxidant and anti-inflammatory activities, making them promising for functional food applications. Similarly, fenugreek seed polysaccharides exhibit hypoglycemic and hypo-cholesterolemic effects, contributing to their potential as health-promoting ingredients. This research aims to explore the efficacy of polysaccharide-based coatings in comparison to traditional waxes, focusing on their impact on fruit preservation, quality enhancement, and potential health benefits.

MATERIALS AND METHODS

Collection of seeds and fruits

Flax seeds, Fenugreek seeds and jowar were collected from the grocery store at Jagatgirigutta Hyderabad. Flaxseeds, fenugreek seeds, and jowar grains were used as the source materials for polysaccharide extraction. Flaxseeds were cleaned and dried, then stored in an airtight container to prevent moisture absorption. Similarly, dried fenugreek seeds and jowar grains were obtained, ensuring that all materials were free from contaminants and debris. Fresh Bananas are collected from the Rythu Bazaar, Shapur Nagar, Hyderabad. These fruits neatly washed with water and cleaned with a cloth.

Extraction of Polysaccharides from flaxseeds

For the extraction of polysaccharides from flaxseeds, 50 grams of clean, dry flaxseed powder were prepared using a laboratory mill. The powder was suspended in 500 mL of distilled water and heated at 70°C with constant stirring for 2 hours. The resulting mixture was then filtered through cheesecloth or filter paper to remove solid residues. The filtrate was concentrated using a rotary evaporator set at 40°C. Polysaccharides were precipitated by adding ethanol in a 3:1 ratio (ethanol to filtrate) and allowed to stand overnight at 4°C. The precipitate was collected by centrifugation at 5,000 rpm for 15 minutes, then dried oven at 40°C, and ground into a fine powder (Li et al., 2012).

Extraction of Polysaccharides from fenugreek seeds

In the extraction of fenugreek polysaccharides, 50 grams of fenugreek seed powder were suspended in 500 mL of distilled water and heated at 80°C with stirring for 2 hours. After filtering the mixture through a fine mesh or filter paper, the filtrate was concentrated using a rotary evaporator at 40°C. Polysaccharides were precipitated by adding ethanol (3:1 ratio of ethanol to filtrate) and allowed to stand overnight at 4°C. The precipitate was then collected by centrifugation at 5,000 rpm for 15 minutes, dried oven at 40°C, and ground into powder (Prakash et al., 2016).

Extraction of Polysaccharides from jowar grains seeds

For jowar, 50 grams of ground jowar grains were suspended in 500 mL of distilled water and heated at 75°C with stirring for 2 hours. The mixture was filtered through a fine cloth or filter paper, and the filtrate was concentrated using a rotary evaporator at 40°C. Polysaccharides were precipitated by adding ethanol (3:1 ratio of ethanol to filtrate) and allowed to stand overnight at 4°C. The precipitate was collected by centrifugation at 5,000 rpm for 15 minutes, then dried using oven at 40°C, and ground into a fine powder (Gopalan et al., 2004).

Coating Preparation and applying on banana fruit

To prepare the polysaccharide coating solutions, 4 grams of each dried polysaccharide powder were dissolved in 100 mL of distilled water at room temperature with continuous stirring. The pH of the solution was adjusted to a range of 4.5-5.5 using citric acid or sodium hydroxide as required. Additionally, any necessary additives such as glycerols or emulsifiers were incorporated and mixed thoroughly to ensure a uniform coating solution. Fruits were cleaned and dried thoroughly before application of the polysaccharide coating. The fruits were either dipped into the polysaccharide solution or the coating was applied using a brush to ensure even coverage. the coated fruits were allowed to air-dry at room temperature.

Formulation of polysaccharides coating from sorghum, fenugreek, and flaxseeds

The effectiveness of fruit coatings composed of polysaccharides from sorghum, fenugreek, and flaxseeds, various formulations were prepared with differing proportions. Stock solutions were made by dissolving 4 grams of each polysaccharide powder in 100 mL of distilled water, adjusting the pH to 4.5-5.5 as needed. Coating solutions were formulated as follows: T(0) served as a control with no coating applied; T1 consisted of equal parts (33% each) sorghum, fenugreek, and flaxseed polysaccharides; T2 had 25% sorghum, 25% fenugreek, and 50% flaxseed polysaccharides; T3 included 50% sorghum, 25% fenugreek, and 25% flaxseed polysaccharides; and T4 comprised 25% sorghum, 50% fenugreek, and 25% flaxseed polysaccharides. Fruits were cleaned, dried, and then coated by dipping or brushing with the respective solutions, followed by air-drying or drying in a controlled chamber.

Table 1 : Formulation of polysaccharide based seed coating for coating of fruits

Observation	Sorghum	Fenugreek	Flaxseeds
$T_{(0)}$	No wax used	No wax used	No wax used
T1	33%	33%	33%
T2	25%	25%	50%
T3	50%	25%	25%
T4	25%	50%	25%

Sensory evaluation of fruits at 0th day, 3rd day, 6th day and 9th day after coating of fruits

The polysaccharides coated fruits that are banana have to be analysed their nutritive values, pH and sensory analysis, for 5 days with frequent intervals i.e. 0 day, 3rd day, 6th day and 9th day of brushing of polysaccharides on the fruits. Sensory analysis for these samples was made using hedonic rating test with the 7 points. The 7 points indicates 7-Liked extremely, 6-Liked, 5-good, 4-Average, 3-Not good, 2-Bad, 1-Very bad

Nutritional analysis

pH

Mix a part of the laboratory sample and grind it, if necessary with a blender or mortar. If the fruit pulp obtained is still too thick, add an equal mass of distilled water and mix well. A volume of the prepared sample should be enough for the immersion of the electrodes Introduce the electrodes into the test portion and set the temperature correction system of the pH meter to the temperature of measurement. When constant value has been reached, read the pH directly, to at least 0.05 pH unit. Take the result as the arithmetic mean of the results of the two determinations. Report the results to at least 0.05 pH unit.

Vitamin C

All samples has been blended then filtered using Buchner, 10 gm of each sample was transferred into a 100ml volumetric flask homogenized by using 50ml acetic acid solution with shaken, 4-5 drops of bromine water has been added until the solution became colored, Then a few drops of thiourea solution were added to it to remove the excess bromine and thus the clear solution was obtained. Then 2, 4-Dinitrophenyl hydrazine solution was added thoroughly with all standards and also with the oxidized ascorbic acid. Then complete the solution up to the mark with acetic acid. The absorbance for all samples has been measured using fruits–UV-visible spectrophotometer to determine the concentration of ascorbic acid in the fruits and vegetables under testing. (Mohammad Idan Hassan AL Majidi, Hazim Y AL Qubury, 2016).

Total Phenolic content

The study involved calculating total phenolics using Folin-Ciocalteu reagent, centrifuging samples, homogenizing, precipitating, dilution, adding, and measuring absorbance in a UVD spectrometer for 60 minutes, presenting findings as mg catechol/100 g of fresh weight material. (G. Laxmi Preethi and Anil B, 2023)

Total Sugar content

TSS or Brix of fruit and vegetables are commonly measured by gravimetric methods using the hydrometer (Nor et al., 2014). A hydrometer is a simple but reliable instrument for measuring the density of liquids and is most often calibrated using a standard liquid. A Brix hydrometer measures specific gravity and is calibrated to read directly in units of sugar concentration (degrees Brix, ◦Brix) at room temperature which is often considered to be 20 ◦C. (Magwaza, L. S., & Opara, U. L, 2015).

Acidity

Take 1 ml of centrifuged juice/aliquot and dilute ti to 15 ml with carbonate free double-distilled water. Add 2 drops of phenolphthalein indicator into it. Now titrate it with standardized (0.097N) NaOH solution and note the volume of NaOH used till pink colour persist for at least 15 seconds or pH reaches to 8.1. (Paul, V., et al. 2010).

Microbial analysis

Microbial analysis such as aerobic total plate count, yeast & molds was carried out after 10 days of study by procedure Indian standard method FSSAI Manual, 2nd Edn. 2022.

RESULTS AND DISCUSSION

Sensory Analysis of Banana fruit by different variation treatment of seed coating

Hedonic rating test was made for 4 days with frequent intervals using 7 points for every sensory attribute for Banana fruit.

Sensory analysis of uncoated banana fruit

Table. 2: Mean and standard deviation of un-coated banana

Sensory attributes	Day 0	Day 3	Day 6	Day 9
Appearance	7.0±0	5.5±0	3.06±0.115	2.46±0.05
Aroma	7.0±0	5.0±0	2.0±0	2.1±0.1
Taste	7.0±0	5.16±0.28	3.1±0.1	2.0±0
Texture	7.0±0	6.0±0	3.33±0.57	2.1±0.1
Overall acceptability	7.0±0	5.5±0.86	2.33±0.57	2.0±0

The sensory evaluation of uncoated banana fruit conducted over a 9-day period demonstrated a significant decline in all assessed attributes—appearance, aroma, taste, texture, and overall acceptability. Initially, on Day 0, the bananas were rated at the highest level (7.0 ± 0) across all attributes. However, by Day 3, noticeable deterioration was evident, with scores decreasing to 5.5 ± 0 for appearance, 5.0 ± 0 for aroma, 5.16 ± 0.28 for taste, 6.0 ± 0 for texture, and 5.5 ± 0.86 for overall acceptability. The decline continued over the next days, with Day 6 showing further reductions, appearance at 3.06 ± 0.115, aroma at 2.0 ± 0, taste at 3.1 ± 0.1, texture at 3.33 ± 0.57, and overall acceptability at 2.33 ± 0.57. By Day 9, all sensory attributes had reached their lowest scores, with appearance at 2.46 ± 0.05, aroma at 2.1 ± 0.1, taste at 2.0 ± 0, texture at 2.1 ± 0.1, and overall acceptability at 2.0 ± 0. This progressive decline in sensory quality highlights the impact of the absence of a protective coating, which likely exacerbated spoilage and quality degradation. The results underscore the importance of employing effective preservation methods to maintain the sensory attributes of bananas over extended storage periods.

Sensory analysis of fruits coated with high proportion of flax seed's polysaccharide

The sensory analysis of bananas coated with a high proportion of flax seed polysaccharide over a 9-day period revealed a generally slower decline in sensory attributes compared to uncoated bananas. Initially, on Day 0, the coated bananas scored 7.0 ± 0 across all attributes: appearance, aroma, taste, texture, and overall acceptability. By Day 3, these scores remained stable at 7.0 ± 0 for appearance and aroma, while taste, texture, and overall acceptability were slightly lower but still high at 6.83 ± 2.3, 6.83 ± 0.23, and 6.66 ± 2.3, respectively. By Day 6, a decline was observed, with appearance dropping to 6.0 ± 0.5, aroma to 5.66 ± 0.11, taste to 5.83 ± 0.28, texture to 5.83 ± 0.28, and overall acceptability to 5.83 ± 0.28.

Table. 3: Mean and standard deviation of coated banana with high proportion of flax seed's polysaccharide

Sensory attributes	Day 0	Day 3	Day 6	Day 9
Appearance	7.0±0	7.0±0	6±0.5	4±0
Aroma	7.0±0	7.0±0	5.66±6.11	4.3±0.57
Taste	6.83±2.3	6.83±0.23	5.83±0.28	4.3±0.57
Texture	7.0±0	6.83±0.23	5.83±0.28	4.3±0.57
Overall acceptability	6.83±2.3	6.66±2.3	5.83±0.28	4.5±0

On Day 9, all attributes continued to decline but at a slower rate compared to uncoated bananas, with appearance at 4.0 ± 0, aroma at 4.3 ± 0.57, taste at 4.3 ± 0.57, texture at 4.3 ± 0.57, and overall acceptability at 4.5 ± 0. This slower degradation in sensory quality indicates that the flax seed polysaccharide coating effectively extended the fruit's shelf life, reducing the rate of spoilage and maintaining sensory attributes better than the uncoated counterparts. The results demonstrate the potential of flax seed polysaccharide as a beneficial coating for preserving the quality of bananas during storage.

Sensory analysis of fruits coated with high proportion of fenugreek seed polysaccharide

The sensory analysis of bananas coated with a high proportion of fenugreek seed polysaccharide over a 9-day period demonstrated a gradual decline in sensory attributes, albeit at a slower rate than uncoated bananas. On Day 0, the coated bananas were rated 7.0 ± 0 for all attributes, including appearance, aroma, taste, texture, and overall acceptability. By Day 3, the scores for appearance and aroma remained high at 7.0 ± 0 and 6.23 ± 1.25, respectively, while taste, texture, and overall acceptability were slightly lower at 6.33 ± 2.02, 6.83 ± 1.73, and 6.23 ± 2.01, respectively. The decline continued over the storage period, with appearance decreasing to 5.5 ± 0 by Day 6 and further to 4.16 ± 0.57 by Day 9. Aroma, taste, texture, and overall acceptability also showed reductions, reaching 5.33 ± 0.57, 5.33 ± 0.57, 5.16 ± 0.28, and 5.16 ± 0.28 by Day 6, and further declining to 4.5 ± 0, 4.0 ± 0, 4.0 ± 0, and 4.33 ± 0.57 by Day 9, respectively.

Table. 4: Mean and standard deviation of coated banana with high proportion of fenugreek seed polysaccharide

Sensory attributes	Day 0	Day 3	Day 6	Day 9
Appearance	7.0±0	7.0±0	5.5±0	4.16±0.57
Aroma	7.0±0	6.23±1.25	5.33±0.57	4.5±0
Taste	6.66±0.86	6.33±2.02	5.33±0.57	4±0
Texture	7.0±0	6.83±1.73	5.16±0.28	4±0
Overall acceptability	6.66±0.86	6.23±2.01	5.16±0.28	4.33±0.57

Sensory analysis of fruits coated with high proportion of jowar's polysaccharide

The sensory analysis of bananas coated with a high proportion of jowar polysaccharide over a 9-day period revealed a progressive decline in sensory attributes, although the rate of deterioration was slower compared to uncoated bananas. On Day 0, the coated bananas received a perfect score of 7.0 ± 0 for all attributes, including appearance, aroma, taste, texture, and overall acceptability. By Day 3, the scores showed a slight decrease, with appearance at 6.8 ± 0.28, aroma at 6.8 ± 0.28, taste at 6.8 ± 0.28, texture at 6.8 ± 0.28, and overall acceptability at 6.66 ± 0.57. The decline became more evident by Day 6, with appearance scoring 5.33 ± 0.28, aroma 5.16 ± 0.57, taste 5.16 ± 0.57, texture 5.33 ± 0.86, and overall acceptability 5.5 ± 0.5. By Day 9, all attributes had further deteriorated, with appearance at 3.83 ± 1.15, aroma at 3.2 ± 0.26, taste at 3.33 ± 0.52, texture at 3.3 ± 0.52, and overall acceptability at 3.66 ± 0.57.

These results indicate that while the jowar polysaccharide coating was effective in slowing down the rate of sensory decline compared to uncoated bananas, it did not fully prevent deterioration over the 9-day period. The coating helped in maintaining better sensory attributes longer but was not as effective as coatings made from other polysaccharides, such as those from flax seed or fenugreek. This suggests that while jowar polysaccharide has potential as a fruit coating, further optimization or combination with other preservation techniques might be needed to improve its efficacy in extending shelf life and maintaining fruit quality.

Table. 5: Mean and standard deviation of coated banana with high proportion of jowar's polysaccharide

Sensory attributes	Day 0	Day 3	Day 6	Day 9
Appearance	7.0±0	6.8±0.28	5.33±0.28	3.83±1.15
Aroma	7.0±0	6.8±0.28	5.16±0.57	3.2±0.26
Taste	6.8±0.288	6.8±0.28	5.16±0.57	3.33±0.52
Texture	7.0±0	6.8±0.28	5.33±0.86	3.3±0.52
Overall acceptability	6.8±0.288	6.66±0.57	5.5±0.5	3.66±0.57

Appearance and quality

check of Banana at O th day to 6 th Day

Fig. A: No wax coated fruits on day 0 **Fig. B: No wax coated fruits on day 6**

Fig. C: High flax seed polysaccharide coated on 0 th day

Fig. D: High flax seed polysaccharide coated on 6 th day

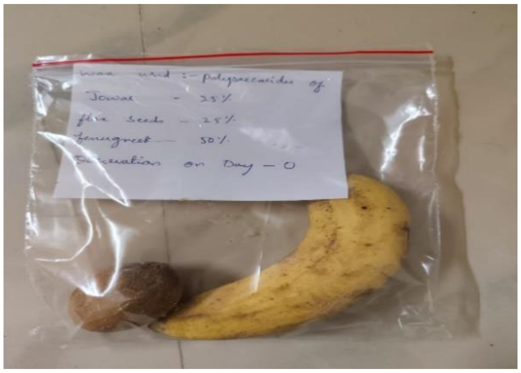

Fig. E: High amount of fenugreek seeds polysaccharide coated on 0 th day

Fig. F: High amount of fenugreek seeds polysaccharide coated on 6 th day

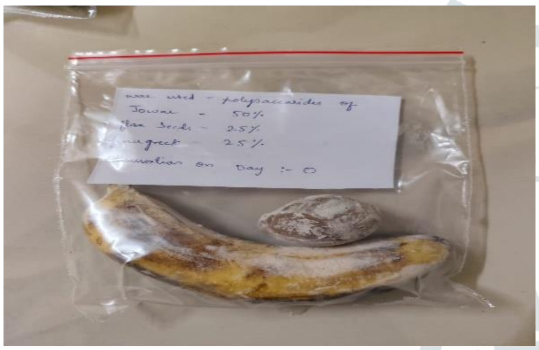

Fig. G: High amount of jowar seeds polysaccharide coated on day 0

Fig. H: High amount of jowar seeds polysaccharide coated on 6 th day

Nutritive analysis of Banana at 6 th day storage of Banana with high proportion of Flaxseed polysaccharide coating

The nutritive analysis of bananas coated with a high proportion of flaxseed polysaccharide, evaluated on the 6th day of storage, revealed several key nutritional parameters (Table 6). The pH of the coated bananas was recorded at 4.9, indicating a mildly acidic environment. The acidity level, classified as mildly acidic, is consistent with the typical pH range of ripe bananas. Vitamin C content was measured at 8.6 mg/100g, reflecting a moderate retention of this essential nutrient despite storage. The total phenolic content was found to be 42.86 mg/100g, suggesting a significant level of antioxidants present in the bananas. Additionally, the total sugar content was 12 g/100g, which is indicative of the fruit's natural sweetness.

The results indicate that the flaxseed polysaccharide coating effectively preserved the nutritional quality of the bananas during storage. The maintenance of a mildly acidic pH and significant levels of vitamin C and phenolic compounds underscores the effectiveness of the coating in reducing nutritional degradation. The total sugar content remained stable, suggesting that the coating helped retain the fruit's natural sweetness. These findings highlight the potential of flaxseed polysaccharide coatings in extending the shelf life of bananas while preserving key nutritional attributes, making them a promising option for fruit preservation

Table. 6: Nutritive analysis of Banana with high proportion of Flaxseed polysaccharide coating at 6 day

Test Parameters	Values (Banana)	Units
pH	4.9	Level
Acidity	Mildly acidic	Level
Vitamin C	8.6	mg/100g
Total phenolic content	42.86	mg/100g
Total sugar content	12	g/100g

Table. 3 represents the nutritive analysis of banana. pH of seeds' polysaccharide coated banana 4.9 that means slightly acidic. Vitamin C in banana showed that 8.6 mg/100 g and. Total phenolic content in banana (42.86 mg/100 g). Total sugar content of banana is 12 g/100 g.

Microbial Analysis of Banana fruit after 6 th Day of Storage for with high proportion of Flaxseed polysaccharide coating

The microbial analysis of bananas coated with a high proportion of flaxseed polysaccharide after 6 days of storage revealed promising results in terms of microbial safety. The total plate count was recorded at 100 CFU/g, indicating a relatively low level of bacterial contamination (Table 7). The yeast and mold count was notably low, at less than 10 CFU/g, suggesting minimal fungal presence. These values reflect the effectiveness of the flaxseed polysaccharide coating in inhibiting microbial growth and preserving fruit quality.

Table. 7: Microbial activity at 6 th day of storage

Test Parameters	Values	Units
Total Plate count	100	CFU/g
Yeast and mold count	<10	CFU/g

By the 9th day of storage, it was observed that all varieties of coated bananas, except those with the high proportion of flaxseed polysaccharide coating, had completely spoiled and were deemed unfit for consumption. This highlights the superior performance of the flaxseed coating in extending the shelf life and maintaining the microbial safety of the bananas. The low microbial counts and delayed spoilage underscore the potential of flaxseed polysaccharide coatings as an effective preservation method, offering a viable solution for extending the freshness and safety of bananas during storage.

CONCLUSION

The study demonstrates that bananas coated with high proportions of flaxseed polysaccharide exhibit superior preservation of sensory attributes, nutritional quality, and microbial safety compared to uncoated bananas and those coated with other polysaccharide types such as fenugreek or jowar. Sensory analysis revealed that flaxseed-coated bananas maintained higher scores across all attributes for a longer period, with slower degradation in appearance, aroma, taste, texture, and overall acceptability. Nutritional analysis on the 6th day of storage confirmed the effective retention of vitamin C, phenolic content, and total sugars. Microbial analysis further supported the coating's efficacy, showing low bacterial and fungal counts and extending the shelf life significantly. These results underscore the potential of flaxseed polysaccharide coatings as an effective method for prolonging the freshness, quality, and safety of bananas during storage, making them a promising option for fruit preservation. Coating bananas with edible polysaccharides, such as those from flax and fenugreek seeds, effectively retains nutrients, prevents water loss, and minimizes physical damage. These polysaccharide coatings maintain the fruit's structure longer than uncoated bananas and are healthier compared to chemical or artificial wax coatings.

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