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Antioxidant and Antimicrobial Activity of Secondary Metabolites Extracted from Bakery Yeast *Saccharomyces cerevisiae*

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ABSTRACT

Background: The deterioration problem of fruits and vegetables after harvesting, marketing and transportation until they reach the consumer is a significant challenge to overcome.

Methods: Use secondary metabolites produced from bakery yeast as an edible coating to extend the shelf life of strawberries through the extraction of secondary metabolites from commercially available bakery yeast and determination of protein, detection of bioactive compounds, estimation of antioxidant activity and antimicrobial activity, Then estimation of weight loss, deterioration value, soluble solids content and sensory evaluation characteristics during storage of coated strawberries.

Result: The protein content of secondary metabolites produced from bakery yeast was (0.521 mg mL^{-1}). The detection of bioactive compounds refers to the finding of glycosides, alkaloids, terpenes, saponins, tannins, coumarins and flavonoids. the antioxidant activity was 86.9, 88.2 and 91.8% at 5, 10 and 20 mg mL^{-1}, respectively and antimicrobial activity at the same concentration was 51, 62 and 69%, respectively, for *Escherichia coli*; 47, 52 and 58%, respectively, for *Salmonella typhimurium*; 64, 69 and 76%, respectively, for *Bacillus cereus*; and 60, 66 and 71%, respectively, for *Staphylococcus aureus*. The results of coating strawberries with Sm1, Sm2 and Sm3 showed that the weight loss was 4.15, 3.74 and 2.38%, respectively; the deterioration value was 3.25, 2.08 and 1.34%, respectively; and the soluble solids content was 8.5, 7.9 and 7.3°Brix, respectively, during storage at 4°C for 10 d. The sensory evaluation revealed significant differences among the treatments, as well as sensory characteristics and an interaction between treatment and day, which were strongly positively correlated with overall acceptability. The treatment Sm3 showed the best effect during storage at 4°C for 10 d.

Key words: Bakery yeast, Bioactive compounds, Edible coating, Fruits shelf life extension, Secondary metabolites.

INTRODUCTION

The yeast *Saccharomyces cerevisiae*, usually famous as baker's yeast, is one of the most widely used microorganisms in the food, medical and industrial sectors that have moderate antimicrobial activity against a wide range of microorganisms (Makky *et al.,* 2021) through the production of various biological compounds in secondary metabolites that are classified as low molecular-weight compounds such as alkaloids, terpenoids, flavonoids, phenolics and killer proteins that have antioxidant and antimicrobial activity (Alsoufi and Aziz, 2017; Al-Jassani *et al.,* 2016; Banach and Ooi, 2014). The intense demand from consumers for fresh fruits and vegetables has led to increased availability in global markets throughout the year from producers of this type of food (Alsoufi and Aziz, 2025; Mohanapriya *et al.,* 2024). Moreover, the deterioration problem of fruits and vegetables after harvesting, marketing and transportation until they arrive at the consumer is a significant challenge to overcome; therefore, the edible coating was considered the primary method for treatment in this case, taking into account that this coverage does not affect the sensory properties and quality of this food (Farswan *et al.,* 2025; Khodaei *et al.,* 2021). To achieve this, extensive research has been conducted and is ongoing to develop edible coatings made from biodegradable materials that are safe for consumers, such as coating strawberries with: bergamot essential oil and bergamot pomace extract (De Bruno *et al.,* 2023), polysaccharides (chitin, cellulose and chitosan) or proteins (gelatin with *Mentha pulegium* essential oil) (Pham *et al.,* 2023); chitosan, Aloe vera gel and guar gum (Shivani *et al.,* 2022); extracellular compounds of *Humphreya coffeata*, pectin and glycerol (Agapito-Ocampo *et al.,* 2021); carboxymethyl

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cellulose and glycerol (Khodaei *et al.,* 2021); sodium alginate and ascorbic acid (Nazoori *et al.,* 2020); chitosan and chitosan nanoparticles (Shahat *et al.,* 2020); composite of banana starch, chitosan and Aloe vera gel (Pinzon *et al.,* 2020). In recent years, natural antioxidant and antimicrobial compounds have gained popularity as alternatives to synthetic compounds, primarily due to the associated side effects of synthetic antioxidants. Thus, there has been considerable interest in identifying safer and more effective natural antioxidant sources (Alsoufi and Aziz, 2025; Naik *et al.,* 2021). Secondary metabolites of *S. cerevisiae* have garnered increased interest as a source of safe, biologically active antioxidants. The safe use of baker's yeast in food production has fostered interest in these yeast products, including their secondary metabolites. It evaluates their antioxidant and antimicrobial activity for use in the food industry (Makky *et al.,* 2021). Thus, this study aims to utilize baker's yeast secondary metabolites as an edible coating to extend the shelf life of strawberries.

MATERIALS AND METHODS

Research period

The research period from March 8, 2024, to May 3, 2025.

Baker's yeast

Commercially available bakery yeast *Saccharomyces cerevisiae* (Saf-instant) from the Iraqi market was used in this study.

Microorganism's strains

Pure microorganism isolates, including *Escherichia coli*, *Salmonella typhimurium*, *Bacillus cereus* and *Staphylococcus aureus*, were obtained from the College of Science, Mustansiriyah University, Iraq, to conduct the necessary tests on them. The morphological, cultural and biochemical characteristics were confirmed according to MacFaddin (2000). All isolates were maintained in their appropriate nutrient agar slants at 4°C throughout the study and used as stock cultures.

Activation of bakery yeast

Bakery yeast activation and growth with a striking method by Barnett *et al.* (2000).

Preparation of yeast broth medium

The yeast broth medium was prepared according to Alsoufi and Aziz (2017) by inoculating yeast in a YEGP broth medium after adjusting the pH to 5.5 and incubating at 30°C for 24 h. After that, 100 mL of the medium was added to a conical flask (250 mL) and inoculated with 3 mL of yeast after the pH was adjusted to 5.5 at 30°C for 24 h in an incubator shaker at 125 rpm.

Extraction of secondary metabolites

Secondary metabolites were extracted using the method described by De Bruno *et al.* (2023), which involved adding ethyl acetate to the yeast liquid culture from the previous step in a 1:1 ratio, followed by shaking the mixture in a separatory funnel for 10 min to complete the extraction and leaving it for 5 min to settle and form two separated layers; the upper layer was collected into Falcon tubes, while the bottom layer was re-extracted for twice to ensure complete extraction of the secondary metabolites. The separated extract was centrifuged at 10,000 rpm for 15 min (instead of 2,900 × g for 5 min) to remove any probable yeast cells. The supernatant was collected and dried at 35-40°C using a rotary evaporator and then stored for subsequent experiments.

Estimation of total proteins

The protein mg mL^{-1} in yeast secondary metabolites was estimated using the method Bradford (1976).

Detection of bioactive compounds

The detection of bioactive compounds (glycosides, alkaloids, terpenes, saponins, tannins, coumarins and flavonoids) in yeast secondary metabolites was performed using the method described by Ullah *et al.* (2011).

Estimation of antioxidant activity

The antioxidant activity inhibition was estimated using the radical scavenging method as Makky *et al.* (2021) using the DPPH by mixing 1 mL of DPPH solution (0.1 M, which was prepared in absolute methanol) with 1 mL of yeast secondary metabolites that dissolved in sterile deionized distilled water at final concentrations (5, 10 and 20 mg mL^{-1}) and mixed well (the same procedure prepared control by mixing DPPH with sterile deionized distilled water, while ascorbic acid that dissolved in sterile deionized distilled water at the same concentrations was used as a comparison sample). Then, incubate the mixtures in a dark place at 25°C for 30 min. Then, it was filtered through filter paper (Whatman No. 1) and absorbency was estimated at 517 nm using a UV-visible spectrophotometer. Methanol was taken as a blank. The antioxidant activity (AA) was calculated and expressed as inhibition through the following equation:

$$\text{Antioxidant activity (Inhibition\%)} = \frac{\text{Absorbance of control - Absorbance of sample}}{\text{Absorbance of control}} \times 100$$

Inhibition of microorganism strains

The inhibition of *E. coli*, *S. typhimurium*, *B. cereus* and *S. aureus* was calculated by adding 500 µL of 5, 10 and 20 mg mL^{-1} of the yeast secondary metabolites to a Petri dish with Mueller-Hinton agar, leaving it for 60 min in the laminar chamber under continuous sterile conditions till completely dry, then transferring 100 µL (10^5 CFU mL^{-1}) of the microorganism strains and distributing it by stirring, followed by incubating at 37°C for 24 h. Sterile deionized distilled water was used as a control. The growth of the microorganism strains was calculated at a rate of triplicate for each sample and the inhibition was determined from

the following equation according to the method of Alsoufi (2024):

$$\text{Inhibition} = \frac{\text{Number of colonies for control}}{\text{Number of colonies for sample}} \times 100$$

Preparation of coating solution

The coating solution was prepared at concentrations of 5, 10 and 20 mg mL^{-1} of the yeast secondary metabolites (Sm), which were dissolved in a 1% glycerol solution (GS) (prepared by mixing glycerol with sterile deionized distilled water). The end solutions were sterilized through a 0.22-µm filter paper and stored at 4°C until use. Sterile deionized distilled water (DDS) was used as a control, as described by Ul Hasan *et al.* (2021) (Table 1).

Strawberry preparation

The strawberries (genus Fragaria) were obtained from local markets in Baghdad, washed with tap water to remove surface dirt and then dipped in a sodium hypochlorite solution (0.1%) for 3 min to reduce microbial contamination. Next, strawberries were rinsed with sterile deionized distilled water (remove traces of sodium hypochlorite) and then kept at 25°C until completely dried, after which they were used in the coating experiment, as described by Ul Hasan *et al.* (2021).

Estimation of weight loss

The strawberries were coated by dipping them in DDS (GS), Sm1, Sm2 and Sm3 for 5 min. They were then dried at room temperature and weighed. The weight loss percentage while stored at 4°C for 10 d was calculated through the following equation as a method of Alsoufi (2024):

$$\text{Weight loss (\%)} = \frac{\text{Weight after a storage period}}{\text{Initial weight}} \times 100$$

Deterioration value

The deterioration value (DV) (%) was estimated during the storage period according to the method of De Bruno *et al.* (2023) by an optical note of any change in strawberries, such as damage, spots, softening and mold appearance, through the following equation:

$$DV = \frac{A}{B} \times 100$$

Where
A = Number of change-appearance strawberries.
B = Number of total strawberries at the beginning of the experiments.

Estimation of soluble solids content

Soluble solids content in the extracted juice of the strawberries was estimated according to a method of Alsoufi (2024) using a KRUSS HR900 manual hand-held refractometer (0-90% Brix/0.2% Brix).

Sensory evaluation

The coated strawberries with DDS, (GS), Sm1, Sm2 and Sm3 were sensory evaluated over 10 d of storage at 4°C, following the method of De Bruno *et al.* (2023), which assessed appearance (color and brightness), aroma (aromatic intensity), taste (sweetness or acidity), texture (hardness or softness) and general acceptability. The test was conducted on strawberry samples at each monitoring time (1 and 10 d) using a 10-member trained panel for this purpose (five men and five women, aged 25-50 years) to determine the degree of acceptability based on a 0-9 point scale (4.5 was done as a limitation of acceptability).

Statistical analysis

The statistical analysis includes ANOVA and Pearson correlation (McKinney, 2010).

RESULTS AND DISCUSSION

Detection of bioactive compounds

The amount of protein in yeast secondary metabolites was 0.521 mg mL^{-1}. The detection of bioactive compounds refers to the presence of glycosides, alkaloids, terpenes, saponins, tannins, coumarins and flavonoids (Table 2).

Secondary metabolites, compounds produced by *S. cerevisiae*, are classified as low molecular-weight compounds such as alkaloids, terpenoids, flavonoids, phenolics and killer proteins that have antioxidant and antimicrobial activity, as many studies have indicated (Makky *et al.,* 2021; Alsoufi and Aziz, 2017; Al-Jassani *et al.,* 2016; Banach and Ooi, 2014).

Antioxidant activity (%Inhibition)

The results show that the antioxidant activity (% inhibition) was 93.8, 94.5 and 94.7% for ascorbic acid and 86.9, 88.2

Table 1: Coating solution of strawberries.

Treatment	Symbol
Sterile deionized distilled water	DDS
1% glycerol solution	GS
Yeast secondary metabolites 5 mg mL^{-1}	Sm1
Yeast secondary metabolites 10 mg mL^{-1}	Sm2
Yeast secondary metabolites 20 mg mL^{-1}	Sm3

Table 2: Detection of the bioactive compounds in the bakery yeast secondary metabolites.

Active compound	Indication
Glycosides	+
Alkaloids	+
Terpenes	+
Saponins	+
Tannins	+
Coumarins	+
Flavonoids	+

(+): Contain the active compound.
(-): Free of the active compound.

and 91.8% for secondary metabolites at concentrations of 5, 10 and 20 mg mL^{-1}, respectively (Fig 1).

The results exhibit that the differences in antioxidant activity value depend on the treatment. Notably, the combination of yeast secondary metabolites yields a higher inhibition percentage compared to other treatments.

Generally, the coating material of fruit contributes to maintaining the antioxidant activity during storage according to what many researchers have shown, such as coating strawberries with bergamot essential oil and natural antioxidant extract from bergamot pomace and stored at 4°C for 14 d (De Bruno *et al.,* 2023); extracellular compounds of *H. coffeata*, pectin and glycerol and stored at 4°C for 10 d (Agapito-Ocampo *et al.,* 2021); carboxymethyl cellulose and glycerol and stored at 4°C for 16 d (Khodaei *et al.,* 2021); a composite of banana starch, chitosan and Aloe vera gel and stored at 4°C 14 d (Pinzon *et al.,* 2020); chitosan and chitosan nanoparticles and stored at 6°C for 16 d (Shahat *et al.,* 2020).

The antioxidant activity of the coated material was attributed to the effect of its content of biological compounds, which work as effective protectors against cellular damage caused by free radicals and other reactive oxygen species (Makky *et al.,* 2021). Also, proteins can inhibit lipid oxidation by inactivating reactive oxygen species, scavenging free radicals, chelating pro-oxidative transition metals and reducing hydroperoxides (Banach and Ooi, 2014).

Inhibition of microorganism strains

The inhibition of growth by secondary metabolites at concentrations of (5, 10 and 20 mg mL^{-1}) were 51, 62 and 69%, respectively, for *E. coli*; 47, 52 and 58%, respectively, for *S. typhimurium*; 64, 69 and 76%, respectively, for *B. cereus*; and 60, 66 and 71%, respectively, for *S. aureus* (Table 3).

According to other studies, the inhibition of growth activity is related to the effects of biological materials, such as killer proteins and bioactive compounds. Therefore, many studies have been done to apply this truth, such as the use of ethyl acetate extract of *S. cerevisiae* to inhibit the growth of *S. aureus*, *E. coli*, *Pseudomonas sp.*, *Staphylococcus epidermidis*, *Salmonella sp.* and *Vibrio cholera* (Makky *et al.,* 2021; Al-Jassani *et al.,* 2016).

The inhibition of growth is attributed to many compounds found in the *S. cerevisiae* secondary metabolites, such as killer proteins, fatty acids, alcohol, phenolic compounds, Sterols, carotenoids, vitamin C and other bioactive compounds that have anti-bacterial, antimicrobial, antifungal, anti-viral, anti-inflammatory, anti-tumor and anti-carcinogenic (Makky *et al.,* 2021; Banach and Ooi, 2014).

Weight loss

The weight loss of coated strawberries with DDS, (GS), Sm1, Sm2 and Sm3 was 7.52, 5.31, 4.15, 3.74 and 2.38%, respectively, during storage at 4°C for 10 d (Fig 2).

The results show that the increase in the percentage of coating solution led to a decrease in the weight loss rate for all treatments. This layer has contributed to improving barrier properties, therefore reducing weight loss (Alsoufi and Aziz, 2021). In this regard, De Bruno *et al.* (2023) refer to the use of a mix of 2.5% bergamot pomace extract, 2% gum Arabic and 1% glycerol as a coating material for strawberries that leads to a decrease in weight loss from 9.27% in the control without any addition to 4.19% of coated fruits during storage for 10 d at 4°C. Regarding the influence

Table 3: Effect of bakery yeast secondary metabolites on growth inhibition of some microorganisms.

Microorganisms	Inhibition growth (%) by secondary metabolites		
	5 (mg mL^{-1})	10 (mg mL^{-1})	20 (mg mL^{-1})
Escherichia coli	51	62	69
Salmonella typhimurium	47	52	58
Bacillus cereus	64	69	76
Staphylococcus aureus	60	66	71

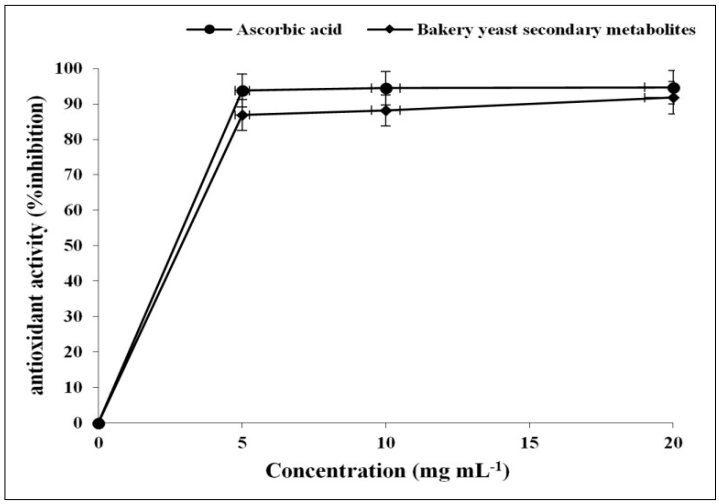


Fig 1: Effect of bakery yeast secondary metabolites on antioxidant activity (%inhibition).

of the nature and composition of the coating on fruit parameters, Pham *et al.* (2023) noted that the use of polysaccharides (chitin, cellulose and chitosan) or proteins (gelatin with *M. pulegium* essential oil) as coating materials for strawberries results in reduced weight loss. Also, Agapito-Ocampo *et al.* (2021) found that the use of a mix of extracellular compounds of *H. coffeata*, 0.7% pectin and 0.5% glycerol lowered the weight loss of strawberries from 22.3% for uncoated fruit to 7.74% for coated fruit during storage for 10 d at 4°C. These results were consistent with those of Nazoori *et al.* (2020), who noticed a decrease in strawberry weight during storage at 4°C for 14 d. To achieve a certain amount of weight loss, 2.97% in uncoated fruit and 1.95% in coated fruit with sodium alginate and ascorbic acid as a coating material. Moreover, Pinzon *et al.* (2020) note that the weight loss of strawberries coated with a composite of banana starch, chitosan and Aloe vera gel was reduced by 5% compared to uncoated fruit.

Weight loss is considered a crucial characteristic used to assess the freshness of fruits; it is generally associated with respiration, transpiration and water loss, which cause a reduction in the fruit's size and weight. It has an unfavorable effect on the general appearance, mellowness, color, flavor and other quality characteristics. Therefore, the coatings work to preserve fruit by creating a barrier layer that protects it after harvesting (during storage and marketing) until it reaches the consumer, thereby maintaining quality and reducing economic losses (De Bruno *et al.*, 2023; Agapito-Ocampo *et al.*, 2021).

Deterioration value

The deterioration value of coated strawberries with DDS, (GS), Sm1, Sm2 and Sm3 was 12.74, 9.17, 3.25, 2.08 and 1.34%, respectively, after storage at 4°C for 10 d (Fig 3).

Deterioration is one of the primary factors responsible for postharvest losses in fruits and vegetables, which results from exposure to contaminating microorganisms through soil, dust, water and postharvest processing equipment. Therefore, coating treatments are used to reduce the percentage of deterioration in fruits during

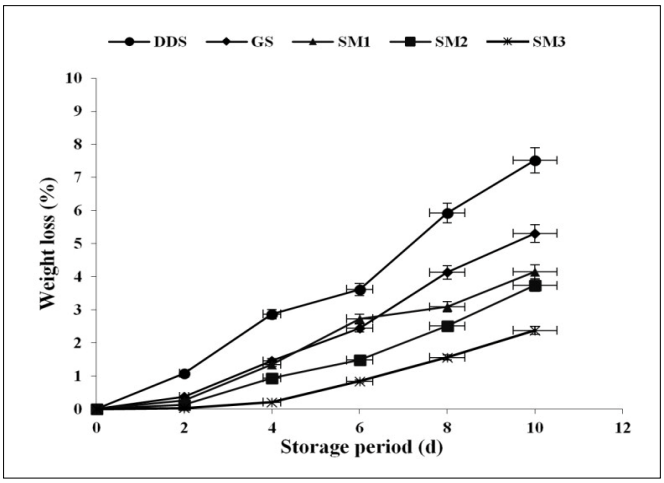


Fig 2: Weight loss values of coated strawberry with bakery yeast secondary metabolites during storage period at 4°C.

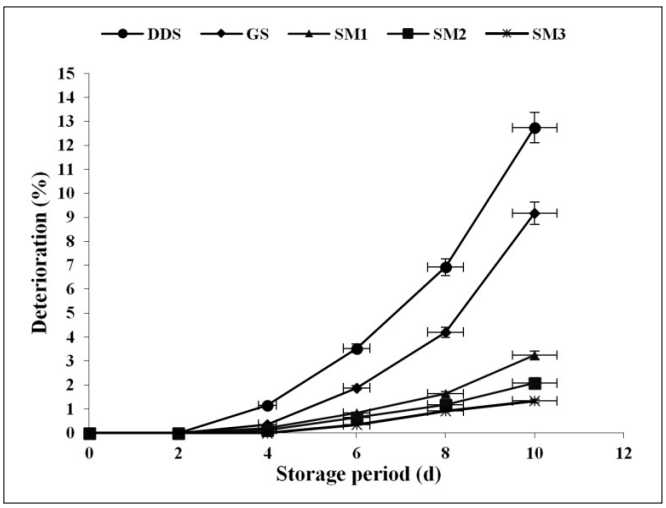


Fig 3: Deterioration value of coated strawberry with bakery yeast secondary metabolites during storage period for 10 d at 4°C.

storage (Shahat *et al.,* 2020). In this context, De Bruno *et al.* (2023) refer that the deterioration value for strawberries coating by a mix of 2.5% bergamot pomace extract, 2% gum Arabic and 1% glycerol was 36%, while it was 100% in control without any addition during storage for 14 d at 4°C; Khodaei *et al.* (2021) found that coating with 1% carboxymethyl cellulose and 30% glycerol reduced the visible mold on strawberries compared to uncoated control samples, which exhibited deterioration of 59.6%, while it was 32.66% for coated samples during storage at 4°C for 16 d; Shahat *et al.* (2020) observed that the use of 1% chitosan and chitosan nanoparticles as a coating material for the strawberries contributed to reducing fungal deterioration. During storage at 6°C, note that visual deterioration started on the uncoated fruit was 10% at the 4th d to be 100% at the 12th d, while it appeared at the 12th d with 20 and 10% to be 70 and 40% at the 16th d, respectively; Pinzon *et al.* (2020) noted that the deterioration of uncoated strawberries during storage at 4°C was 10% on the 2nd d and 100% on the 10th d, while the deterioration of coated fruits with a composite of banana starch, chitosan and Aloe vera gel (20%) was showing after the 7th d to be 18% at the 14th d of storage. He concluded that increasing the coating concentration significantly reduced deterioration. He attributed the antifungal activity of chitosan against common strawberry pathogens to the activation of chitinases, which leads to chitin hydrolysis and the ability to cause cellular damage to the molds. Likewise, Shivani *et al.* (2022), who use chitosan, Aloe vera gel and guar gum; and Agapito-Ocampo *et al.* (2021), who use a mix of extracellular compounds of *H. coffeata*, 0.7% pectin and 0.5% glycerol, noticed a reduction in the visible mold on coated strawberries compared to uncoated fruit during storage conditions.

Estimation of soluble solids content

The soluble solids content was 6.7% of all strawberries treatments at the beginning of storage at 4°C for 10 d to 10.2, 8.6, 8.5, 7.9 and 7.3°Brix for DDS, GS, SM1, SM2 and SM3, respectively, after storage at 4°C for 10 d (Fig 4).

The soluble solids content in fruits, particularly sugars and organic acids, is responsible for the product's taste and flavor, in addition to serving as an energy source for cellular respiration. Therefore, the coating treatments are used to reduce the loss percentage during storage (Nazoori *et al.,* 2020). In this regard, De Bruno *et al.* (2023) refer that the soluble solids content for strawberries coated by a mix of bergamot pomace extract, gum Arabic and glycerol and control without any addition was highest from 6.4°Brix (%) at the beginning of storage at 4°C to be 6.6 and 7.0°Brix (%), respectively, at 7th d and lowest at 10th d to be 5.8 and 5.9°Brix (%), respectively. This was attributed to the fact that the initial increase and subsequent decrease were due to the hydrolysis of carbohydrates, which leads to sugar accumulation during fruit ripening, followed by degradation through respiration during storage. Agree with him, Pinzon *et al.* (2020) report that the soluble solids content for strawberries coated with a composite of banana starch, chitosan and Aloe vera gel and control without any addition was highest at 8.13 and 8.20°Brix (%) at the beginning of stored at 4°C for 14 d, to be 8.81 and 9.44°Brix (%), respectively. This was attributed to the use of edible coatings, which can slow down the degradation process, resulting in a minor increase in total suspended solids values. The ability of coating materials to control water vapor permeability and the permeability of O_2 and CO_2 increases with the concentration of the coating.

Many researchers who studied the effect of coating strawberries on the content of soluble solids content during storage observed this fact and referred to it, such as Shivani *et al.* (2022), who use chitosan, Aloe vera gel and guar gum; Agapito-Ocampo *et al.* (2021) who use a mix of extracellular compounds of *H. coffeata*, pectin and glycerol; Khodaei *et al.* (2021) who use carboxymethyl cellulose and glycerol; Nazoori *et al.* (2020), who use sodium alginate and ascorbic acid; Shahat *et al.* (2020) who use of chitosan and chitosan nanoparticles.

Sensory evaluation

The results of the sensory evaluation for coated strawberries by sterile deionized distilled water (control), a 1% glycerol

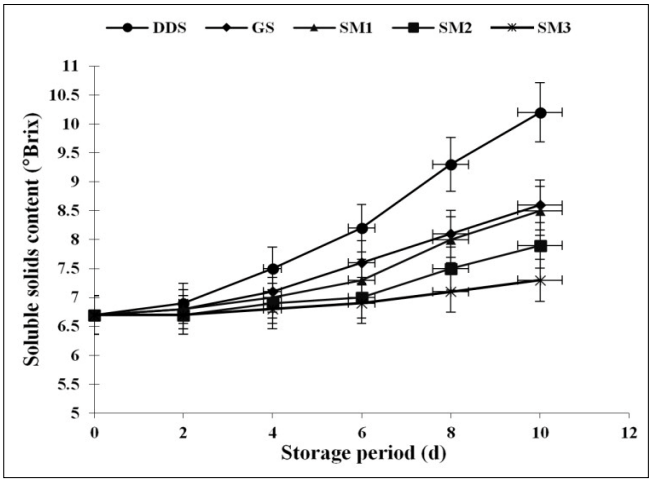


Fig 4: Soluble solids content of coated strawberry with bakery yeast secondary metabolites during storage period for 10 d at 4°C.

Table 4: The static analysis for sensory evaluation of characteristics of appearance, aroma intensity, sweetness, turgidity and overall acceptability for coated strawberries by sterile deionized distilled water (control), a 1% glycerol solution (GS) and the coating solution (5, 10 and 20 mg mL^{-1}) of the yeast secondary metabolites with 1% glycerol solution) during storage at 4°C for 10 d.

Characteristic	Statically analysis							
	One-way ANOVA		Two-way ANOVA			Pearson correlation		
	Probability value (P-value)	Significant difference (P≤ 0.05)	Treatment (p)	Day (p)	Treatment × Day (p)	Relation -ship	Correlation coefficient (r)	Potential Significance
Appearance	0.00026	Yes	5.37×10^{-13}	1.29×10^{-26}	6.16×10^{-7}	Overall acceptability	0.77	Strong positive
Aroma	0.22106	No	7.33×10^{-4}	8.31×10^{-24}	5.00×10^{-10}	Overall acceptability	0.75	Strong positive
Sweetness	0.00033	Yes	2.67×10^{-11}	1.79×10^{-24}	5.29×10^{-4}	Overall acceptability	0.80	Strong positive
Turgidity	0.00123	Yes	8.54×10^{-8}	8.17×10^{-19}	1.00×10^{-2}	Overall Acceptability	0.85	Very strong positive
Overall acceptability	0.00009	Yes	8.13×10^{-17}	2.65×10^{-31}	2.87×10^{-9}			

solution (GS) and the coating solution (5, 10 and 20 mg mL^{-1}) of the yeast secondary metabolites with 1% glycerol solution during storage at 4°C for 10 d revealed significant differences among the treatments in terms of appearance, sweetness, turgidity and overall acceptability. At the same time, there is no significant difference in aroma (as determined by one-way ANOVA). Significant differences were observed in sensory characteristics for each treatment, day and the interaction between treatment and day (two-way ANOVA). Additionally, all sensory charact-eristics were strongly positively correlated, especially with overall acceptability (Pearson correlation). The treatment (20 mg mL^{-1} of yeast secondary metabolites in a 1% glycerol solution) showed the best effect for coated strawberries, indicating a more effective treatment (Table 4).

The coating treatment should not alter the sensory or nutritional characteristics of the fruit and the coating concentration should be considered, as high concentrations may show an adverse effect on these characteristics (Pham *et al.,* 2023). Therefore, sensory evaluation is crucial in determining the consumer's acceptability of coated fruits (Khodaei *et al.,* 2021). Accordingly, many studies have been conducted on this case, such as De Bruno *et al.* (2023) who note that using a combination of bergamot pomace extract, gum Arabic and glycerol for coating strawberries yields the best results in sensory evaluation of the overall acceptability parameter, which encompasses appearance, aroma, taste and texture, during storage at 4°C for 14 d; Khodaei *et al.* (2021) who showed that coating strawberries with carboxymethyl cellulose and glycerol resulted in the highest sensorial score in terms of color, flavor, taste, texture and overall acceptance during storage at 4°C for 10 d. The differences between treatments and changes in sensorial properties during the storage period were attributed to weight loss and mold contamination on the fruit; also, Nazoori *et al.* (2020) found that coating strawberries with sodium alginate and ascorbic acid results in improvements in sensory evaluation, including taste, aroma, acceptance and browning during storage at 4°C for 14 d.

CONCLUSION

The study demonstrates the feasibility of using secondary metabolites produced from commercially available bakery yeast as an edible coating to extend the shelf life of strawberries during refrigerated storage, with a strong positive correlation with overall acceptability in consumer sensory evaluations.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

No animal experiments in this study.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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