Evaluation of the turmeric dye extraction residue in the formation of protective coating on fresh bananas (*Musa acuminata* cv. ‘Maçã’)

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Abstract We evaluate the flour obtained from the residue of turmeric dye extraction, designated turmeric flour, as a protective coating to extend banana (*Musa acuminata*) shelf life. The coating formulation consists of 6 g of turmeric flour/100 g of solution and 30 g of glycerol/100 g of turmeric flour, produced by immersion. We also investigate how the coating affects banana weight loss, firmness, pH, titratable acidity, soluble solids and reducing sugars contents, and peel color along 15 days of storage at 27 ± 2 °C and 65% RH. Coatings based on turmeric flour display good antioxidant activity, which is attributed to the presence of curcuminoids, mainly curcumin. These coatings delay weight loss, color development, and firmness reduction, and they afford lower acidity and sugars content in coated bananas as compared to control bananas. Compared to uncoated samples, turmeric flour-based coatings extend the original characteristics of bananas stored at 27 °C by 3 days.

Keywords Turmeric flour · Agro-industrial residue · Coating · Bananas

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Introduction

Edible films and protective coatings produced from renewable sources can help to reduce the use of synthetic packaging, mainly for storage of post-harvest products. Antioxidant or antimicrobial agents can be incorporated into coating formulations, offering additional benefits when compared to conventional films (Dainelli et al. 2008; Bodaghi et al. 2013). Coatings with antioxidant property prevent fruit surface browning, delay ripening, and prolong shelf life for many days (Awad et al. 2017).

Polysaccharides such as pectin, alginate, carrageenan, starch, cellulose, and their derivatives as well as proteins like gelatin, casein, egg albumin, wheat gluten, and zein (Sohail et al. 2006; Ghanbarzadeh et al. 2007) have been tested as polymers to produce coatings. However, the water vapor barrier of these coatings is not effective due to their hydrophilic nature.

Flours from cereals and tubers are a natural mixture of starch, proteins, and lipids that can yield films and coatings with better ability to act as water vapor barrier. These flours can also be obtained from agro-industrial residues, such as the residue from turmeric dye extraction. Maniglia et al. (2014, 2015) demonstrated that films based on turmeric flour present residual content of curcuminoids (curcumin, demethoxycurcumin, and bisdemethoxycurcumin), which exhibit antioxidant activities. Curcumin is the main compound underlying the bioactivity of processed films (Paramasivam et al. 2009).

Banana is the second most produced and most consumed fruit in Brazil—the 2017 production is seven million tons (IBGE 2017). Bananas are climacteric fruit with high respiratory rate; they produce elevated ethylene levels after harvesting, a factor that plays a critical role in ripening (Duan et al. 2007). After harvesting, bananas undergo

numerous physicochemical changes that rapidly modify the pulp texture, the fruit ability to convert starch to sugar, the banana aroma and flavor, and the banana peel color due to polyphenol degradation and chlorophyll breakdown (Alkarkhi et al. 2011; Popa et al. 2015). According to Thompson and Burden (1995), (a) ripe banana susceptibility to physical damage during transport and marketing, mainly via intensive manipulation of the bunches; (b) attack of pathogenic fungi at any time before or after harvest; and (c) irregular and unpredictable fruit maturation under natural conditions affect bananas during and after harvest. In this sense, implementing postharvest practices to maintain banana quality and to prolong shelf life is essential (Siqueira et al. 2017). Application of protective coatings with antioxidant property could minimize or even prevent banana quality loss and avoid food waste (Awad et al. 2017; Soradech et al. 2017).

One advantage of preparing coating formulations from the flour obtained from the turmeric dye extraction residue is the fact that this flour, designated turmeric flour hereafter, has intrinsic antioxidant activity, which dismisses the need for an additional additive. This study aims to evaluate how turmeric flour affects postharvest quality and shelf life of bananas stored at 27 °C.

Materials and methods

Materials

Dyes Industry Firace S.A. (Paraná, Brazil) supplied the residue obtained from turmeric dye extraction, designated turmeric residue, in containers protected from light and stored under refrigeration. The turmeric residue was submitted to wet milling and sieving (0.075 mm) before drying in an oven (MA Q314M, Quimis, Brazil) at 45 °C for 24 h, which afforded turmeric flour.

Hive Climate & Fruit Distributor (Ribeirão Preto, Brazil) provided bananas (*Musa acuminata* cv 'Maçã') in maturation stage 2 (green with yellow traces). Fruits were washed with water and detergent, disinfected by immersion in a sodium hypochlorite solution at 0.2 g/L for 3 min, rinsed with distilled water, and dried.

Glycerol, used as plasticizer, was purchased from Sigma-Aldrich (São Paulo, Brazil).

Turmeric residue and turmeric flour chemical composition

Crude protein and ash contents were determined according to standard AOAC methods (AOAC 1997). Lipid content was calculated by using the method described by Bligh and Dyer (1959). Cellulose was determined on the basis of the

methodology presented by Sun et al. (2004). Hemicellulose was analyzed by HPLC according to the procedure reported by Gouveia et al. (2009). Klason lignin was determined by the TAPPI T 222 om-22 (2002) method, and soluble lignin was analyzed by UV–Vis absorbance measured at 280 nm. All analyses were performed in triplicate.

Curcuminoids and total phenolics antioxidant activity and contents in turmeric residue, turmeric flour, and turmeric flour-based film

The antioxidant activity was determined by the ABTS (2,2'-azinobis (3-ethylbenzoathiazoline-6-sulfonic acid)) method according to the procedure described by EMBRAPA (2007). This method consisted in soaking 100 mg of sample in 2 mL of absolute methanol, which was followed by stirring at room temperature (~ 25 °C) for 3 h, in the absence of light. Then, the solution was filtered (0.45-µm filter Millipore, Brazil), and 30 µL of the filtered extract was added to 3 mL of a methanolic solution of ABTS radicals (solution containing ABTS at 7 mmol/L and potassium persulfate at 2.45 mmol/L), which was followed by homogenization at room temperature for 30 min in the absence of light. After this period, absorbance at 734 nm was read on a Hewlett Packard HP8453 spectrophotometer. The antioxidant activity was obtained by interpolating sample absorbance to an analytical curve constructed with an antioxidant standard named Trolox (10 to 2000 µmol/L) and expressed as µmol/L Trolox g⁻¹ of sample. The resulting curve was adjusted to a linear equation, $y = -0.0003x - 0.6949$ ($R^2 = 0.996$) (y = absorbance and x = µmol/L Trolox g⁻¹ of sample), for numerical antioxidant activity determination.

Curcuminoids concentrations were determined by HPLC according to the methodology described by Martins et al. (2012). Briefly, 20 µL of the filtered extract was analyzed by HPLC (Shimadzu, CTO-10ASVP) equipped with a C-18 column (250 × 4.6 mm, 5 µm), an oven operating at 40 °C, a LED detector (420 nm), and a sample loop of 20 L; the flow rate was 1.0 mL min⁻¹. The mobile phase consisted of 450 mL/L of acetonitrile in 550 mL/L of aqueous acetic acid solution at 10 mmol/L. The gradient program was as follows: 0–12 min, 45 mL/L of acetonitrile; 12–32 min, 450–1000 mL/L of acetonitrile; and 32–40 min, 1000 mL/L of acetonitrile. Standard curcumin, demethoxycurcumin, and bisdemethoxycurcumin were acquired from Fluka Analytical, Switzerland (98%). All the other chemicals and reagents were purchased from E-Merck in analytical grade. Standard curcuminoids methanol solutions were freshly prepared, and analytical curves were constructed by measuring five solutions of each standard at different concentrations (curcumin: from 0.002 to 0.035 g L⁻¹; bisdemethoxycurcumin: from

0.0002 to 0.035 g L⁻¹; and demethoxycurcumin: from 0.008 to 0.242 g L⁻¹). Curves were constructed by plotting the peak area versus the concentration of each analyte. All determinations were carried out in triplicate.

Phenolic compounds content in the samples was determined by the Folin-Ciocalteu method. To this end, 5 g of each sample was weighed and individually homogenized in 20 mL of 95% ethanol under vigorous stirring. The resulting solutions were allowed to rest at 4 °C for 24 h and filtered. Next, 8 mL of distilled water and 0.5 mL of an aqueous Folin-Ciocalteu reagent solution (1:7) were added to 0.5 mL of filtrate under stirring for 3 min. After homogenization, 1 mL of Na₂CO₃ at 0.5 mol/L was added and allowed to react for 10 min. Measurements were carried out in triplicate, at 725 nm, in the absorbance mode. The total phenolics content was determined by interpolating sample absorbance to an analytical curve constructed with gallic acid standards (45–650 mg L⁻¹) and expressed as mg of GAE (gallic acid equivalents) per g of sample. An equation of the adjusted curve was obtained by using gallic acid as reagent to calculate the total phenolics content, more specifically $y = 0.006 \times x - 0.0068$ ($R^2 = 0.992$), where y = absorbance and x = mg of GAE g⁻¹ of sample.

Turmeric flour-based coating preparation and application

Turmeric flour-based coating formulations were prepared by suspending 6 g of turmeric flour/100 g of solution in deionized water and homogenizing the suspension in a magnetic stirrer (IKA MAG[®] C-HS7-Marconi, Brazil) for 30 min. pH was adjusted to 8.4, and the suspension was heated to 84.5 °C for 4 h. During this period, the solution was submitted to 2-min homogenization cycles at 12,000 rpm at every hour with an ultra-turrax homogenizer (Ultracleaner 1400, Unique, Brazil). Before the end of the heating cycle, 30 g of glycerol/100 g of turmeric flour was added. The mixture was heated for 20 min and was then cooled to room temperature.

Bananas were dipped into the turmeric flour-based coating formulation for 1 min, and excess gel was allowed to drain away. After drying in air, fruits were stored at 27 °C and 65% RH in a BOD (MA Q314 M, Quimis, Brazil) for 15 days. Analyses were performed 0, 2, 4, 6, 9, 12, and 15 days after the coating was applied. Uncoated bananas were also stored as control.

To measure soluble solids content, pH, titratable acidity, and reducing sugars content, fruits were peeled, pulps were centrifuged at 10,000 rpm (MA Q222RM, Quimis, Brazil) and 10 °C for 15 min, and the supernatant was analyzed.

Weight loss

Weight loss was determined as the average of individual sample weights measured on a digital balance (Sartorius BL210S, New Jersey, USA). Results are expressed as the percentage loss of initial weight (weight on day 0).

Firmness

Banana pulp firmness was examined with a texture analyzer TA TX Plus (TA Instrument, England). Maximum penetration force (N) was assessed by puncture test at a constant speed of 2 mm s⁻¹; a round stainless steel probe with diameter of 5 mm was used to penetrate 20 mm into the central region of three 25-mm slices per sample.

pH and titratable acidity

To determine pH, 6 g of supernatant was diluted in 50 mL of water. Reading was performed in a pH meter (MA522, Marconi, Brazil) with automatic correction of values as a function of temperature.

Titratable acidity was estimated by weighing 1.2 g of supernatant and by adding 10 mL of water and two drops of phenolphthalein to it. Sodium hydroxide at 0.1 M was used during titration (Brazil 2005). Results are expressed as mg of malic acid per 100 g of sample because malic acid is the organic acid that prevails in banana fruit (Equivalent-gram = 67.04) (Cano et al. 1997).

Soluble solids

Soluble solids content was obtained by direct measurements in a digital refractometer (HI 96801, Hanna, Brazil). Results are expressed as total soluble solids (%TSS).

Reducing sugars

Reducing sugars content was determined by the DNS method (3,5-dinitrosalicylate) and is expressed as milligrams of reducing sugar as glucose g⁻¹ of pulp.

Skin color

Banana skin color was visually scored by adopting the standard banana color chart, ranging from 1 to 8, where 1 = green; 2 = green with yellow stains; 3 = more green than yellow; 4 = more yellow than green; 5 = yellow with green tinge; 6 = completely yellow; 7 = yellow slightly mottled brown, and 8 = yellow with big brown areas (Alves 1999).

Statistical analysis

An analysis of variance (ANOVA) and Tukey's test at 5% significance level were performed with the software Statistic 12.0 to evaluate how the turmeric flour-based coating affected banana shelf life.

Results and discussion

Turmeric residue and turmeric flour chemical composition

The turmeric residue and the turmeric flour (obtained after wet milling of the turmeric residue) contained mainly starch, fibers, and small fractions of proteins and lipids, as listed in Table 1. Tukey's test revealed a significant difference between the residue and the flour chemical compositions ($p < 0.05$). This difference could be attributed to wet milling process, which removed a great fraction of ashes, lipids, cellulose, and hemicellulose present in the turmeric residue, to yield turmeric flour with higher amount of proteins and starch as compared to the residue. Regarding soluble and insoluble lignin contents, there were no significant differences at $p < 0.05$, indicating that wet milling did not affect the contents of these components in the residue or flour.

Our initial intention was to produce coatings directly from the turmeric residue, but we did not succeed in doing so due to the intrinsic characteristics of this material, as also reported by Maniglia et al. (2014). On the other hand, the high starch content in turmeric flour associated with an inferior content of fibers enhanced the film forming ability, which suited coating processing.

Total phenolics and curcuminoids antioxidant activity and contents in turmeric residue, turmeric flour, and turmeric flour-based film

Phenolic compounds have attracted much interest because they can function as antioxidants (Moo-Huchin et al. 2015). Curcuminoids are the main phenolic compounds in *Curcuma longa* L. (Osorio-Tobón et al. 2014).

Table 2 summarizes the contents of total phenolics and curcuminoids as well as the corresponding antioxidant activity measured in the turmeric residue, turmeric flour, and turmeric flour-based coating formulation. Turmeric flour presented the highest total phenolics and curcuminoids contents, so it displayed the best antioxidant activity. In the flour, curcuminoids and starch formed strong complexes, which caused major curcuminoids retention (Hoover and Vasanthan 1994). According to Bhawana and Jain (2011), curcuminoids have low solubility in water and

Table 1 Chemical composition of the turmeric residue and the turmeric flour (g/100 g of material on dry basis)

Sample	Moisture ^a	Ashes	Lipids	Proteins	Hemicellulose	Cellulose	Soluble lignin	Insoluble lignin	Starch
Turmeric residue	11.33 ± 0.19 ^a	5.76 ± 0.12 ^a	4.93 ± 0.21 ^a	4.17 ± 0.18 ^b	5.90 ± 0.40 ^a	8.27 ± 0.05 ^a	1.55 ± 0.06 ^a	5.58 ± 0.84 ^a	63.84 ± 0.25 ^b
Turmeric flour	5.80 ± 0.54 ^b	2.77 ± 0.04 ^b	3.88 ± 0.14 ^b	6.05 ± 0.59 ^a	2.07 ± 0.12 ^b	4.44 ± 0.12 ^b	1.63 ± 0.20 ^a	6.42 ± 0.55 ^a	72.74 ± 0.83 ^a

^aExpressed on a wet basis. Mean of three replicates ± standard deviation. Means in the same column with different letters indicates significant difference between the turmeric residue and the turmeric flour according to Tukey's test, $p < 0.05$

Table 2 Antioxidant activity and contents of curcuminoids and total phenolics as measured in turmeric residue, turmeric flour, and turmeric flour-based coating formulation

Sample	Total phenolics (mg of GAE/g of sample)	Curcumin (mg L ⁻¹)	Demethoxycurcumin (mg L ⁻¹)	Bisdemethoxycurcumin (mg L ⁻¹)	Antioxidant activity (μM Trolox/g of sample)
Turmeric residue	7.10 ± 0.05 ^b	401.75 ± 4.70 ^b	118.30 ± 8.10 ^b	171.70 ± 15.96 ^b	202.74 ± 7.14 ^b
Turmeric flour	8.09 ± 0.43 ^a	453.64 ± 9.45 ^a	173.74 ± 12.58 ^a	292.19 ± 29.24 ^a	243.42 ± 6.98 ^a
Turmeric flour-based coating	1.08 ± 0.12 ^c	74.28 ± 1.10 ^c	14.70 ± 0.70 ^c	18.40 ± 2.10 ^c	65.03 ± 3.74 ^c

Mean of three replications ± standard deviation. Means in the same column with different letters indicates significant difference between the studied materials according to Tukey's test, $p < 0.05$

Fig. 1 **a** Weight loss and **b** firmness of coated and uncoated bananas (cv. ‘Maçã’) stored at 27 °C along 15 days. Each point is the mean of three replicate samples. Different letters (a, b) indicate significant differences ($p < 0.05$) between the uncoated and coated bananas for the same storage time

tend to bind to starch, to form agglomerates with sizes that are commonly retained in the sieve.

Table 2 shows that, the greater the amount of total phenolics and, in particular, the higher the curcuminoids

content (as in the case of turmeric flour), the better the antioxidant activity of the material. The turmeric flour-based coating formulation contained the lowest total phenolics and curcuminoids contents and consequently displayed the lowest antioxidant activity. Curcuminoids are sensitive to temperature, so they may have been degraded along the heating process applied during the turmeric flour-based coating preparation (Bhawana and Jain 2011). Despite its lower activity, the turmeric flour-based coating displayed considerable antioxidant effect.

Weight loss

Figure 1(a) depicts the percentage of weight loss as a function of storage time for coated and uncoated bananas. Both sets of samples behaved similarly. Data were adjusted to a simple linear regression model like “ $y = a + bx$ ”. The coefficients of determination (R^2) of the curves were higher than 0.9, confirming excellent fit and indicating that both samples lost mass by the same mechanism.

Weight loss increased over time and was more accentuated for uncoated bananas, mainly as compared to coated bananas 6 days after the coating was applied. By the end of 15 days, uncoated bananas had lost approximately 30% of their initial mass as compared to 24% mass loss in the case of coated bananas. This indicated that the coating provided a physical barrier to evaporation and respiration through the fruit skin, which are processes that usually account for drop in fresh weight. Literature papers have reported similar numerical results. For example, Maqbool et al. (2011) reduced banana mass loss (cv. Pisang Berangan) by 10% after they stored fruits coated with gum Arabic in the cold (12 °C) for 15 days. Malmiri et al. (2011) also decreased banana mass loss (cv. Berangan) by 10% after storing fruits coated with chitosan-glycerol formulations at room temperature for 10 days. Kittur et al. (2001) reported an outstanding 30% reduction in weight loss after storing bananas coated with chitosan-carboxymethylcellulose at room temperature for 12 days.

Fig. 2 Changes in **a** pH and **b** titratable acidity of uncoated and coated banana cv. ‘Maçã’ pulp stored at 27 °C for 15 days. Each data point is the mean of three replicate samples. Different letters (a, b) indicate significant differences ($p < 0.05$) between the uncoated and coated bananas for the same storage time

Firmness

Figure 1b shows how coated and uncoated banana pulp firmness changed along storage. Both coated and uncoated bananas had their firmness gradually decreased in the first 4 days of storage, which was followed by intensive decay thereafter. Coating application delayed softening, particularly between the fourth and the twelfth day, but both samples had similar percentage of softening by the end of the storage period; i.e., 0.41 N or 97.14% for uncoated samples and 0.72 N or 95.02% for coated fruits. Firmness loss during maturation is associated with three concomitant mechanisms: (a) breakdown of starch into sugar, (b) cell wall degradation, and (c) reduced cohesion between intermediate lamella due to pectic acid solubilization and water movement as an osmotic effect. The coating may have reduced the O_2 supply, to generate a modified internal atmosphere that delayed maturation.

Fig. 3 Changes in **a** soluble solids content and **b** reducing sugars content in uncoated and coated bananas cv. ‘Maçã’ stored at 27 °C for 15 days. Each data point is the mean of three replicate samples. Different letters (a, b) indicate significant differences ($p < 0.05$) between the uncoated and coated bananas for the same storage time

pH and titratable acidity

Acid content correlates with pH: fruit pH increases as fruit acidity decreases (Fig. 2). The difference between these parameters is that pH expresses dissociated acid, while titratable acidity refers to the total amount of acids present in the material as salts and phenolic compounds. According to Fig. 2a, pH varied little during storage. pH values ranged from 5.8 (day 1) to 6.0 (day 15). pH slightly decayed to values around 4.7–5.0 from the fourth to the ninth day of storage for both coated and uncoated bananas. pH values of uncoated and coated bananas were statistically different only on the second and on the twelfth day (Fig. 2a). Gol and Rao (2011) also observed that coatings influenced banana pulp pH very little when they evaluated several coating formulations. The pH fluctuation detected herein was close to the fluctuation measured by Baez-Sañudo et al. (2009) when they tested storage of bananas with chitosan-based coatings at 22 °C.

Figure 2b presents variations in pulp titratable acidities. The turmeric flour-based coating effectively reduced pulp acidity on the sixth day, which corresponded to the fruit climacteric peak. The percentage of titratable acidity of coated and uncoated samples increased simultaneously up to the sixth day, reaching a maximum of 0.84% for uncoated and 0.76% for coated fruits. After this period, titratable acidity decreased to similar levels for both samples (0.47% for uncoated 0.49% for coated samples).

Soluble solids

Soluble solids are an indirect measure of sugar content (Fig. 3). The soluble solids content increases as these solids accumulate in the fruit. However, determination of soluble solids content cannot be taken as the exact sugar content because other substances like vitamins, phenolics, pectins, and organic acids could also be solubilized in the mobile content.

On the basis of Fig. 3a, the coating did not modify the soluble solids content in the fruit. Both uncoated and coated samples had significantly higher soluble solids content after the fourth day, and values stabilized at 23.6 and 22.8% for uncoated and coated bananas, respectively. The low amount of soluble solids indicated lower conversion of starch into simple sugars and inferior maturation stage.

Reducing sugars

Figure 3b represents variation in reducing sugars content in uncoated and coated bananas. Coated bananas had lower reducing sugars content as compared to uncoated samples. At the end of the storage period, values of 10.0 and 11.3% reducing sugars were recorded for coated and uncoated bananas, respectively.

The aforementioned results suggested that the coating slowed the maturation process. Indeed, the presence of reducing sugars indicated hydrolysis of starch and inversion of sucrose into glucose plus fructose, which are directly related to fruit ripening. Other authors also reported a lower amount of reducing sugars in coated bananas (Kittur et al. 2001; Gol and Rao 2011).

Skin color

Variation in banana peel color is directly related to the degree of maturation. Chlorophyllase degrades chlorophyll during ripening, to increase the concentration of other pigments such as carotene and xanthophyll, which are the main pigments accounting for the yellow peel color (Saradech et al. 2017). The major carotenoids in yellow-ripe banana are α -carotene, β -carotene, and lutein.

Development of darker shades and loss of yellow tones could indicate banana over-ripeness and quality loss (Yap et al. 2017). Banana peel also contains phenolic compounds, which can be oxidized by polyphenoloxidase, to produce quinone and increase the levels of macromolecules, intensifying brown pigment (Anal et al. 2014).

Color variation in uncoated and coated fruits emerged on the ninth day: coated and uncoated fruits were classified as level 7 (yellow slightly mottled brown) and level 8 (yellow with big brown areas), respectively (supplementary material). Classification based on the color chart is not precise, although classifier algorithms have been developed for an automatic decision (Prabha and Kumar 2015), the grading levels is still subjective.

On the basis of the photographic records, uncoated fruits contained browner areas than coated fruits during the final period of storage (days 9, 12, and 15), which was consistent with the comparative analyses of reducing sugars: the higher the maturity stage, the higher the sugar content in the pulp. Although ripening resulted in peels with non-homogeneous color, both uncoated and coated fruits had similar color up to the sixth day of storage, and coated bananas maintained their color up to the ninth day, as evaluated by visual inspection. In other words, in the experimental conditions assessed herein, uncoated bananas had shelf life of around 6 days, whereas coated bananas had shelf life extended to 9 days.

The coating delayed banana peel color deterioration because it increased the CO_2 concentration and decreased O_2 concentration, thereby reducing metabolic rates and inducing slow degradation of the chlorophyll present in the peel. Hence, the coating created a modified atmosphere around the fruit, to reduce fruit respiration by restricting O_2 access to the tissue and consequently diminishing the enzymatic browning rate (Jiang and Li 2001; Wang et al. 2014). In addition, curcuminoids and phenolic compounds present in the coating acted as enzymatic inhibitors because they contained aromatic acids such as carboxylic, benzoic, and cinnamic acids, which are competitive inhibitors of polyphenoloxidase due to their structural similarity with phenolic substrates.

Conclusion

Turmeric flour, produced from turmeric residue by wet milling, has high starch, curcuminoids, and phenolic compounds contents and presents high antioxidant activity associated with good ability to form coatings. When applied on bananas, the turmeric flour-based coating effectively reduces mass loss, reducing sugars content, and oxidation of the pigment underlying skin color along the storage period (15 days). Coated samples have lower

titratable acidity as compared to uncoated fruits up to the sixth day, which corresponds to the climacteric peak. The coating also reduces firmness decay during the first ripening stage (sixth to twelfth day) and preserves the original peel color. The coating does not impact pH or soluble solids content. Overall, the turmeric flour-based coating extends the shelf life of coated bananas by 3 days in the storage conditions adopted here (in air, at 27 °C), and the shelf life could even be longer at lower temperatures. Thus, turmeric flour is suitable for application on fruits that are sensitive to oxidation, thereby extending their shelf life during post-harvest storage.

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