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Application of sodium caseinate and *Aloe vera* gel coatings as novel technologies to improve the sensory and physicochemical quality indices of tilapia fish (*Oreochromis niloticus*) fillets during chilled storage

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ABSTRACT

In the current study, tilapia fish fillets were preserved by the application of natural coats (sodium caseinate and *Aloe vera* gel) to investigate their effects on the organoleptic and physiochemical attributes of fish fillets kept at 4°C for 7 days. The results revealed that the *A. vera* gel coat possessed lower pH and higher scavenging activity than caseinate. The application of both coats on fish fillets led to an improvement in all sensory scores when compared to the control, as its scores became unacceptable on the 5th day of chilling, whereas the coated groups remained acceptable until the 7th day of storage. Moreover, coating of fish fillets resulted in increased moisture and redness (a*) values and decreased fat, ash, TBARS, TVBN, cooking loss, shear force, lightness (L*), and yellowness (b*) values compared to the control group. When comparing the two applied coats, *A. vera* gel application was accompanied by an enhancement in all examined parameters compared with the sodium caseinate coat, although the protein of fish fillets was enhanced mainly by coating with sodium caseinate. Therefore, coating fish fillets with sodium caseinate or *A. vera* gel can easily be used by food processors as a novel technique to improve the quality and extend the shelf life of fish fillets.

Introduction

Over the past few decades, there has been a marked increase in consumer awareness of healthy foods, leading to a corresponding increase in the consumption of fish and fishery products. Fish are an important source of essential proteins, unsaturated fatty acids, and micronutrients, which are vital for a healthy diet. Tilapia (*Oreochromis niloticus*) is a freshwater fish that is widely cultivated in many governorates in Egypt and has the highest production rate among all other fish species (FAO, 2020). Egypt is the 3rd largest producer country of tilapia (954,154 t) after China and Indonesia (Soto-Rodriguez *et al*., 2023). Fast growth and exceptionally high feed conversion rate are the reasons behind its selectivity to be aqua-cultured, as well as its lower price and higher nutritional value making it one of the staple fish across the world.

Regardless of the nutritional value of fish, they have a high degree of perishability owing to their higher content of moisture, unsaturated fatty acids, free amino acids, and nitrogenous volatiles compared to other meats. Chilled fish are highly susceptible to spoilage shortly after capture. The spoilage of chilled fish is a multi-faceted process triggered by spontaneous chemical and enzymatic reactions, bacterial invasion, and leaching by melting ice into water (Jeon *et al*., 2002). Moreover, fish filleting acts as an additional factor in the acceleration of fish spoilage, particularly when performed under unsatisfactory conditions. Therefore, it is necessary to develop suitable preservation methods, such as freezing, salting, vacuum packaging, and the use of chemical preservatives, to ensure optimal quality and extend the shelf life of fish fillets. Although chemical preservatives are widely and easily used, both food processors and consumers have expressed a desire to reduce their use for food preservation to avoid their hazards. Consequently, the use of natural preservatives has emerged as a novel strategy for enhancing food safety.

Edible coatings are an efficient and eco-friendly method to preserve the quality and safety of foods. These coatings are easily applied and can be safely eaten with foods, providing several health benefits to consumers. Edible coatings can be formulated using a variety of materials, including lipids, proteins, polysaccharides, or their combinations. Casein is the most used material in the formulation of protein-based edible coatings. Casein coatings can form a transparent, odorless, and tasteless layer around food. This layer acts as a physical barrier against aroma and oxygen, protecting food from oxidative changes that could negatively affect its sensory attributes and decrease its shelf life (Qiu *et al*., 2020).

Generally, when edible coatings are applied to the food surface, they form primary active packaging because of their direct exposure to the food surface (Galus and Kadzińska, 2015). Currently, this concept is not considered a new technology, and many researchers aim to develop a novel edible active packaging using various compounds of herbal plants that can provide physical barriers and increase the added value of food.

Aloe vera is an herbal plant known as the plant of immortality. It has been known since the ancient Egyptians for its pharmaceutical and cosmetic purposes. *A. vera* gel exhibits potent antidiabetic, antiarthritis, anti-inflammatory, antiviral, antitumor, antifungal, antioxidant, and wound-healing properties (Maan *et al*., 2018). Moreover, it acts as an excellent source of biologically active ingredients including fibers, carbohydrates, vitamins, minerals, sugars, amino acids, flavonoids, and phenolic compounds.

Although edible coatings are widely used in the meat and fish industries, there is insufficient knowledge about the application of casein-based edible coatings in fish fillets. Moreover, the application of *A. vera* gel as a natural coating is restricted to the preservation of fruits & vegetables and has not been applied to meat and fish preservation. Therefore, the main goal of this study was to explore the effect of the application of sodium caseinate and *A. vera* gel coatings on the sensory and physicochemical quality indices of tilapia fish fillets during chilled storage at 4°C for seven days.

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Materials and methods

Raw materials

Fresh tilapia (*Oreochromis niloticus*) (450±50 g) was obtained from a local market in Giza, Egypt. The fish was freshly caught, placed in crushed ice, and transported to the Laboratory of the Faculty of Veterinary Medicine, Cairo University, Egypt within 30 min. A three-year-old *A. vera* plant was purchased from the Ministry of Agriculture in Egypt. Sodium caseinate, glycerol, and Tween-80 were bought from Avi-Chem Laboratories, India.

Preparation of fish fillets

Upon arrival at the laboratory, the fish were thoroughly washed several times with tap water to remove all adhering dirt and let fish dry for few minutes. Each fish was filleted manually by removing its head, skin, viscera, and spines. A total of 120 fish slices with a mean weight of 50 g were obtained and dried in a hot-air oven (Heraeus, D-63450 Hanau, Germany) using only forced airflow without heat to facilitate the application of the coat.

Preparation and application of the coat

The dried fish fillets were divided into three groups (n = 40 in each group): the first group was not coated and was marked as a control, and the second and third groups were coated with sodium caseinate and *A. vera* gel, respectively. To prepare the sodium caseinate coating, a 2.5% caseinate solution was prepared by dissolving 150 g of sodium caseinate in 6 liters of distilled water, followed by stirring for three hours at room temperature by using magnetic stirrer. After stirring, 1.5% glycerol and 0.1% Tween 80 were added to improve the physical properties of the coating (Moreira *et al*., 2011). The *A. vera* gel coating was prepared by the separation of leaves from the plant, sterilized with 0.1% sodium hypochlorite for 3 min, and then split with a sharp knife to obtain the inner viscous gel. A gel–water mixture was prepared at a ratio of 1:1 (v/v) and stirred until a clear solution was obtained. Glycerol and Tween 80 were added to the prepared *A. vera* gel coating solution at ratios of 1.5 and 0.1%, respectively.

Sodium caseinate and *A. vera* coats were applied separately by dipping the fish fillets in the coating solution for 2 min, dried by airflow in a hot-air oven without heat, and then dipped again in the coating solution for another 2 min, followed by drying in the same manner. All fish fillet groups were packaged and stored in a refrigerator at 4°C for seven days.

Investigation of coats

pH value

The pH values of caseinate and *A. vera* gel coating solutions were detected in which 20 mL of distilled water was added to a 5 ml coating solution and homogenized effectively until a completely homogenous solution was obtained. The pH value was obtained after calibration of the pH meter (Lovibond Senso Direct) equipped with a probe electrode (Senso Direct Type 330) using a buffer solution of pH 4 and 7. Three readings were taken for each coating solution, and the average was calculated.

Antioxidant scavenging activity {2, 2-Diphenyl-2-picrylhydrazyl (DPPH)}

To determine the antioxidant scavenging activity, 2.5 ml of the coating solution was mixed with 20 ml ethanol and allowed to stand for 20 min, after which the volume was made up to 25 ml. One and a half ml of the previous mixture was transferred to a 100 ml glass beaker and 1.5 ml freshly prepared DPPH reagent (0.06 mM) was added, mixed, and allowed to stand for 30 min in a dark place. A Blank was prepared by mixing 2.5 ml distilled water with 22.5 ml ethanol, after that 1.5 ml of the blank was transferred to a test tube and mixed well with 1.5 ml DPPH solution to prepare a control sample. The absorbance of coating solutions was read against the control sample and a blank at a wavelength of 517 nm and the scavenging activity was calculated according to the formula set by Mensor *et al*. (2001).

Investigation of coated fish fillets

Immediately after application of the coats on fish fillets (0-time), three samples from each coated treatment were taken for measurement of coat uptake. Sensory analysis and physicochemical parameters (proximate chemical composition, pH, TBARS, TVBN values, cooking loss, shear force, and instrumental color evaluation) were performed on the 1st, 3rd, 5th, and 7th days of chilling storage, where three replicates from each treatment were considered as a sample for evaluation of each parameter.

Coat uptake

Fish fillets were weighed before and after dipping in the coating solution, and the difference in fillet weight was calculated as the coat uptake.

Sensory evaluation

Twenty-one well-trained panelists (aged 25-40, 11 males and 10 females) from the Meat Hygiene Department, Faculty of Veterinary Medicine, Cairo University, were asked to score the sensory parameters of different treatments of raw and cooked coated fish fillets, separately after receiving plenty of training based on the instructions of AMSA (2015) to be familiar with such food. Raw fish fillet treatments were randomly selected and evaluated for appearance, color, odor, and overall acceptability. To estimate the sensory scores of cooked fish fillets, the fillets from each trial were wrapped individually with aluminum foil and cooked in a convection oven (Heraeus, D-63450 Hanau, Germany) set at 180°C until reaching a core temperature of 65°C. The cooked fillets were kept warm at 50°C when served to the panelists to give scores for their appearance, color, flavor, juiciness, tenderness, and overall acceptability. The scores for both raw and cooked fillets ranged from 0 to 8, where 0 was the lowest and 8 was the highest. Sensory analysis was conducted according to the human ethics established by ACFNP (2003).

Physicochemical analysis

Proximate chemical composition

Moisture, protein, fat, and ash contents (g/100g) of fish fillets from different treatments were determined for each replicate at different examination times, according to the method described by AOAC (2005).

pH, thiobarbituric acid reactive substances (TBARS), and total volatile base nitrogen (TVBN) values

To measure the pH value of the fillet samples, fish slurry was prepared by homogenizing 5 g of fillet sample with 20 ml distilled water and mixed well for 30 seconds. The pH value was measured using a digital pH meter (Lovibond Senso Direct) with a probe-type electrode (Senso Direct Type 330), where three readings for each sample were obtained, and the average was calculated. The procedures described by Torres-Arreola *et al*. (2007) were followed to determine the TBARS value that was expressed as mg malonaldehyde/kg of the sample, while the distillation method described by Malle and Tao (1987) was used to determine the TVBN value that was expressed in mg nitrogen/100 g of sample.

Cooking loss

To calculate cooking loss, the fish fillets were blotted with blotting paper and weighed accurately just before cooking. Fish fillets were cooked following the procedures performed for sensory analysis to reach an internal temperature of 65°C. After cooking, the fish fillets were cooled to room temperature, wiped with blotting paper, and weighed. Cooking loss as a percentage was calculated based on the difference in the weights of the fillets before and after cooking.

Shear force

Six core samples (11 mm diameter) parallel to the cooked fish fillets from each trial were cut using a hand-held coring device, and the method described by Ezquerra Brauer *et al*. (2003) was followed to measure the shear force for each core using a Warner–Bratzler shear force (WBSF) device attached to an Instron (Model 2519 105; Instron Corp., Canton, MA, USA).

Instrumental color evaluation

After the bloom time of the samples was over (around 30 min), a colorimeter (Konica Minolta, CR 410, Japan) was used to determine the instrumental color of the fish fillet samples in triplicate. The device probe was applied to a 5×5 cm sample cube for direct measurement of color indices. Color indices were obtained using a CIE standard illuminant D65 light source at a viewing angle of 10°.

Statistical analysis

The IBM SPSS version 23 T-test was used to compare the mean values of pH and DPPH between the different coating solutions at a statistical significance of ($P<0.05$). One-way ANOVA was applied to calculate the mean differences in coat uptake, sensory, and physicochemical values among the control group and fish fillets coated with caseinate and *A. vera* gel using Least Significant Differences (LSD) procedures at a significance level of ($P<0.05$). The comparison of coat uptake was performed immediately after coating application (0 time), while that of sensory and physicochemical parameters was done on the 1st, 3rd, 5th, and 7th days of refrigeration storage at 4°C either between the different treatments at specified examination time or within the same trial throughout the different examination time.

Results

pH and DPPH values of sodium caseinate and A. vera gel coating solutions and coat uptake of coated fish fillets

The pH values of the coating solutions revealed that the pH of *A. vera* gel was significantly lower than that of sodium caseinate (Table 1). The results also showed that the DPPH value of the *A. vera* coating solution was significantly higher than that of sodium caseinate. However, the coat uptake results of the fish fillets coated with *A. vera* gel had a significantly higher coat uptake percentage than the sodium caseinate-coated fillets.

Table 1. pH and DPPH values of sodium caseinate and *A. vera* gel coating solutions and coat uptake of coated fish fillets immediately after coatings application.

	pH	DPPH (%)	Coat uptake (%)
S. Caseinate	6.75±0.14^{a}	23.23±0.62^{b}	8.00±0.03^{b}
A. vera	4.51±0.03^{b}	73.88±1.24^{a}	12.36±0.12^{a}

Values represent the mean of three independent replicates ± standard error. $^{a\text{-}b}$ Values with different superscripts within the same column differ significantly at $P < 0.05$

Sensory attributes of coated fish fillets

The sensory panel scores of the examined parameters of raw and cooked fish fillets coated with sodium caseinate and *A. vera* gel coating were significantly higher than those of the control group throughout a week of chilled storage (Table 2). However, the caseinate-coated group showed intermediate scores between the control and *A. vera*-coated fillets for color, odor, and overall acceptability for raw fillets and tenderness for cooked fillets particularly on the 7th day of chilled storage. The results also revealed that chilled storage had negative impacts on all examined sensory parameters, which appeared mainly in the control group compared to both coated groups. The raw fillets of the control group showed an odor score below the unacceptable score (4.00) on the 7th day of chilled storage, whereas the color, flavor, juiciness, and overall acceptability scores of cooked fillets became unacceptable on the 5th day of storage. In contrast, the sensory panel scores of all examined parameters for raw and cooked fillets coated with sodium caseinate or *A. vera* gel were within acceptable limits until the end of the storage period.

Physicochemical analysis of coated fish fillets

Application of sodium caseinate and *A. vera* gel coats on fish fillets resulted in a significant increase in moisture content and a significant decrease in fat and ash contents particularly at 5th and 7th days of chilled storage when compared to the control group (Table 3). Chilled storage had a noticeable effect on the proximate analysis of fish fillets, where the moisture content was significantly decreased, while protein, fat, and ash content were significantly increased on the 7th day of storage compared to the 1st day of chilling. These changes were more pronounced in the control group, followed by the caseinate-coated fillet group, and finally, the *A. vera*-coated fillet group. However, coating fish fillets with sodium caseinate led to a significant increase in protein content on the 3rd, 5th, and 7th days of chilled storage in comparison to the *A. vera*-coated fillets and the control groups.

Conversely, chilling storage of fish fillets resulted in a significant elevation in pH, TBARS, and TVBN values with variable degrees between different fish fillet groups, where pronounced changes were observed in the control group and the least changes were observed in the *A. vera*-coated group (Table 4). The application of *A. vera* gel as a coating on fish fillets led to a significant decline in the pH value over 7 days during chilling, as compared to both the control and caseinate-treated groups. However, there were no significant differences in the pH values between the control and caseinate-coated fillet groups immediately after the coating application and during the storage period. TBARS and TVBN results showed that both coated fillet groups had lower values than the control group from 1st day to the end of the chilled storage period (Table 4). The results also showed that the *A. vera* gel coating possessed more potent antioxidant activities than the sodium caseinate coating, where the lowest TBARS and TVBN values were observed in the *A. vera*-coated fillets.

Coating of fish fillets with sodium caseinate and *A. vera* gel resulted in a significant reduction in cooking loss at all examination times compared to the control group (Table 4). Cooking loss was reduced by the rate of 44.23 and 78.13% by the application of sodium caseinate and *A. vera* gel coatings on fish fillets on the 1st day of chilling and reached 21.75 and 70.70% on the 7th day of chilling, respectively in comparison with the control. The results also showed that cooking loss was significantly increased by chilled storage in different fish fillet groups, with the control group showing the highest percentage and the *A. vera*-coated group showing the lowest percentage.

Instrumental color analysis revealed that the three trials were remarkably different in lightness (L*), redness (a*), and yellowness (b*) values among different examination days, where the L* and b* values in the control group were the highest, followed by the caseinate-treated group, and then the *A. vera*-coated fish fillet group (Table 5). However, a* value was

Table 2. Sensory attributes of sodium caseinate and *A. vera* gel-coated fish fillets during storage at 4° C for seven days.

	Raw fish fillet							
	Appearance				Color			
	1st day	3rd day	5th day	7th day	1st day	3rd day	5th day	7th day
Control	6.00±0.76^{b,A}	5.17±0.44^{b,B}	5.09±0.70^{b,B}	5.00±1.00^{a,B}	6.50±0.50^{b,A}	5.20±0.16^{c,AB}	4.94±0.30^{c,B}	4.67±0.44^{b,B}
S. Caseinate	8.00±0.28^{a,A}	7.17±0.83^{a,B}	7.11±0.54^{a,B}	7.00±0.28^{a,B}	7.00±0.28^{b,A}	6.50±0.33^{b,B}	6.67±0.25^{b,B}	5.83±0.33^{ab,B}
A. vera	8.00±0.00^{a,A}	7.83±0.16^{a,A}	7.48±0.11^{a,A}	7.17±0.83^{a,A}	8.00±0.00^{a,A}	8.00±0.00^{a,A}	7.83±0.55^{a,B}	6.33±0.00^{a,C}
	Odor				Overall acceptability			
	1st day	3rd day	5th day	7th day	1st day	3rd day	5th day	7th day
Control	5.17±0.16^{c,A}	5.00±0.57^{b,A}	4.45±0.71^{c,A}	3.83±1.00^{b,A}	5.89±0.47^{b,A}	5.12±0.39^{b,A}	4.78±0.14^{b,A}	4.50±0.81^{b,A}
S. Caseinate	7.00±0.00^{b,A}	5.83±0.16^{ab,B}	5.70±0.42^{b,B}	5.50±0.57^{ab,B}	7.33±0.19^{ab,A}	6.50±0.44^{ab,A}	6.31±0.09^{a,A}	6.11±0.39^{ab,A}
A. vera	7.83±0.57^{a,A}	7.00±0.57^{a,A}	6.82±0.31^{a,AB}	6.50±1.00^{a,B}	7.94±0.20^{a,A}	7.61±0.24^{ab,A}	7.22±0.21^{a,A}	6.67±0.61^{a,A}
	Cooked fish fillet							
	Appearance				Color			
	1st day	3rd day	5th day	7th day	1st day	3rd day	5th day	7th day
Control	6.00±0.00^{a,A}	5.83±0.16^{b,A}	5.55±0.22^{b,A}	5.17±0.44^{b,A}	6.00±0.57^{b,A}	4.33±0.66^{b,AB}	3.95±0.10^{b,B}	3.67±0.33^{b,B}
S. Caseinate	8.00±0.00^{a,A}	7.00±0.57^{ab,AB}	6.98±0.51^{a,B}	5.83±0.16^{b,B}	7.50±0.28^{a,A}	6.50±0.28^{a,AB}	6.41±0.31^{a,B}	6.17±0.44^{a,B}
A. vera	8.00±0.00^{a,A}	8.00±0.00^{a,A}	7.91±0.48^{a,A}	7.50±0.28^{a,A}	8.00±0.00^{a,A}	7.17±0.44^{a,AB}	6.91±0.25^{a,B}	6.50±0.50^{a,B}
	Flavor				Juiciness			
	1st day	3rd day	5th day	7th day	1st day	3rd day	5th day	7th day
Control	5.17±0.16^{c,A}	4.33±0.66^{b,AB}	3.77±0.11^{b,B}	3.00±0.28^{c,B}	5.83±0.16^{c,A}	4.00±0.00^{b,B}	3.66±0.11^{b,B}	3.00±0.57^{b,B}
S. Caseinate	7.00±0.00^{b,A}	6.33±0.33^{a,AB}	6.00±0.00^{a,AB}	5.83±0.16^{b,B}	7.00±0.00^{b,A}	7.00±1.00^{a,A}	6.85±0.29^{a,A}	6.00±0.15^{a,A}
A. vera	8.00±0.00^{a,A}	7.00±0.57^{a,A}	6.90±0.45^{a,A}	6.83±0.16^{a,A}	8.00±0.00^{a,A}	8.00±0.00^{a,A}	7.11±0.50^{a,A}	7.50±0.28^{a,A}
	Tenderness				Overall acceptability			
	1st day	3rd day	5th day	7th day	1st day	3rd day	5th day	7th day
Control	6.50±0.28^{b,A}	4.33±0.66^{b,AB}	4.17±0.18^{b,B}	4.00±1.00^{b,B}	5.90±0.23^{b,A}	4.56±0.43^{b,AB}	3.83±0.05^{c,B}	3.77±0.52^{b,B}
S. Caseinate	7.17±0.44^{ab,A}	6.00±1.00^{ab,A}	5.19±0.05^{b,A}	5.83±0.16^{ab,A}	7.33±0.14^{ab,A}	6.57±0.64^{a,A}	6.21±0.14^{b,A}	5.93±0.21^{a,A}
A. vera	8.00±0.00^{a,A}	8.00±0.00^{a,A}	7.78±0.32^{a,A}	7.50±0.28^{a,A}	8.00±0.00^{a,A}	7.63±0.40^{a,A}	7.47±0.10^{a,A}	7.17±0.30^{a,A}

Values represent the mean of three independent replicates ± standard error. $^{a-c}$ Values with different superscripts within the same column differ significantly at $P < 0.05$. $^{A-C}$ Values with different superscripts within the same row differ significantly at $P < 0.05$

Table 3. Proximate chemical composition (g/100 g) of sodium caseinate and *A. vera* gel-coated fish fillets during storage at 4° C for seven days.

	Moisture				Protein			
	1st day	3rd day	5th day	7th day	1st day	3rd day	5th day	7th day
Control	78.64±0.22^{a,A}	78.28±0.16^{a,A}	76.98±0.23^{b,A}	75.60±0.30^{c,B}	17.66±0.34^{a,B}	18.00±0.15^{b,AB}	18.52±0.19^{b,A}	18.60±0.22^{b,A}
S. Caseinate	79.67±0.22^{a,A}	77.22±0.44^{a,B}	77.30±0.42^{ab,B}	77.38±0.41^{b,B}	18.00±0.15^{a,B}	20.18±0.62^{a,A}	20.21±0.42^{a,A}	20.27±0.21^{a,A}
A. vera	79.97±0.23^{a,A}	78.90±0.72^{a,A}	78.73±0.58^{a,A}	78.53±0.43^{a,A}	17.50±0.34^{a,B}	17.96±0.12^{b,AB}	18.30±0.20^{b,A}	18.50±0.28^{b,A}
	Fat				Ash			
	1st day	3rd day	5th day	7th day	1st day	3rd day	5th day	7th day
Control	3.13±0.13^{a,A}	3.20±0.09^{a,A}	3.75±0.19^{a,A}	4.40±0.28^{a,A}	0.70±0.09^{a,B}	0.87±0.07^{a,B}	1.15±0.01^{a,A}	1.35±0.07^{a,A}
S. Caseinate	1.35±0.18^{c,C}	2.02±0.13^{b,B}	2.70±0.11^{b,AB}	3.20±0.18^{b,A}	0.74±0.04^{a,A}	0.79±0.08^{a,A}	0.81±0.03^{b,A}	0.83±0.02^{b,A}
A. vera	1.98±0.06^{b,B}	2.40±0.09^{b,A}	2.51±0.07^{b,A}	2.53±0.12^{b,A}	0.60±0.03^{a,A}	0.68±0.09^{a,A}	0.68±0.07^{c,A}	0.70±0.04^{b,A}

Values represent the mean of three independent replicates ± standard error. $^{a-c}$ Values with different superscripts within the same column differ significantly at $P < 0.05$. $^{A-C}$ Values with different superscripts within the same row differ significantly at $P < 0.05$

Table 4. pH, TBARS, TVBN values and cooking loss of sodium caseinate and *A. vera* gel-coated fish fillets during storage at 4°C for seven days.

	pH				TBARS (mg malonaldehyde/ kg)			
	1st day	3rd day	5th day	7th day	1st day	3rd day	5th day	7th day
Control	6.81±0.01^{a,B}	6.86±0.01^{a,B}	6.98±0.04^{a,AB}	7.04±0.02^{a,A}	0.14±0.02^{a,C}	0.55±0.03^{a,C}	1.78±0.07^{a,B}	2.95±0.01^{a,A}
S. Caseinate	6.83±0.01^{a,B}	6.86±0.01^{a,B}	7.01±0.11^{a,AB}	7.12±0.02^{a,A}	0.08±0.01^{b,C}	0.31±0.08^{b,C}	0.50±0.04^{b,B}	0.61±0.03^{b,A}
A. vera	6.76±0.02^{b,A}	6.74±0.02^{b,A}	6.78±0.03^{b,A}	6.80±0.03^{b,A}	0.04±0.01^{b,D}	0.15±0.02^{b,C}	0.29±0.01^{c,B}	0.35±0.02^{c,A}
	TVBN (mg nitrogen/100 g)				Cooking loss (%)			
	1st day	3rd day	5th day	7th day	1st day	3rd day	5th day	7th day
Control	4.42±0.01^{a,D}	8.78±0.03^{a,C}	15.87±0.25^{a,B}	22.53±0.29^{a,A}	12.30±0.32^{a,C}	12.59±0.78^{a,C}	14.78±0.27^{a,B}	16.83±0.38^{a,A}
S. Caseinate	3.69±0.02^{b,C}	7.78±0.13^{b,B}	9.55±0.19^{b,AB}	10.56±0.24^{b,A}	6.86±0.69^{b,D}	8.74±0.19^{b,C}	10.18±0.26^{b,B}	13.17±0.10^{b,A}
A. vera	2.79±0.01^{c,C}	6.45±0.27^{c,B}	7.62±0.13^{c,AB}	8.66±0.17^{c,C}	2.69±0.46^{c,C}	3.32±0.17^{c,C}	4.25±0.21^{c,B}	4.93±0.15^{c,A}

Values represent the mean of three independent replicates ± standard error. $^{a-c}$ Values with different superscripts within the same column differ significantly at $P < 0.05$. $^{A-D}$ Values with different superscripts within the same row differ significantly at $P < 0.05$

Table 5. Instrumental color and shear force values of sodium caseinate and *A. vera* gel-coated fish fillets during storage at 4° C for seven days.

	Lightness				Redness			
	1st day	3rd day	5th day	7th day	1st day	3rd day	5th day	7th day
Control	57.23±0.03^{a,A}	56.06±0.14^{a,B}	55.06±0.74^{a,C}	52.64±0.06^{a,D}	5.65±0.04^{c,A}	5.12±0.10^{c,B}	4.94±0.56^{c,B}	3.56±0.03^{c,C}
S. Caseinate	56.04±0.04^{b,A}	54.16±0.16^{b,B}	53.50±0.27^{b,C}	51.15±0.16^{b,D}	7.41±0.02^{b,A}	6.65±0.06^{b,B}	6.00±0.06^{b,C}	5.05±0.07^{b,D}
A. vera	51.60±0.02^{c,A}	50.34±0.44^{c,B}	48.60±0.18^{c,C}	47.43±0.19^{c,D}	7.54±0.02^{a,A}	7.06±0.07^{a,B}	6.92±0.09^{a,B}	6.04±0.03^{a,C}
	Yellowness				Shear force (kg/f)			
	1st day	3rd day	5th day	7th day	1st day	3rd day	5th day	7th day
Control	9.47±0.12^{a,D}	10.15±0.14^{a,C}	10.88±0.13^{a,B}	12.08±0.65^{a,A}	12.22±0.35^{a,A}	11.21±0.12^{a,B}	10.85±0.21^{a,B}	9.82±0.17^{a,C}
S. Caseinate	8.85±0.17^{b,C}	9.49±0.25^{b,B}	10.14±0.19^{b,A}	10.62±0.21^{b,A}	10.21±0.11^{b,A}	9.07±0.36^{b,B}	8.81±0.18^{b,B}	6.78±0.17^{c,C}
A. vera	8.38±0.12^{c,C}	8.84±0.14^{b,B}	9.10±0.12^{c,A}	9.50±0.08^{c,A}	9.24±0.24^{c,A}	9.02±0.14^{b,A}	8.25±0.24^{b,B}	7.80±0.18^{b,B}

Values represent the mean of three independent replicates ± standard error. $^{a-c}$ Values with different superscripts within the same column differ significantly at $P < 0.05$. $^{A-D}$ Values with different superscripts within the same row differ significantly at $P < 0.05$

highest in the *A. vera*-coated group, followed by the caseinate-coated group, and finally the control group. The results also showed that L* and a* values were significantly decreased, while the b* value was significantly increased by the chilled storage period; the control group exhibited pronounced changes and the *A. vera*-coated group showed the lowest changes.

The shear force values showed that the application of different coating materials resulted in sensational differences, where fish fillets coated with *A. vera* gel had the lowest shear force values and the control group had the highest values (Table 5). Coating fish fillets with *A. vera* gel can preserve the texture of fillets throughout chilled storage, which appeared by retardation of increasing the shear force values from 1st to 7th days of chilled storage compared to the other two groups. The results also revealed that the rate of shear force values elevation during chilled storage was similar in the control and caseinate-coated fillet groups.

Discussion

The acidic pH of *A. vera* gel can be attributed to its components, which include higher amounts of anthraquinones and low-molecular-weight compounds with acidic properties, such as aloetic acid, salicylic acid, and chlorogenic acid (Abdalla *et al*., 2022). Moreover, the *A. vera* coat exhibited more potent scavenging activity than the caseinate coat owing to its higher content of inorganic compounds, including zinc, manganese, iron, magnesium, phosphorous, and potassium, as well as vitamins such as vitamins A, C, B12, folic acid, and E. choline, which are responsible for its antioxidant properties (Saeed *et al*., 2022). Furthermore, the difference in coat uptake between the two groups may be related to the high-water absorption capacity of *A. vera* gel.

The results indicated that the sensory quality of fish fillets was better improved by the application of the *A. vera* gel coat than by the sodium caseinate coat. The improved sensory scores of the coated fish fillets may be attributed to their ability to retain water inside the fish, leading to higher tenderness and juiciness scores (Murmu and Mishra 2018; Seyed *et al*., 2021). Moreover, the antioxidant properties of these coats are the main reasons for the enhanced color, odor, and flavor of the raw and cooked fillets. According to Asamenew *et al.* (2011), A.vera gel contains unique antibacterial and antioxidant compounds, which make it exhibit extraordinary preservation properties than other coats. On the other hand, the rapid sensory deterioration of the control group may be explained by the putrefaction of proteins by enzymes and proteolytic microorganisms in lean fish.

The maintenance of the chemical composition of fish fillets by the application of coats may be related to their moisture barrier ability. Seyed *et al*. (2021) proved that *A. vera* gel application retains water evaporation due to the formation of a glassy semi-compromised layer when added as a coating material to the fruit surface. Moreover, Murmu and Mishra (2018) reported that the addition of sodium caseinate in the coat formulation retards the water evaporation rate owing to the formation of intermolecular hydrogen bonds because of OH and–NH groups present in its structure. While the increased protein content in sodium caseinate coated group may be attributed to the proteinaceous nature of casein.

The obtained pH results were consistent with Kim *et al*. (2019), who reported a significant reduction in pH values with the addition of *A. vera* gel in the formulation of frankfurter and he referred this reduction to the acidic nature of *A. vera* gel. On the other hand, the slight elevation in the pH value of fish fillets by the application of casein coat may be simplified by the fact that as pH increases, protein surface coverage increases (Liu *et al*., 2012). The barriers made by both caseinate and *A. vera* gel are the main contributors to the antioxidant properties of these coats, where these barriers prevent the interaction between oxygen and unsaturated fatty acids found in fish. In addition, *A. vera* gel contains strong antioxidant compounds, such as salicylic acid, inorganic compounds, and vitamins, as well as unique antimicrobial compounds such as aloin and 7-Omethylaloeresin (Asamenew *et al*., 2011). Moreover, *A. vera* gel can inhibit the activity of protease enzymes, leading to a decrease in protein catabolism and a subsequent reduction in TVBN values in treated food (Saeed *et al*., 2022). Although, TBARS and TVBN values of all fish fillet treatments were within the regulatory limits (4.5 mg MDA/kg for TBARS and 30 mg N/100g for TVBN) set in EOS/3494 (2005) until the end of chilled storage, the TBARS value of control group reached the limit that made the fish fillets unacceptable for sensory evaluation at 5th and 7th days of chilled storage. Connell (1990) reported that fish flesh exhibits an unappealing odor and taste when TBARS levels are higher than 1-2 mg MDA/kg. The marked increase in the TBARS value in the control group may be related to the lack of coating material in such a group, where fish fillets were directly subjected to oxidative rancidity, which was spontaneously triggered by the high percentage of unsaturated fatty acids found in fish. Moreover, the higher bacterial load and action of endogenous enzymes may be another cause for the elevation of TBARS and TVBN values in the control group.

Cooking loss findings may be related to the moisture retention properties of both coats. The higher moisture retention of *A. vera* gel coating may be attributed to its higher content of glucomannans, which give the jelly texture of *A. vera* gel and can scavenge high amounts of water in their structure (Bahmani *et al*., 2016). Conversely, a lower reduction rate of cooking loss was observed by coating fillets with caseinate owing to its higher water vapor permeability than that of the *A. vera* gel coating (Bonnaillie *et al*., 2014).

However, the elevation of cooking loss results throughout the storage period may be explained by increasing the denaturation incidence of naturally occurring protein found in fish by the storage time in addition, Janjarasskul and Krochta (2010) reported that the degradation of coating by enzymes, brittleness, and susceptibility to cracking are the main disadvantages of protein-based edible coating.

It is well known that color indices are affected by the chemical

composition and oxidation of food. Thus, the lower lightness value of *A. vera*-coated fish fillets may be related to their higher water content. These findings are in agreement with those reported by Sharifimehr *et al*. (2019), who found that the L* values decreased as the concentration of *A. vera* gel in shrimp-coated emulsions increased. The authors explained this phenomenon as the complete dissolution of *A. vera* in the water during coating preparation, which led to the decreased induction of light reflection and scattering, resulting in decreased brightness. The higher L* values of the caseinate-coated group compared to the *A. vera*-coated group may be because the casein coat does not contain particles that strongly scatter light (Chung *et al*., 2013). The higher a* and lower b* values obtained by the application of both caseinate, and *A. vera* gel coatings can be explained by the formation of physical barriers on fish fillets that prevent the entrance of oxygen, thus decreasing the incidence of oxidation (Seyed *et al*., 2021). Furthermore, the presence of salicylic acid and other antioxidant compounds in *A. vera* gel acts as an extra factor in the preservation of fish fillet color during the chilled storage period (Saeed *et al*., 2022).

The outcomes of shear force analysis may be correlated with the moisture retention ability of both coats (Murmu and Mishra, 2018; Seyed *et al*., 2021). The moisture content results obtained in this study were substantiated by this correlation, in which the shear force decreased as moisture content increased. Moreover, Lad and Murthy (2013) related the lower shear force of food treated with *A. vera* gel to the shear thinning behavior of such gel. Although our results showed a significant reduction in shear force value with the application of sodium caseinate coating compared to the control group, Valentino *et al*. (2020) stated that the application of this coat led to increased shear force owing to its ideal Newtonian behavior, which occurred because of the swelling of caseinate particles, resulting in increased thickening of food. Moreover, the degradation of casein by enzymes and cracking of the coat with storage time (Janjarasskul and Krochta, 2010) may be the main causes of the marked elevation in shear force at the end of storage in caseinate-coated fish fillets.

Conclusion

The *A. vera* gel and sodium caseinate-coated groups showed promising results, including improvement in organoleptic and physiochemical parameters during chilled storage due to their extraordinary properties, such as strong antioxidant and antibacterial effects when compared to the control group. However, the group treated with *A. vera* gel showed better amelioration in all examined parameters than the sodium caseinate-coated group. Therefore, it can be concluded that either coat (*A. vera* or sodium caseinate) can be used as a natural method to improve the quality and delay the onset of spoilage for perishable chilled fish fillets.

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Conflict of interest

The authors declare that they have no conflict of interest.

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