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Evaluation of the Effects of Edible Coatings of *Ocimum sanctum* and *Aloe vera* on Jaggery Shelf Life

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: In western Uttar Pradesh, jaggery is a widespread cottage enterprise based on agriculture, and farmers are forced to sell their product at a lesser price when it is still fresh. Therefore, it was thought to be desirable to create better storage techniques in order to extend its shelf life. *Aloe vera,* and *Ocimum sanctum*, often known as "Tulsi," are frequently utilised as antimicrobial food additives because they offer a host of other health advantages in addition to their well-known antibacterial qualities. Because the edible coatings made of these herbs provide a semi-permeable barrier to gases and water vapours, they may prolong the shelf life of jaggery by preventing degradation.
Objective: The goal of the current study was to assess the ability of edible coatings of common Indian herbs, such as tulsi and *Aloe vera,* to extend the shelf life of jaggery while maintaining attributes that are equal to those of fresh jaggery, in accordance with the guidelines set forth by the Food Safety and Standards Authority of India (FSSAI).

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Methodology: The physicochemical characteristics, antioxidant activity, total viable count, and antibacterial activity of tulsi-Aloe vera, coated (TAC), Ocimum sanctum, and Aloe vera, (AC) jaggery were assessed and compared with non-coated control. The physicochemical properties were ascertained using standard methodology for measurement of reducing sugars, proteins, phenols, saponins, tannin, alkaloids, and flavonoids. The antimicrobial activity was ascertained by means of the agar double diffusion method. According to established protocol, antioxidant activity was assessed using the DPPH radical scavenging assay and the reducing power assay.
Results: According to the research, there is no discernible microbiological deterioration and the edible coatings containing tulsi and *Aloe vera,* extend the shelf life of jaggery during storage. When compared to uncoated jaggery, coatings were efficient at preventing the growth of both Gramme positive and Gramme negative microorganisms. Over the course of six months, the herb-infused coatings also retained their phenolic, flavonoid, and tannin contents, which improved their anti-oxidant efficacy when compared to the untreated control group.

Keywords: Jaggery; edible coating; tulsi; Aloe vera; anti-oxidant activity; antimicrobial activity; bacteria; sugar industry.

1. INTRODUCTION

The second-biggest agro-based sector in India, the sugar industry has a major impact on the socioeconomic advancement of the rural populace. In addition to supporting 50 million farmers and their families, the sugarcane sector employs 0.5 million skilled and semi-skilled people. India currently produces 27.7 million metric tonnes of sugar and 6.6 million metric tonnes of jaggery, according to Quadri et al. [1]. For decades, jaggery has been used in many traditional foods as a natural sweetener, flavour enhancer, and immune system booster [2,3]. It is widely used in many Asian countries as well as in Africa, Latin America, the Caribbean, India, Pakistan, and Sri Lanka. Many names are used to refer to jaggery in Asia, such as "Gur: India, Desi: Pakistan, Naam Taan Oi: Thailand, and Hakura: Sri Lanka" [4]. The numerous culinary and therapeutic applications of sugar cane jaggery are described in ancient literature. Many authors have assessed the nutraceutical profile of jaggery, which is regarded as one of the world's healthiest and most nutritious sugars [5-7]. Jaggery is cytoprotective, antibacterial, antioxidant, and anticancer properties [8-11]. Additionally, jaggery has a high dietary fibre content that promotes peristaltic movements in the gut, which has anti-inflammatory effects on the gut [12].

The shelf life that the product keeps is largely dependent on its chemical and physical composition as well as the conditions in which it is stored. According to FSSAI, the temperature and humidity levels in the atmosphere have a significant impact on sugarcane jaggery's shelf life, which begins to deteriorate after four months of room temperature storage [13]. Due to its hygroscopic nature, jaggery ages most quickly during the rainy season. The outer layers of jaggery take up moisture from the air when the humidity is high. The settings are set up perfectly for the growth of different bacteria and fungi by this moisture absorption, which happens before other alterations happen. This eventually results in the creation of organic acids, alcohols, and complicated breakdown products. The process of inversion increases the amount of invert sugar present, which further enhances moisture absorption, creating a cycle that perpetuates deterioration [14]. There are many complexities associated with storing different food products, particularly jaggery, and there isn't a single, effective way to store jaggery that works for all of India.

The storage techniques vary throughout tracts based on local resources, customs, and climate. Some research have demonstrated the methods used thus far for the storage of different food products, such as jaggery with different edible coatings, as well as the use of multilayered or herbal-based edible coatings to ensure more accurate control of coating qualities and usefulness. Coating jaggery has been found in several studies to have positive effects during long-term storage [8,14–16]. Herbs can be used alone or in combination with other edible coatings to create edible herbal coatings. *Aloe vera* gel, neem, lemon grass, rosemary, tulsi, and tulsi are frequently utilised herbs in these coatings because they are antimicrobial and rich in vitamins, antioxidants, and vital minerals [17].

Ocimum sanctum, or tulsi, has potent antiviral, antifungal, and antibacterial properties that protect people from a variety of diseases while enhancing natural immunity and halting the spread of disease [18]. Tulsi also has hepato-protective, cardio-protective, reno-protective, analgesic, antipyretic, anti-oxidant, anti-inflammatory, and anti-diarrheal properties [19].

Aloe vera has been identified as having a multitude of biological properties, including the ability to combat fungal infections [20], bacteria, viruses, and antioxidants [21], wound healing [22], and skin diseases [23]. Both Tulsi and *Aloe vera* gel have gained widespread use in coating food due to its antimicrobial characteristics and its ability to reduce moisture and moisture loss [24].

Therefore, the goal of this study is to assess the physico-chemical qualities, microbiological traits, antioxidant activity, and antibacterial activity of the Tulsi and *Aloe vera* coating on jaggery that is based on carboxy methyl cellulose (CMC).

2. MATERIALS AND METHODS

2.1 Sample Collection and Materials

We acquired fresh jaggery samples (produced from the sugarcane variety 'Co 0238') from a nearby small-scale Muzaffarnagar, India, jaggery producing plant. The tulsi liquid extract (Ocimum sanctum) and *Aloe vera* gel (BRM chemicals, India) were provided by the neighbourhood pharmacy. Analytical-grade glycerol, food-grade CMC (99.9%) with an average molecular weight of 41,000 g.mol-1, and other reagents were supplied by Himedia Laboratories, Mumbai, India. The jaggery was analysed twice in 2023: once in April and again in September, after six months of storage. This particular study period was chosen because, in northern India, the monsoon season runs from June to August, and during that time jaggery tends to deteriorate more regularly.

2.2 Edible Coating Formulation and Sample Storage

After dissolving the 1.5 g CMC in 100 mL of distilled water, the mixture was agitated at a regulated temperature of 75°C until it turned transparent. The plasticizer added was 5% glycerol. Following a 50°C cooling period, 2% w/v herbal extracts (*Aloe vera* and tulsi extracts) were added while continuously stirring [14]. Three different kinds of coating solutions were made: tulsi plus *Aloe vera* (equal concentration) coated (TAC), tulsi coated (OC), and *Aloe vera* coated (AC). After dipping the 100 g cubes of jaggery into the prepared coating solutions for 120 seconds at room temperature, they were allowed to dry for another 60 seconds. For additional analysis, non-coated (NC) and coated samples (OC, AC, and TAC) were kept for six months in aluminium pouches (20 microns) [25].

2.3 Physico-chemical Characterization

Using Guerra and Mujica's [26] approach for physico-chemical characterisation (pH, colour, turbidity, filterability, insoluble particles, and water activity), additional analysis was carried out on the coated and non-coated stored jaggery samples. Samples were dissolved in sterile water, and a digital pH metre (Labman, India) was used to record the pH. The colour of the 5% w/v solution of jaggery samples was determined by measuring the optical density (OD) at 540 nm using a visible spectrophotometer (Labman, India). The water activity was ascertained by placing the sample in a water activity metre (Labtron, India) and monitoring the equilibrium relative humidity. In order to ascertain the turbidity of the 5% w/v jaggery sample solution, transmittance at 740 nm was measured. After three minutes of filtering via filter paper, the filtered volumes of 100 ml of sucrose (28 0Brix) solution and 5% w/v jaggery sample solution were divided to estimate the percentage of filterability (%). To determine the amount of insoluble particles, the residue that was left on filter paper after filtering 1g of the jaggery sample solution was dried and weighed.

The moisture, protein, ash, reducing sugars, and sucrose contents of jaggery were measured using the Official AOAC procedures [27]. After drying 1g of jaggery sample for 24 hours in a hot air oven, the moisture content (%) was estimated by expressing the weight ratio. The jaggery sample solution was diluted with a known volume of Fehling's solution to determine the percentage decrease of sugars. The proportion of sucrose (%) was estimated using similar titration techniques, but the sample solution was first inverted with acid and then neutralised with alkali. The ash content of the sample was determined by burning 10g of jaggery in a muffle furnace and comparing the weight with air-dried jaggery sample. A mixture of 100 µL sample solution and 5 mL Bradford solution was

incubated for 5 minutes to assess the quantity of protein. The absorbance at 595 nm was recorded and plotted against the standard curve of bovine serum albumin.

2.4 Phyto-chemical Characterization

Total flavonoid, tannin, saponin, total alkaloid, and total phenol contents of jaggery were ascertained by using the aluminium chloride method [28] and Folin-Ciocalteu's method [29], respectively. For every assay, a 5% w/v solution of the jaggery samples was prepared.

2.4.1 Determination of total phenol

Two millilitres of the Folin-Ciocalteu reagent and two millilitres of a 10% sodium bicarbonate solution were mixed with 500 microliters of the sample. The combination was then allowed to incubate at room temperature for one hour in order to calculate the concentration of total phenol. The absorbance was measured at 765 nm. Gallic acid was used as the reference, and the total phenol content was expressed as mg of gallic acid equivalent (GAE)/ml of sample.

2.4.2 Determination of total flavonoids

After incubating for 30 minutes at room temperature, the absorbance at 415 nm was measured in the reaction mixture for total flavonoids, which was created by mixing 5 millilitres of 10% aluminium chloride solution with 5 millilitres of sample solution. Total flavonoid content is given as mg catechin per gramme of sample (mg/ml), with catechin serving as the reference.

2.4.3 Determination of total alkaloids

After combining 100 µl of the sample with 40 millilitres of 10% acetic acid in ethanol, the reaction mix for total alkaloids was created and left to rest for four hours at room temperature. The mixture was then progressively supplemented with ammonium hydroxide, and the residue was allowed to settle for an entire hour. The residue was then weighed, dried, and filtered. Weight of alkaloids (mg)/ml of sample is the formula used to calculate alkaloids.

2.4.4 Determination of tannin content

A 35% sodium carbonate solution, 0.5 ml of the Folin-Ciocalteu reagent, 7.5 ml of distilled water, and 1 ml of the sample are combined. After an hour, absorbance was measured at 760 nm. Tannic acid equivalent (mg)/ml of sample is the unit of measurement for tannin content.

2.4.5 Determining the saponin content

20 millilitres of each sample, containing 20 percent ethanol, were divided into 1 millilitre each, and they were heated in a hot water bath for 4 hours while being constantly stirred, to a temperature of around 55° C. After the mixture was filtered, it was boiled in boiling water to a temperature of around 90˚ C and then reduced to 40 ml. Following reduction, 1 ml of 5% aqueous sodium chloride was used twice to wash the extract before 2 ml of Diethyl ether and 6 ml of n-butanol were added. After that, the mixture was dried, heated, and weighed. In terms of weight of saponins (mg)/ml of sample, saponins are expressed.

2.5 Anti-oxidant Activity

We evaluated the jaggery's ability to scavenge DPPH radicals by applying the Yamaguchi et al. [30] approach. A 1 millilitre sample solution was combined with different amounts of standard BHT. After adding 3 ml of DPPH to the mixture, it was left in the dark for 30 minutes. The absorbance was measured at 517 nm, and the DPPH radical scavenging was represented as I%= (A control-A sample)/A control * 100. Furthermore, the computation of the 50% DPPH effective concentration (EC50) was done. Additionally, the previously described approach [31] was used to determine the reducing power of jaggery. Different quantities of the jaggery sample solution were mixed with the standard antioxidant Trolox, and then an equivalent volume of 0.2M phosphate buffer and 1% potassium ferricyanide were added and incubated for 30 minutes. 10% trichloroacetic acid was added, and the mixture was centrifuged once more at 3000 rpm. After collecting the supernatant, sterile water and a 1% ferric chloride solution were mixed together and absorbance reading at 700 nm was taken.

2.6 Statistical and Microbiological Analysis

The dilution plate method was used to determine how many live bacteria, yeast, and mould were present. While yeast and mould were counted using potato dextrose agar, bacteria were estimated using plate count agar. The agar well diffusion assay was used to measure the antibacterial activity [32]. Data were statistically

analysed using the Analysis of Variance (ANOVA) approach to determine their significance.

3. RESULTS AND DISCUSSION

3.1 Physico-chemical Characterization of Coated Jaggery

Table 1 shows the physical property results of coated and uncoated jaggery in relation to the FSSAI parameters. For both coated and uncoated jaggery, the pH range was 5.7-9. One possible explanation for jaggery's low pH is that not enough lime was added during the juice's clarification process.

The primary factor influencing consumer preference and commercial viability in jaggery is its hue, which is shaped by dark compounds generated throughout the refining process. Browning of jaggery can be caused by the Maillard process, phenolic chemical oxidation, alkaline breakdown of sucrose, or caramelization of sugars [33]. When jaggery is coated, its absorbance at 540 nm is higher (TAC>OC>AC) than when jaggery is not coated (NC). NC is golden brown, but all coated jaggery samples turned out to be dark brown. Water content determines how long a food product lasts; increased moisture content shortens shelf life and makes food more prone to microbial deterioration. According to FSSAI, cane jaggery moisture ranges from 4.5% to 7% [13]. When compared to NC, the moisture content of TAC exhibited a significant drop (0.9%), but the moisture content of OC and AC showed a minor decrease. This shows that covering the jaggery samples helped to reduce the moisture level to some extent. Water status in the food chain is determined by water activity (aw), which regulates microbial development [34]. The data obtained for the non-coated and coated samples showed a substantial ($p \leq 0.01$) difference in water activity after the coating of the jaggery samples.According to the results, jaggery stored with TAC and AC may have a longer shelf life and better quality. However, it has been discovered that aw in the range of 0.60–0.68 is optimal for the growth of xerophilic and osmophilic bacteria, such as Aspergillus and Saccharomyces, which encourages their growth on jaggery and results in rotting [35].

When compared to NC jaggery, the turbidity of all coated jaggery gradually increased (TAC<AC<OC). There was a noticeable 7.5-8.8% rise in turbidity between NC and AC and OC, respectively. There is a little improvement in filterability between NC and OC jaggery. Results, however, indicated that the ash concentration varied by 0.02 percent across all coated jaggery, despite the initial notable increases in filterability in AC and TAC of 7 and 16 percent.

Table 1 displays the results of chemical characteristics. The coated jaggery exhibited a very slight rise in sucrose and lowering sugar content (TAC>OC>AC). The protein level of OC and AC jaggery did not differ significantly from that of NC jaggery; however, TAC revealed a 0.3 mg/g increase in protein content. All coated jaggery showed an increase in total phenol, tannin, and flavonoid levels (TAC>AC>OC). From NC jaggery, the concentrations of phenol (12.0-, 12.5–17%); tannin (13.5–14.0–16.0%) and flavonoids (9–6.5–7.0%) increased in OC, AC, and TAC, respectively.

Flavonoids are the most common type of dietary polyphenols with antioxidant potential due to their unique functional groups. The levels of flavonoids and total phenols are consistent with the previously published research [25,35,36]. Our findings thus showed that jaggery with an edible coating may be employed as an antioxidant source. Total alkaloid concentration and saponin content values showed only a slight increase in coated samples as compared to non-coated samples, with no significant differences seen between samples.

3.2 Antioxidant Activity

Two in vitro tests, the DPPH radical scavenging ability and the reducing power assay, were used to evaluate the antioxidant activity of coated jaggery.When stable free radical DPPH is in its radical state, it absorbs at 517 nm; when an electron or hydrogen atom is absorbed from an antioxidant, DPPH-H, its non-radical form, is generated, and absorption decreases [37]. The degree of DPPH decolorization can be used to stoichiometrically quantify the antioxidant potential of test samples. The EC50 values for TAC, OC, and AC, which indicate their scavenging capacities, are shown in Table 2. Concentration determined coated jaggery's capacity to scavenge free radicals. The EC50 concentration of coated jaggery was lower than that of uncoated jaggery. The EC50s for OC, AC, and TAC were 3.08, 3.076, and 3.045 mg/mL, respectively, in contrast to 3.78 for NC. At 0.0075 mg/mL, the standard BHT EC50 was found. The EC50 concentration of coated and

uncoated jaggery was found to be greater (450 times) than that of regular BHT. The total phenolics of OC, AC, and TAC jaggery exhibited a positive association (r = 0.94, 0.88, and 0.89), according to the results of the DPPH radical assay. Strong relationships between total phenolics and DPPH radical scavenging suggested that the polyphenols in the coated jaggery serve as the primary antioxidants.

Additionally, the assay for reducing capacity quantifies a compound's capacity to contribute electrons and lessen the oxidised intermediates produced during the peroxidation process. The decrease of the Fe+3-ferricyanide complex, which is measured at 700 nm, provides the basis for the assay. Increased reductive capacity is indicated by increased absorbance [38]. Coated jaggery is tested for lowering power capacity since it is a key predictor of a compound's antioxidant activity [39]. Coated jaggery showed an increased in-vitro ferric reduction potential in Table 2. When compared to uncoated jaggery, coated jaggery had a higher absorbance at 700 nm. At 50 lg/mL, the standard, trolox, has an absorbance of 1.37. The reducing potential of OC, AC, and TAC increased by 23.00, 25.00, and 24.55%, respectively, in comparison to non-coated jaggery.

The acceptability, safety, and capacity of the food chain to stop and reverse oxidative damage are all greatly influenced by natural antioxidants. They serve as a potent preservative and keep the food stable against oxidation by inhibiting microbial growth. Preserving biological function and protecting against ailments such as cirrhosis, diabetes, heart disease, gastropathy, chronic renal disease, and malignancies are just a few of the numerous health advantages of antioxidants [40]. Furthermore, plants' antioxidant activity is frequently linked to polyphenols that have the ability to donate hydrogen, which prevents oxidation caused by free radicals [31]. Sugarcane juice's phenolic components provided a variety of biological actions in addition to showing antioxidant potential [41]. Previous research [25,36] indicated that the antioxidant components isolated from jaggery had greater antioxidant capacity than BHT. The current study found that the edible coatings of *Aloe vera* and tulsi increased the total phenolic content and anti-oxidative potential of jaggery in a synergistic manner. Because of their combined nutritional and therapeutic effects, these foods are classified as functional foods.

Table 1. Physicochemical properties of non-coated and coated jiggery

Property	FSSAI standard parameters	Non-coated (NC)	Tulsi coated (OC)	Aloe vera coated (AC)	Tulsi + Aloe vera coated (TAC)
pH	5.5-6.5	5.7	5.8	5.8	5.9
Color (OD=450nm)	Golden brown to dark brown	1.2	1.2	1.4	1.3
Turbidity (%T at 720 nm)	-	19.5	20.5	21.4	23.6
Filter-ability (%)	-	64.5	78.5*	79.5*	83.3*
Insoluble solids (%)	1-1.5	1.45	1.47	1.52*	1.67*
Water activity (aw %)	0.6 - 0.7	0.68	0.68*	0.63	0.62
Moisture (%)	4 - 7	6.34*	5.85*	5.8	4.7*
Ash (%)	0.3-0.4	0.3	0.4	0.4	0.4
Sucrose (%)	70-75	73	73.66	73.75	74.00*
Reducing Sugar (%)	15-20	17.32	17.32	17.43	17.72
Protein (mg BSA/ml)	-	1.21	1.22	1.55	1.85*
Phenols (mg GAE/ml)	-	3.66	4.18	4.85*	5.13
Flavanoids (mg Catechin/ml)	-	0.65	0.75	0.85*	0.83
Saponin (mg/ml)	-	30.3	34.1	35.4	35.1
Tannin (mg Tannic acid/ml)	-	50.69	51.28	53.15	54.05
Alkaloids (mg/ml)	-	2.14	2.20	1.88	2.30

*Values expressed as mean (n=3). * depicting difference among means (P <0.05). NC= non-coated jaggery; OC= tulsi coated jaggery; AC= Aloe vera coated jaggery; TAC= tulsi plus Aloe vera coated jaggery*

Table 2. DPPH radical scavenging activity (BHT standard) and reducing power (Trolox standard) of coated and non-coated jiggery

EC50 (mg/ml)	**BHT**	**NC**	**TC**	**AC**	**TAC**
	0.0075	3.78	3.08	3.076*	3.045**
Absorbance (700 nm)	**Trolox**	**NC**	**OC**	**AC**	**TAC**
	1.37	0.46	0.49	0.55**	0.60**

*(*P <0.05; **P<0.01, ***P<0.001)*

Table 3. Inhibition zone (mm) of jaggery against selective bacterial strains

Sample	**Zone of Inhibition (mm)**			
	Gram +ve		**Gram -ve**	
	Bacillus subtilis	***Staphylococcus aureus***	***Escherichia coli***	***Pseudomonas aeruginosa***
Non-coated (NC)	-	-	7.5	8.5
Tulsi coated (OC)	12.25	7.25	12.50	21.50
Aloe vera coated (AC)	14.5	8.75	11.50	24.50
Tulsi + Aloe vera coated (TAC)	15.0	8.25	10.50	27.50

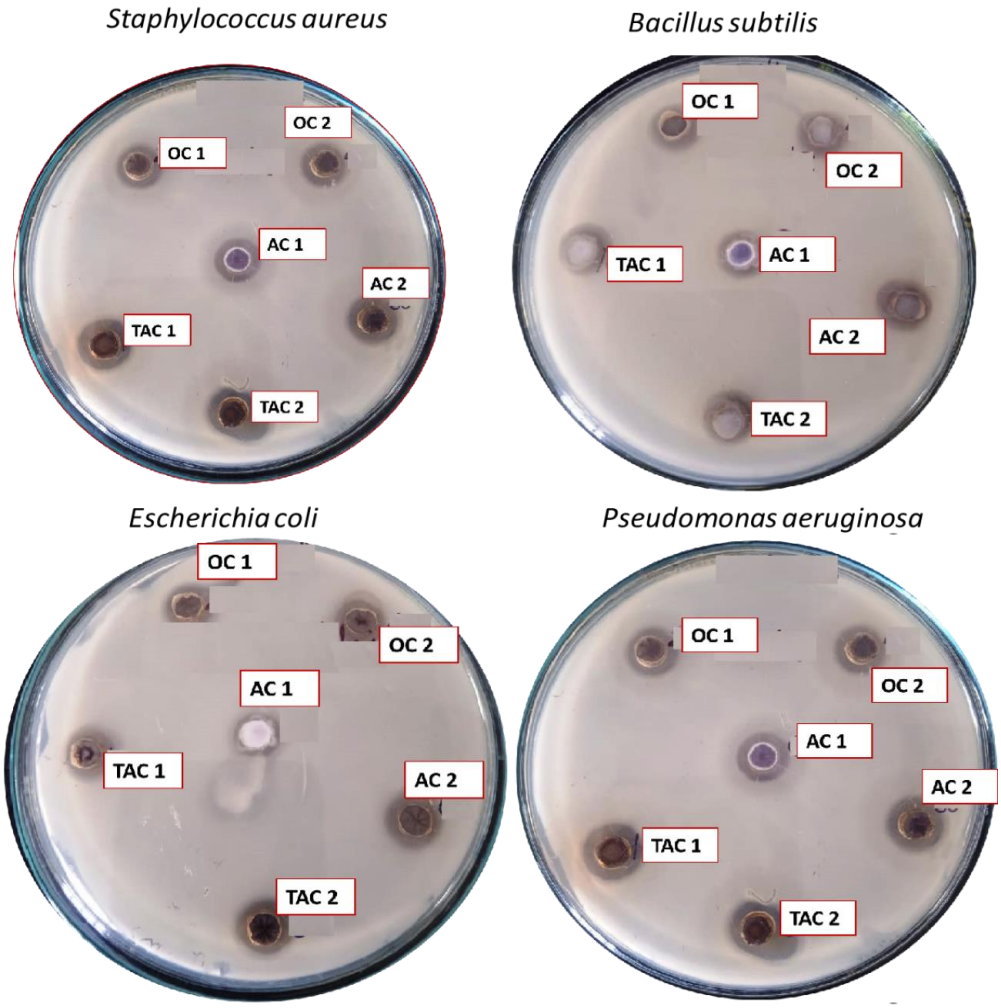

Fig. 1. Inhibition zone of OC, AC and TAC (in 2 replicates each) against *Staphylococcus aureus* and *Bacillus subtilis* (Gram's positive) and *Escherichia coli* and *Psuedomonas aeruginosa* (Gram's negative)

3.3 Microbial Characterization

After six months of storage, the total viable count (TVC) in cfu/g (Colony Forming Units per gramme) for jaggery in NC, TAC, OC, and AC was 4x103, 2.0x103, 1.5 x103, and 3.8x103, respectively. The application of edible coating to jaggery samples had a substantial ($p \leq 0.01$) impact on microbial counts, as evidenced by the notable variation in TVC measured between the coated and untreated samples. This illustrates how applying an edible coating on the jaggery samples may help to partially stop the microbial deterioration of the fruit. There have been earlier reports of similar findings [14,16,25,42]. Previous research [43] has revealed the bacterial microflora of stored jaggery, which was categorised into the genera *Alteromonas, Micrococcus, Xanthomonas, Acinetobacter, Enterococcus, Corynebacterium, and Alcaligenes*. When ingested as part of a diet, jaggery may harbour harmful microorganisms for human health. Therefore, during jaggery storage, our antimicrobial herbal coatings may stop these bacteria from growing.

3.4 Antibacterial Activity

The diameter of the inhibitory zone was measured to assess the bactericidal activity of both coated and uncoated jaggery, as illustrated in Fig. 1 and Table 3. When compared to NC jaggery, only TAC and AC coated jaggery effectively inhibited the development of gram-positive bacteria. When compared to NC jaggery, TAC, AC, and OC jaggery significantly suppressed the growth of gram-negative bacteria. Gram-positive bacteria were shown to be more sensitive to the coated jaggery samples than gram-negative bacteria, based on the diameter of the inhibitory zone. The antibacterial action of jaggery may be attributed to its antioxidant and polyphenolic qualities [44]. Tulsi is rich in vitamin C, antioxidants, antiviral, and antibacterial properties. Owing to its antimicrobial qualities, tulsi is utilised as a natural hand sanitizer [45]. Molluscides that were also extracted from the leaf extract were molludistin, ursolic acid, luteolin, luteolin-7-O glucuronide, orientin, and luteolin. It also includes cholesterol, stigmasterol, bornyl acetate, and camphene, among other monoterpenes and sesquiterpenes [46]. Tulsi is a powerful herb with numerous therapeutic uses and well-being advantages. This simple-to-grow plant boosts immunity and wards off harmful viruses and bacteria.

Aloe vera gel contains a few significant polysaccharides that have been shown to have antibacterial action against both Gram (+Ve) and Gram (-Ve) microorganisms. *Aloe vera* contains compounds called saponins and anthraquinones that are utilized to fight bacterial infections [20]. *Aloe vera* gel works against a variety of bacterial species, including *Streptoccocus faecalis*, *Shigella flexneri*, and *Streptoccocus pyogenes*. Acemannan prevents *Pseudomonas aeruginosa* from attaching to human lung epithelial cells, and it is utilized as a disinfecting agent against the pathogen [21]. Flavonoids, alkaloids, terpenoids, and anthraquinone found in *Aloe vera* latex have been shown to be strongly connected with antibacterial action [47]. Evaluated results also decited that the antibacterial activity of coated jaggery is directly correlated with its flavonoid and phenolic component concentrations, and *vice versa*.

The advantage of edible coatings is their ability to incorporate beneficial components including flavors, antioxidants, and antimicrobials. Food value, stability, functionality, and safety can all be improved with this ability. When tulsi and Aloe vera were applied to jaggery samples, the results showed a considerable inhibition of microbial growth and an elevated capacity for antioxidants compared to uncoated jaggery [25]. Applying an edible coating based on proteins to jaggery, vacuum-packaging it, and keeping it in a controlled environment with regulated temperature and relative humidity can help prevent moisture absorption and microbiological attack [14]. When compared to uncoated jaggery, researchers came to the conclusion that edible coating consisting of whey protein concentrate may help protect the quality and lengthen the shelf life of jaggery since, the overall effects of edible coating during storage were positive [16]. Coating a jaggery sample could help it preserve the ideal moisture content to a certain level [15]. It can also improve the quality of the jaggery by applying an edible coating made of whey protein concentrate and carboxymethyl cellulose.

4. CONCLUSION

Edible coatings have been used by the food industry as a food storage solution for many years. These coatings are made of a variety of components, including as proteins, waxes, and hydrocolloids. It has been demonstrated that edible coatings increase the shelf life of fresh product, reduce moisture loss, slow down the ripening process, and successfully stop the

growth of microorganisms, especially in food. Herbal edible coatings are a recent development in edible coatings that have shown improved results and health advantages. Edible coatings made of herbs preserve nutrients in food while also having therapeutic benefits, which is an added benefit. The current study's findings suggest that tulsi-*Aloe vera* and *Aloe vera* coated jaggery may provide a longer shelf life and more promising quality during storage because they partially inhibit the microbial destruction of the fruit. Additionally, adding these herbal extracts to jaggery boosts its phenolic content and antioxidant capacity. Therefore, jaggery coated with tulsi and *Aloe vera* may be used in place of conventional jaggery and have added health benefits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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