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Development and evaluation of edible films using corn, raw banana and taro root starch

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Abstract

The present study focused on the development and analysis of edible film using corn starch (CS), raw banana starch (BS) and taro root starch (TS). The starch was extracted from raw material and was evaluated for bulk density, tapped density, water-holding capacity, oil-holding capacity, dispersibility and colour analysis. Edible films were developed from as such starch namely, (CS, TS, BS) and different blending of starches, namely CBS 40:60, CBS 50:50, CTS 40:60, and CTS 50:50, by casting method using sorbitol as a plasticizer. The developed films were analyzed for thickness, solubility, transparency, colour, tensile strength, elongation at break, Young's modulus, and Fourier-transform infrared spectroscopy (FTIR). The starch analysis revealed significant variation in bulk density, tapped density, water and oil holding properties, dispersibility, and brightness, in order corn starch> raw banana starch> taro root starch. The thickness of developed edible films ranged from 0.180 mm to 0.215 mm, and solubility from 32.756 to 72.453%. Among all the developed films, CBS 50:50 film had significantly higher transparency (0.678) after corn starch film (0.908), whereas, taro root starch-based film had the lowest transparency (0.388). The blending of raw banana starch with corn starch showed better mechanical properties among the developed films. Overall, the CBS 50:50 blend demonstrated the most favourable properties for edible film and holds great potential for use in biodegradable, edible packaging solutions.

Key words: Edible film, corn starch, raw banana starch, taro root starch, physical properties

Introduction

Awareness of the production of edible films and coatings has increased in recent years with increasing customer demand for high-quality, ready-to-eat foods, a long shelf life, and environmental issues over the disposal of non-renewable food packaging materials (Nunes *et al.,* 2023). Edible films improve food quality and extend shelf life by preventing moisture transfer, oxygen uptake, lipid oxidation, and aroma loss. Both edible films and coatings serve similar functions but differ in application; films are typically made separately and then applied, whereas coatings are formed directly on the food surface (Saklani *et al.,* 2019). Edible biodegradable films for primary packaging in the biodegradable film industry is explored nowadays to emphasize the possibility for food processing to employ these films. Most edible coatings are made from GRAS-certified food components (Thakur *et al.,*2019; Chandla *et al.,* 2020).

One of the common biopolymers used in developing biodegradable plastics is starch. Starch, a ubiquitous and naturally occurring polysaccharide, has gathered significant attention in edible film development due to its remarkable properties, sustainability, and widespread availability. Among all biodegradable films, starch-based films account for more than 60% (Niu *et al.,* 2021), and they exhibit desirable mechanical, barrier, and optical properties, rendering them suitable for a variety of food packaging applications. Starch-based films present a promising eco-friendly option as compared to traditional petroleum-based plastics and this might be useful in the demand for biodegradable packaging solutions as well as the increasing concern about environmental impact (Shanbhag *et al.,*2023).

Bananas (*Musa paradisiaca*) are an important fruit crop found in tropical and subtropical regions around the world, and are an attractive source of starch (Wang *et al.,* 2019). Unripe bananas, widely available in local markets, contain approximately 36% starch. Banana starch contains more amylose than potato, maize, or wheat starch and is also resistant to oxidation. Pelissari *et al.* (2013) examined the optimal conditions for producing films derived from banana starch. These films exhibited increased opacity, lower water solubility, higher water vapour permeability, flexibility, mechanical strength, and stiffness.

Root crops and tubers are significant agricultural products in subtropical and tropical regions. Among them, taro (*Colocasia esculenta*) surpasses other root crops like cassava, potatoes, and sweet potatoes in starch content (Singla *et al.,* 2020). It is an important source of starch, characterized by a dry starch yield of 28.7%, comprising 5.55% amylose and 74.45% amylopectin. However, starch-based edible films made from taro face challenges such as low water resistance and poor water vapour barrier properties (Wulandari *et al.,* 2018).

Raw banana starch and taro root starch were the least explored for the development of edible films. Hence, the present study aimed to develop and analyze edible films prepared from different starches at different concentrations, namely corn starch, raw banana starch, and taro root starch. The edible films were developed from starch by casting method using sorbitol as a

plasticizer and analyzed for thickness, solubility, opacity, colour analysis and mechanical properties.

Materials and methods

Corn starch, raw banana and taro roots were purchased from the local market of Vallabh Vidyanagar, Anand. Starch extraction (raw banana and taro root) was done using the method described by Espinosa-Solis *et al.* (2009) with modifications. Raw bananas were peeled using a kitchen knife, sliced into 2 cm sections, and immediately immersed in a 1% citric acid solution to prevent oxidation. The slices were transferred in a 1% sodium bisulfite solution and blended for 2 minutes. The resulting homogenate was filtered, washed with distilled water until no solutes or suspended solids remained, and centrifuged at 2000 rpm for 5 minutes. The white starch sediment was dried in a hot-air oven at 60ºC for 24 hours. The dried solids were ground, sieved, and stored in airtight container at 4ºC until further use. The same method was applied for taro root starch extraction, omitting the citric acid immersion step. All starch samples were subsequently used for the analysis and development of edible film.

Physical parameters of starch

Bulk density and tapped density: Bulk and tapped density were estimated using the method described by Šavikin *et al.* (2021). A one-gram starch sample was placed in a 20 mL graduated glass cylinder and manually tapped 3 times and 300 times for bulk and tapped density, respectively.

Water holding capacity and oil holding capacity: The water and oil holding capacities of corn starch, taro starch, and raw banana starch were evaluated following the method described by Sofi *et al.* (2013). Briefly, 2.5 g of starch (dry weight basis) was mixed with 20 mL of distilled water for water holding capacity and oil for oil holding capacity in a pre-weighed centrifuge tube. The mixture was then centrifuged at 3000 rpm for 10 minutes at 25°C. An excess amount of water and oil was removed, and the weight gain was recorded.

Dispersibility: Dispersibility was assessed following the method of Sosulski *et al.* (1979). A 10 g sample was placed in a 100 mL stoppered measuring cylinder, diluted to 100 mL with distilled water, stirred vigorously, and allowed to settle for 3 hours. The volume of settled particles was subtracted from 100 mL, and the difference was recorded as the percentage dispersibility.

Colour analysis (Hunter 'L*' 'a*' 'b*'): The colour of the starch was determined using a colour flex EZ 45º/0º spectro-colorimeter (Hunter Lab). After standardization of the instruments using Hunter Lab Colour standards, 'L*' (lightness), 'a*' (redness to greenness) and 'b*' (yellowness to blueness) values were measured by placing the sample in a sample cup.

Table 1. Composition of edible film

Edible film	Corn starch (g)	Raw banana starch (g)	Taro root starch (g)	Sorbitol (g)
CS	6.0	-	-	3.0
BS	-	6.0	-	3.0
TS	-	-	6.0	3.0
CBS 40:60	2.4	3.6	-	3.0
CBS 50:50	3.0	3.0	-	3.0
CTS 40:60	2.4	-	3.6	3.0
CTS 50:50	3.0	-	3.0	3.0

Physical properties of edible film

Film thickness: The thickness of developed films from different starches was determined by the handheld digital screw gauge (Insize company) with a precision of 0.001 mm. The samples were taken in triplicates, and the average of three measurements at different locations in the film were recorded.

Transparency: Film transparency was measured using a UV-visible spectrophotometer (M/s PerkinElmer/Lambda, 25). Samples for the test were cut into rectangular pieces (1cm × 4 cm) and placed on the inner side of the cuvette. A cuvette without a sample was used as a blank. Absorbance was recorded at 600 nm.

Solubility: The solubility of the edible films was assessed following the method of Wu *et al.* (2013). Before the water solubility test, the films were stored in a desiccator at 0% relative humidity (RH). The initial weight of the 20 mm × 20 mm dry film sheet (W_0) was recorded. The film was then immersed in 5 mL of distilled water at 25 ± 1 °C for 5 minutes at 50 rpm. The insoluble portion of the film was carefully separated and dried in an oven at 100 °C until a constant weight (W_1) was achieved.

Tensile strength: Tensile strength was measured following the standard test method using a Texture Analyzer (TA Plus, Lloyd Instruments, Largo, FL) at a crosshead speed of 2 mm s^{-1}. Films were cut into 10 cm × 2 cm strips and tested. Only samples rupturing at the centre were included in the analysis. The mean and standard deviation were calculated for all valid measurements.

Fourier transform infrared spectroscopy: The Fourier-transform infrared (FTIR) spectroscopy of the developed edible film was conducted using a Spectrum GX (Perkin Elmer, U.S.A). The spectra were obtained as an average of 45 scans with a spectral resolution of 2 cm^{-1} using FTIR spectrum of 500 to 4500 cm^{-1} (Hazrol *et al.*, 2021).

Statistical analysis: The obtained data were analyzed for mean, standard deviation, and ANOVA using SPSS version 20.0.

Result and discussion

The physical properties of different types of starch were investigated, and the results are presented in Table 2. A significant difference (P<0.01) was observed among the starch samples in terms of bulk density, tapped density, water-holding capacity, oil-holding capacity, and dispersibility. No significant difference was observed in bulk density between corn starch (0.896 g mL^{-1}) and raw banana starch (0.890 g mL^{-1}), whereas the taro root starch showed the lowest bulk density (0.530 g mL^{-1}). For tapped density, raw banana starch showed the lowest tapped density (0.640 g mL^{-1}), with the increasing trend for taro root starch (0.663 g mL^{-1}) and corn starch (0.736 g mL^{-1}). Similarly, taro root starch showed the lowest water holding capacity (1.240 g g^{-1}) and oil holding capacity (1.120 g g^{-1}) than raw banana starch (1.700 g g^{-1} and 1.360 g g^{-1}) and corn starch (2.110 g g^{-1} and 1.680 g g^{-1}). Regarding dispersibility, an order was observed as corn starch (95.99%) >taro root starch (93.50%) >raw banana starch (91.66%). These findings offer insightful

information about the unique characteristics of different types of starch, which can have significant implications in various food processing applications.

Table 2. Physical properties of different types of starch

Types of starch	Bulk density (g mL^{-1})	Tapped density (g mL^{-1})	Water holding capacity (g g^{-1})	Oil holding capacity (g g^{-1})	Dispersibility (%)
Corn starch	0.896^{b} ± 0.005	0.736^{c} ± 0.015	2.110^{c} ± 0.036	1.680^{c} ± 0.050	95.333^{b} ± 0.577
Banana starch	0.890^{b} ± 0.020	0.640^{a} ± 0.020	1.700^{b} ± 0.026	1.360^{b} ± 0.026	91.666^{a} ± 1.527
Taro root starch	0.530^{a} ± 0.026	0.663^{a} ± 0.015	1.240^{a} ± 0.055	1.120^{a} ± 0.020	93.500^{ab} ± 0.500
F - Value	349.529**	26.443**	334.294**	197.333**	10.371**

Values are mean ± standard deviation of three observations, **indicates significant difference at $P<0.01$. Different alphabetical superscripts indicate significant difference within a column.

A lower water-holding capacity (1.01 g $g^{-1}$to 1.10 g g^{-1}) and oil-holding capacity (0.80 g g^{-1} and 0.85 g g^{-1} **)** of corn starch varied according to the cultivars was reported by Kurniawansyah *et al.* (2022). The findings for raw banana starch are in line with the values documented by Miah *et al.* (2023). They reported bulk density (0.86 g mL^{-1} to 0.91 g mL^{-1}), water absorption capacity (1.66 g g^{-1} to 1.71 g g^{-1}), and oil absorption capacity (1.32 g g^{-1} to 1.68 g g^{-1}) for raw banana starch obtained from two cultivars of banana. Moreover, Boahemaa *et al.* (2024) reported similar values for bulk density (0.55 g mL^{-1} to 0.57 g mL^{-1}), water holding capacity (1.17 g g^{-1} to 1.35 g g^{-1}), and oil holding capacity (1.00 g g^{-1} to 1.15 g g^{-1}) for taro starch obtained from two cultivars. Hydroxyl groups in starch chains can decrease water absorption capacity. The elevated water binding capacity is chiefly attributed to the weak interactions between amylose and amylopectin molecules within starch granules. Additionally, the molecular structure of starch affects oil absorption capacity, with corn starch aiding in oil absorption during soaking by breaking down complex molecules into simpler forms (Ali *et al.,* 2016).

Regarding tapped density, similar observation was made for corn starch (0.74 g cm^{-3}) by Adeleke *et al.* (2022), raw banana flour (0.53 g mL^{-1} to 0.66 g mL^{-1}) by Savlak *et al.* (2016). More *et al.* (2022) reported 83% dispersibility of taro root starch, which is lower than the present study. The density of powder depends on particle size; smaller particles form more compact connections. Homogeneous particle size distribution reduces interparticle space, inhibiting particle habitation (Kurniawansyah *et al.,* 2022).

Table 3 shows the colour analysis of different types of starch. A significant variation in ' L*', 'a*' and 'b*' values were noted among the starch samples. The 'L*'value of corn starch, taro root starch, and raw banana starch ranged from 86.84 to 95.07. The 'a*' value of corn starch, taro root starch, and raw banana starch ranged from -0.053 to -0.03, and the 'b*' value of corn starch, taro root starch, and raw banana starch ranged from 4.48 to 13.89.

Table 3. Colour analysis of starch

Types of starch	L*	a*	b*
Corn starch	95.070^{c} ± 0.020	0.0467^{b} ± 0.005	5.470^{b} ± 0.020
Banana starch	92.500^{b} ± 0.043	0.053^{b} ± 0.0115	4.483^{a} ± 0.046
Taro root starch	86.840^{a} ± 0.040	-0.033^{a} ± 0.005	13.896^{c} ± 0.056
F - Value	40912.840**	104.667**	41772.760**

Values are mean ±S.D. of three observations, **indicates significant difference at $P<0.01$. Different alphabetical superscripts indicate significant difference within a column

Similar 'L*'value (94.22), lower 'a*' value (0.27) and higher 'b*' value (8.26) was observed for native corn starch by Teli *et al.* (2009). Ahmed *et al.* (2020) found the similar value of the 'L*' (92.56) and lower 'a*'(-0.87), 'b*' (-0.15) for banana flour. Kahraman *et al.* (2020) reported higher values of 'L*' (90.87), 'a*' (2.19), and lower 'b*' (4.7) for taro root starch. The variation in colour values may be attributed to the type of starch and starch processing, including heat, pH, chemical modification, and oxidation (Sindhu *et al.,* 2023; Paramasivam *et al.,* 2023; Ribeiro *et al.,* 2023).

Table 4. Physical properties of different types of starch based edible film

Edible films	Thickness (mm)	Solubility (%)	Transparency
CS	0.211^{c} ± 0.003	47.883^{c} ± 1.888	0.904^{e} ± 0.002
BS	0.187^{a} ± 0.003	46.583^{c} ± 1.977	0.475^{b} ± 0.019
TS	0.202^{b} ± 0.0035	72.453^{d} ± 1.974	0.388^{a} ± 0.017
CBS 40:60	0.215^{c} ± 0.004	36.773^{b} ± 1.760	0.590^{c} ± 0.011
CBS 50:50	0.180^{a} ± 0.005	32.756^{a} ± 1.333	0.678 ± 0.020
CTS 40:60	0.185^{a} ± 0.006	45.520^{c} ± 1.931	0.393 ± 0.008
CTS 50:50	0.230^{d} ± 0.005	36.533^{b} ± 1.429	0.588 ± 0.013
F - Value	51.782**	167.208**	471.438**

Values are mean ±S.D. of three observations, **indicates significant difference at $P<0.01$. Different alphabetical superscripts indicate significant difference within a column

Table 4 presents the physical properties of various types of starch-based edible film, specifically thickness, solubility and transparency. Notably, no significant difference was found in the thickness of edible films and it ranged from 0.187 mm (BS) to 0.202 mm (TS). Similar observations were made by Nouraddini *et al.* (2018) that the thickness values for eggplant flour and corn starch-based films ranged from 0.217 to 0.244 mm. They reported that highest thickness among the film formulations was observed in the films prepared with only starch. As per Japanese Industrial Standards (JIS, 1975), the desirable thickness for edible film is below 0.25 mm. Cross-linking appears to enhance the internal bonding within starch, increasing molar volume. Increased interactions between starch and the plasticizer during gelatinization, may form thicker films (Sanyang *et al.,* 2016). Moreover, thickness of the film is crucial that influences various properties, including water vapour permeability, light transmission, and transparency, mechanical properties such as tensile strength and elongation at break (Putri *et al.,* 2023).

In terms of solubility, taro starch-based edible film exhibited the highest solubility (72.45%), followed by corn starch (47.88%), raw banana starch (46.58%), and CTS 40:60 (45.52%). Whereas, CBS 40:60, CBS 50:50, and CTS 50:50 showed solubility below 40%. The solubility of edible film is an essential factor in the packaging material. Solubility is influenced by hydrophilic and hydrophobic components (Ulfah *et al.,* 2018).

Film transparency greatly impacts the product's acceptability. Higher transparency is desirable for food packaging films and coatings since consumers can see foods clearly through the package (Yoo and Krotcha, 2011; Wardak *et al.,* 2024). A significant (P<0.01) variation in transparency value was observed for different edible films and it ranged from 0.388 (TS) to 0.904 (TS). CBS 50:50 film had better transparency (0.678) after corn starch film among all the developed films. Higher values indicate higher transparency of the films. Siskawardani *et al.* (2020) noted the thickness and composition of the films significantly affect their optical properties, with a positive correlation between transparency and the quantity of constituents. Moreover, the pink coloration of the film suggests that raw material concentration plays a crucial role in determining the final appearance. Wardak *et al.* (2024) reported that adding sunflower oil increases the opacity while additional citric acid reduces it.

Films, as packaging, need to possess strong mechanical properties, including tensile strength and elongation at break, to resist external stress, maintain their integrity, as well as serve as effective barriers throughout the packaging process. The tensile strength of the developed film is presented in Fig.1. The order of tensile strength was CS (9.6MPa)> CBS 40% (7.66MPa)> CBS 50% (7.49MPa)> BS (5.15MPa)> CTS 40:60 (3.64MPa)> CTS 50:50 (3.41MPa)> TS (1.63MPa). Corn starch-based edible film showed the highest tensile strength of the other combinations. In addition, banana starch and corn starch blending showed higher tensile strength than taro root starch and corn starch blending.

The results of the tensile strength of corn starch-based edible film were in line with the study by Mohammed *et al.* (2022). They reported a tensile strength of 9.2 MPa for corn starch-based film using glycerol and 10.2 MPa when sorbitol was used as the plasticizer. The results for tensile strength of raw banana starch-based edible film were in line with the banana starch-based edible film (3 MPa to 5 MPa) studied by Zamudio-flores *et al.* (2006). They reported that oxidation of starch will increase the tensile strength of films due to more structural integrity in the polymeric matrix. Similar tensile strength for taro starch film was observed by Wahyudi and Muljani, (2021). They also reported that increasing glycerol content reduces tensile strength and increases flexibility due to decreased intermolecular forces

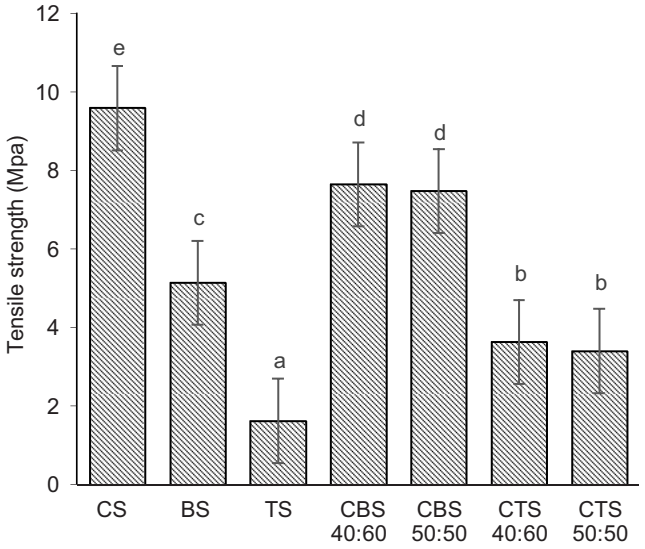

Fig. 1. Tensile strength (MPa) of edible films

in the edible film. According to Gabriel *et al.* (2021) higher tensile strength and better mechanical properties were found for the film prepared from starch with low amylopectin or high amylose content, resulting in high tensile strength (TS) in starch-based film. Corn starch (28.50%) contains higher amylose than banana starch (23.16%) and taro root starch (5.55%) (Gabriel *et al.,* 2021; Li *et al.*, 2020)**.**

Young's module (YM) of different types of starch-based edible film is shown in Fig. 2. It is a fundamental mechanical property that measures the stiffness of a material (Nandane *et al.,* 2015). Young's modulus provides insight into the film's rigidity and elasticity under tensile stress for starch-based edible films. It is defined as the ratio of tensile stress (force per unit area) to tensile strain (proportional deformation) in the linear elasticity region of the material. In the present study, corn starch (160.71 MPa) showed the highest values followed by CBS 50:50 (136.89 MPa), BS (130.46 MPa), and CBS 40:60 (121.72), CTS 50:50 (66.02 MPa), CTS 40:60 (38.68MPa) and TS (29.39 MPa). Prabhu *et al.* (2021) found a similar value for Young's module of banana starch-based edible film (145 MPa). In starch-based edible films, Young's modulus is influenced by several factors, including the type of starch used, the presence of plasticizers, and cross-linking agents (Nandane *et al.,*2015: Wang *et al.,* 2022).

Fig. 3 represents the elongation at break (EB) of different types of starch-based edible film. Elongation at break is significant for starch-based edible films used in food packaging and coating applications, where flexibility and durability are required to

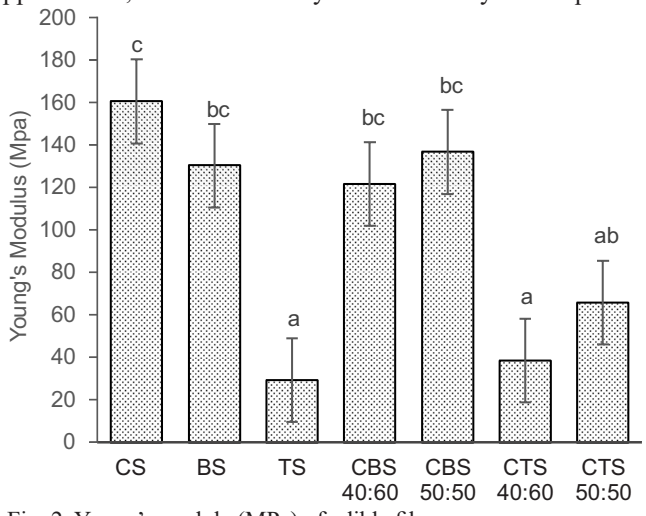

Fig. 2. Young's module (MPa) of edible films

protect food products and maintain integrity during handling and storage. Films with higher elongation at break can better withstand mechanical stresses, such as stretching or bending, without tearing or breaking (Shanbhag *et al.,* 2023). In the present study, corn starch film showed the highest EB (44 mm), whereas the taro root starch-based edible film showed the least EB (8.48 mm). Highest values followed by CBS 40:60 film and CBS 50:50 film showed 26.32 mm and 24.61 mm, respectively. Shanbhag *et al.* (2023) reported edible film prepared from arrowroot powder, corn starch, vinegar, and glycerol showed similar elongation at break (46 mm).

Table 5 presents the results of the colour analysis conducted on various types of starch-based edible film. A significant (P<0.01) differences was observed across all colour values, confirming

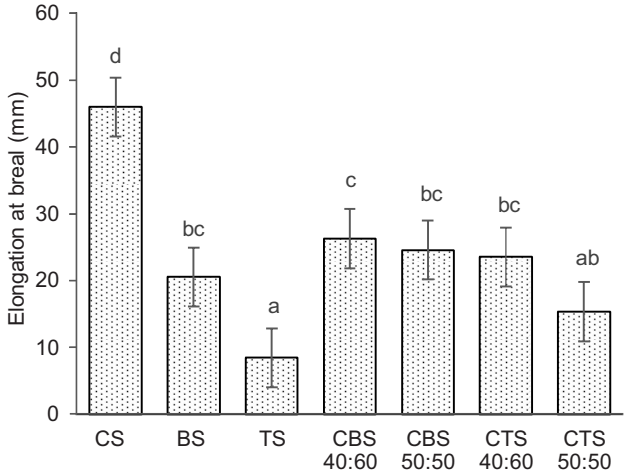

Fig. 3. Elongation at break (mm) of edible films

Table 5. Colour analysis of starch-based Edible film

Edible films	L*	a*	b*
CS	87.243^{f} ±1.000	4.893^{b} ±0.023	-12.240^{a} ±0.096
BS	76.610^{b} ±0.910	3.410^{a} ±0.087	4.423^{f} ±0.279
TS	57.100^{a} ±0.838	25.223^{d} ±1.425	11.413^{g} ±1.409
CBS 40:60	77.336^{c} ±0.344	3.826^{a} ±0.015	-3.716^{b} ±0.025
CBS 50:50	82.326^{e} ±0.127	3.666^{a} ±0.072	1.256^{d} ±0.426
CTS 40:60	79.060^{d} ±0.600	5.563^{b} ±0.3121	-2.360^{c} ±0.722
CTS 50:50	73.943^{b} ±0.128	7.503^{c} ±0.061	2.876^{e} ±0.167
F - Value	619.992**	602.229**	409.381**

Values are mean ±S.D. of three observations, **indicates significant difference at $P<0.01$. Different alphabetical superscripts indicate significant difference within a column

the film variations. The 'L*'value of developed film ranged from 57.10 to 87.24, indicating variation in lightness levels. CS, CBS 40:60, and CBS 50:50 films are comparatively lighter in colour than other films. The 'a*' and 'b*' value ranged from 3.41 to 25.22 and -2.36 to 11.41, respectively. CBS 50:50 and CTS 40:60 show moderate lightness and values of 'a*' near zero, indicating more balanced color spectrums. These findings suggest that the color properties of the edible film can be influenced by the type of starch used and its combinations as well as the processing methods employed during film formation (Thakur *et al.,* 2019).

The Fourier transform infrared (FTIR) spectrum of starch-based edible films is depicted in Fig. 4. The FTIR spectrum is mainly fragmented in two regions, namely between 900 cm^{-1} to 1700 cm^{-1} and 2800 cm^{-1} to 3500 cm^{-1}. In all the developed films, the signal at 3270 cm^{-1} to 3290 cm^{-1} is indicative of O-H stretching vibrations, which are typically associated with hydroxyl groups, such as those found in alcohols and carboxylic acids at the end of the polymer chain of starch and plasticizer. The signal at 2925 cm^{-1} to 2930 cm^{-1} corresponds to C-H stretching vibrations, indicative of the alkane group in aliphatic hydrocarbons. This signal is often seen in the spectra of compounds containing CH_2 or CH_3 groups. A signal at 1635cm^{-1} to 1645 cm^{-1} indicates O-H bending of the absorbed water. Moreover, in all starch-based films, a signal between 1149 cm^{-1} to 1151 cm^{-1} was assigned to C-O stretching vibration, which is indicative of the form of glycosidic linkages between glucose units as well as present in

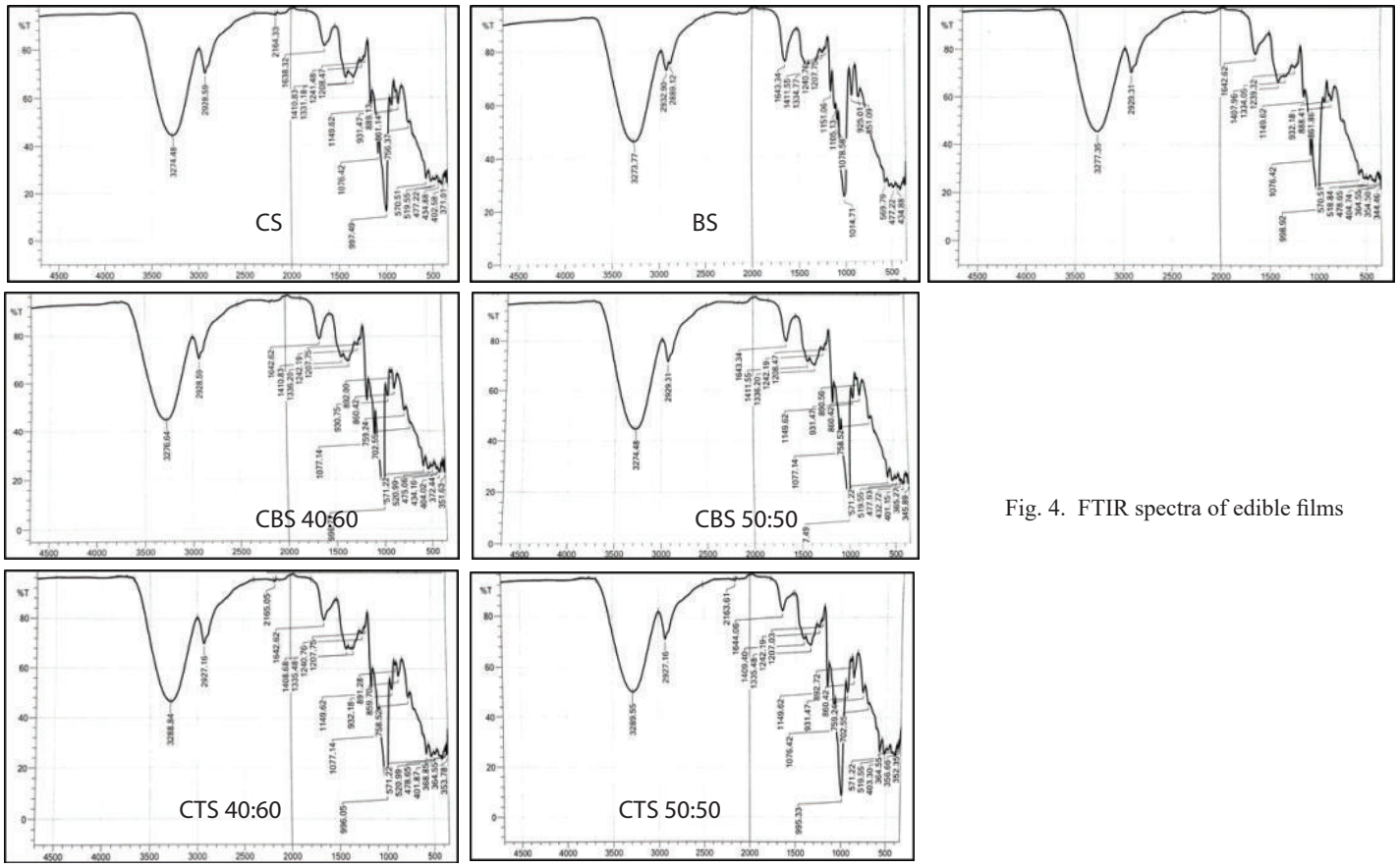

Fig. 4. FTIR spectra of edible films

sorbitol molecules. A strong signal ranging between 996 cm^{-1} to 1016 cm^{-1} for edible films indicative of C-H bending depicts sugar molecules in starch. Overall, the FTIR spectra of all the developed films confirm the presence of starch and sorbitol. Pinzon *et al.* (2018) reported that the broad band at 3320 cm^{-1} was attributed to the vibrational stretches of the starch O—H groups. Salleh *et al.* (2009) also reported that a sharp band at 2926.3 cm^{-1} is characteristic of C-H stretches. The bands at 1658.7 and 1459 cm^{-1} are assigned to the O-H bending of water and CH_2, respectively.

Overall, the properties of the starch-based films can be influenced by many factors, including types of starches, temperature and time during film formation, plasticizers, co-biopolymers, and storage conditions (Thakur *et al.,* 2019).

The study concludes that the CBS 50:50 showed the most suitable characteristics for edible films among all the blends studied. It established better transparency, mechanical characteristics, and performance than the other polymers under examination and, thus, may be further explored for biodegradable and edible packaging applications. The findings indicate that the incorporation of raw banana starch with corn starch improves the mechanical characteristics of the films and its prospects for usage in food packaging.

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