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Evaluation of the effect of edible coating based on ShahriBalangu seed mucilage containing cinnamon essential oil onphysicochemical, microbial, and sensory properties of strawberry during storage

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ABSTRACT

Antimicrobial edible coatings containing plant essential oils have various advantages and are currently being used to design biodegradable packaging.In this study, cinnamon essential oil was added at concentrations of 0, 0.3, 0.6 and 0.9% to the ShahriBalangu seed mucilage solution to produce a bioactive edible coating. Strawberry samples were coated with the edible coating and their physicochemical, microbial, and sensory changes were evaluated during a 10-day storage period at 4 °C.Compared to the control sample, the use of edible coating based on ShahriBalangu seed mucilage containing 0.9% of cinnamon essential oil, significantly inhibited the changes in pH, acidity, soluble solids (13.69% *vs*. 43.5% increase), microbial count (3.22 *vs*. 3.98 log CFU/g increase), hardness (6.74% *vs*. 33.05%), and sensory properties (color, odor, texture, and overall acceptance) of strawberry fruit during storage.Therefore, the edible coating based on ShahriBalangu seed mucilage containing cinnamon essential oil can be used as an active packaging to improve the quality and safety characteristics of various food products.

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1. Introduction

Strawberry (*Fragaria in pineapple*) is cultivated all over the world and is widely appreciated due to its special aroma, bright red color, juicy texture, and sweetness. Currently, the United States of America, Spain, Turkey, Russia, and Korea are the main strawberry producing countries [1]. [. Due to its high levels of vitamin C, folate and phenolic compounds, strawberries are a good source of bioactive compounds, most of which show antioxidant capacity in vitro and in vivo. In addition, strawberries are economically and commercially important and are widely consumed fresh or processed such as jam, juice, and jelly [2].

To achieve maximum quality in terms of appearance (freshness, color and absence of decay or physiological disorders), texture (firmness, freshness and crispness), taste and nutritional value (vitamins, minerals and dietary fiber), strawberries must be harvested at full maturity. . Gray mold by*Botrytis cinehra*[1] occurs, is the most important postharvest pathogen of strawberry fruits from an economic point of view. Strawberry spoilage after harvest can also occur with mechanical damage and drying [3].

Low storage temperatures and modified atmospheres with high levels of carbon dioxide are common methods to prevent mold and mildew growth and thus increase the shelf life of strawberries. However, long-term exposure of the fruit to high concentrations of carbon dioxide can cause bad taste in the product [4 and 5]. The use of synthetic chemical fungicides has been the main method to reduce post-harvest disease. However, consumer concern about pesticide residues in foods, along with pathogen resistance to many currently used pesticides, has increased the need to find alternative methods for rot control. Recently, bioactive natural products have become an effective alternative to synthetic fungicides [6, 7].

Preservation of fresh produce using edible coatings has been widely used. Several mechanisms are involved in increasing the shelf life of fruits and vegetables by edible coating/film, including reduced moisture loss and controlled gas exchange (CO_2/O_2) which leads to a decrease in breathing rate. Edible films can also prevent mechanical damage caused during handling and post-harvest processing [8-11]. In the last decade, there has been an increasing trend in the development of biodegradable and edible coatings based on polysaccharide [9, 12].

Mucilage of urban balangoi seeds (*Lallemantiaiberica*) is a low-cost carbohydrate source for the production of edible films and coatings based on biopolymers for use in food packaging. Balangu city of the family*Lamiaceae* It is used as a strong biological medicine to treat fever, cough, stress, liver and kidney diseases [13]. However, polysaccharide-based coatings rarely have antimicrobial or antioxidant effects, and therefore bioactive additives, such as antioxidant and antimicrobial compounds, are usually included in edible coatings to improve their technological performance [9].

Essential oils are one of the most widely used natural compounds, and because of their antioxidant and antimicrobial compounds, they are known as safe compounds in food preservation technologies [14]. Cinnamon (*Cinnamomum zeylanicum*) belongs to the family*Lauraceae* It grows wild in India, Sri Lanka, India, China and Madagascar. Its inner bark has been used as a powerful therapeutic agent in traditional medicine and as a flavoring agent in foods. The antioxidant, anti-mutagenic and antimicrobial activities of the essential oil and its extract have been evaluated in different studies [15]. However, so far, no study has been conducted on the potential effect of edible coatings based on mucilage of urban balangoo seed containing cinnamon essential oil on the quality and shelf life of strawberry fruit during storage in the refrigerator. Therefore, the present study was conducted with the aim of investigating the inhibitory effect of bioactive edible coating on the physicochemical, microbial and sensory changes of strawberry fruit under cold storage conditions.

2- Materials and methods

2-1- Materials

Balango Shahri and cinnamon seeds were purchased from Attari in Ahvaz. Extraction of essential oil from cinnamon bark was done by water distillation extraction method [15]. Other materials used in this study were of laboratory

[1]. *Botrytis cinerea*

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grade and were obtained from Merck (Germany) or Sigma (USA).

2-2- Mucilage extraction

In order to extract the mucilage, first the urban balango seeds were sieved and then soaked in ethanol for 30 minutes to remove dust and possible contamination. Then the seeds were dried in an oven at 30°C for 12 hours. The water coating process was applied to extract mucilage according to the following conditions: water-to-grain ratio of 20 to 1, pH equal to 7, and stirring for 3 hours at a temperature of 50 degrees Celsius. The extracted mucilage was then obtained by filtering the initial seed-water mixture through a cotton cloth and then centrifuging at 3000 rpm for 15 minutes. The semi-purified mucilage was finally dried in an oven at 50°C for 6 hours. Dry mucilage was then packed and stored at room temperature [16].

2-3- Fruit selection and preparation

Infected, rotten and unripe fruits were separated from other fruits and the remaining fruits were checked for shape, color and size to be uniform. Then the fruits were completely washed with distilled water and dried.

2-4- Preparation of edible coating

The oral coating was prepared by dissolving 2 g of mucilage and 0.1 g of Tween 80 in 100 ml of sterilized distilled water. The mixture was stirred and heated for 2 hours. After that, essential oil was added to the mucilage solution in concentrations of zero, 0.3, 0.6 and 0.9% and the obtained solution was used as a bioactive food coating to increase the shelf life of strawberry fruits. The strawberry fruits were immersed in the emulsion for 5 minutes and then transferred to a container containing a net to be drained. At this stage, the samples were exposed to wind flow for 1 hour at a temperature of 25°C to dry. The samples were then packed in a perforated box to prevent atmospheric changes and finally stored at 4°C. To prepare the control sample, a group of fruits were immersed in distilled water under the same conditions. The physicochemical, microbial, and sensory characteristics of strawberry samples were investigated on days 1, 4, 7, and 10 of storage at 4°C [13, 17, 18].

5-2- Acidity and pH

The pH value of strawberry juice was determined using a pH meter (HI 221, Hanna Instruments, Woonsocket, RI) at ambient temperature. In order to measure the acidity of the samples, the filtered fruit juice (5 ml) was made up to 100 ml with distilled water. Next, a few drops of phenolphthalein reagent were added to it and the solution was titrated with 0.1 normal interest. Each milliliter of 0.1 normal soda is considered equivalent to 0.0067 grams of citric acid [19].

2-6- Solution solids

The amount of dissolved solids of the samples (filtered fruit juice) was checked by a refractometer at ambient temperature.

2-7- Counting mushrooms

The fruit samples were crushed in a sterile porcelain mortar to obtain a uniform solution. Next, 25 grams of the solution was combined with 225 ml of physiological serum to prepare successive dilutions. Each of the successive dilutions was cultured in Saborud dextrose agar medium. After that, the culture medium was placed in a greenhouse for 3-5 days at a temperature of 25°C and the resulting colonies were counted [20 and 21].

2-8- tissue stiffness

A texture analyzer (Stable Micro System Texture Analyzer, TA, XT2i, UK) was used to determine the hardness of the samples during the storage period. A cylindrical probe with a diameter of 6 mm was penetrated into the fruit tissue by 3 mm at a speed of 0.2 mm per second, and the force applied was recorded in Newtons and reported as the hardness of the samples [17 and 22].

9-2- Sensory characteristics

Sensory parameters of smell, color, texture and overall acceptance of the samples were evaluated by 20 evaluators through a 9-point hedonic test. Sensory scores were rated from very excellent (9) to very poor (1) [9].

2-10- Statistical analysis

The results of this study were analyzed using one-way analysis of variance using SPSS software (version 26). Duncan's test at 95% confidence level ($P < 0.05$) was used to determine the difference between the average data. It should be noted that all experiments were repeated three times.

3. Results and Discussion

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The results of the effect of edible coating and storage time on the amount of pH and acidity changes of strawberry samples are shown in Figure 1. Increasing the storage time from 1 to 10 days increased the pH and decreased the acidity of the samples ($p > 0.05$). The type of edible coating also did not show a significant effect on the pH and acidity of the samples. On the tenth day of storage, the highest pH value was in the control sample and the lowest value was in the coated samples. In this regard, the control and coated samples showed the lowest and highest levels of acidity, respectively, on the tenth day of storage at 4°C. Lesser changes in acidity and pH in the samples covered with mucilage containing cinnamon essential oil may be due to a decrease in breathing intensity in this group. In fact, enzyme activity during the storage period of strawberry fruit causes a decrease in the acidity of the fruit [19]. Therefore, the greater drop in acidity in the control sample can be due to the increase in the decomposition rate of acids and organic compounds in this sample. Similar results have been reported by other researchers [19 and 23].

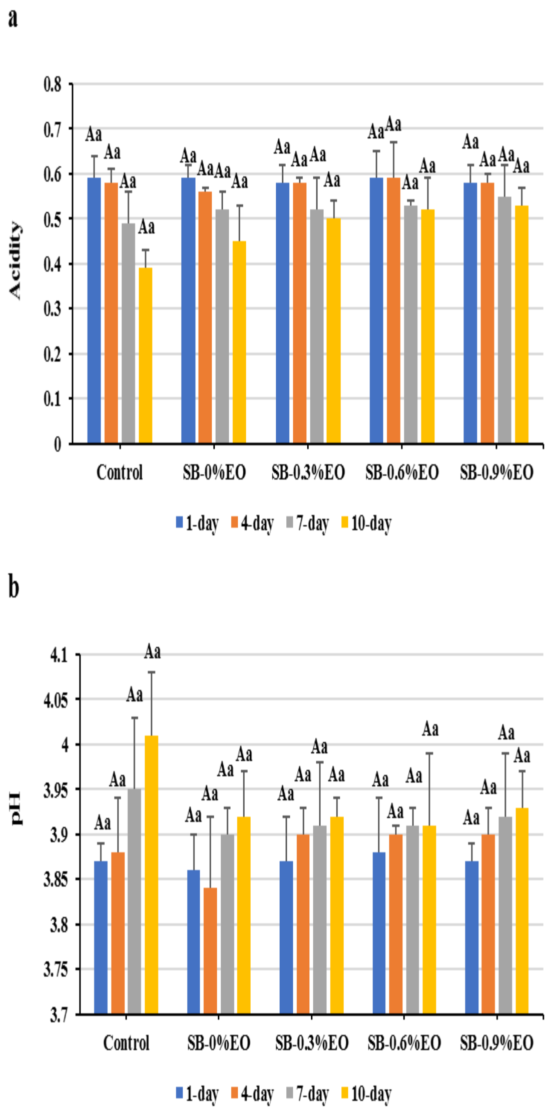

Fig 1 Changes in acidity (a) and pH (b) of strawberries during storage at 4 °C; SB, ShahriBalangu, EO, Essential oil.Significant small and capital letters indicate the effect of coating type and storage time, respectively ($p < 0.05$).

The trend of changes in the amount of soluble solids of the control and coated strawberry samples with urban balango mucilage containing cinnamon essential oil during the storage period is shown in Figure 2. The increase in the amount of soluble solids during fruit storage is mainly due to the decomposition of carbohydrates and the beginning of fruit spoilage, along with the conversion of acid to sugar during respiration [24]. According to the results, increasing the storage time caused a significant increase in the amount of dissolved solids in the samples. However, the increasing trend of soluble solids decreased with increasing concentration of essential oil in edible coating. So that the amount of increase of soluble solids in control samples, covered with mucilage without essential oil, covered with mucilage containing 0.3, 0.6 and 0.9% concentrations of essential oil is equal to 43.5, 35.68, 33.3, respectively. 25, 18.36 and 13.69 percent, which can be caused by less breathing in covered samples. In accordance with the results of this research, it has been reported that the use of starch-based edible coating on strawberry fruit prevented a significant increase in soluble solids in the fruit compared to the control sample [25].

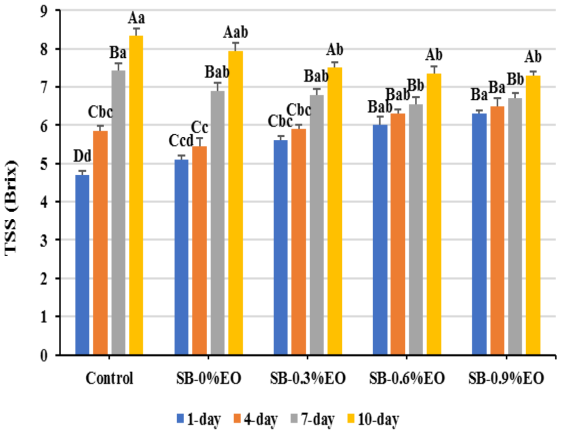

Fig 2 Changes in total soluble solids of strawberries during storage at 4 °C; SB, ShahriBalangu, EO, Essential oil.Significant small and capital letters indicate the effect of coating type and storage time, respectively ($p < 0.05$).

The total number of fungi in the samples increased significantly with increasing storage time (8.38% to 27.56%), but this increase was not significant in the strawberry samples covered with urban balango mucilage loaded with cinnamon essential oil (Figure 3). On the tenth day of storage, the highest number of mushrooms in the control sample (3.98 log CFU/g) and the lowest in the coated sample contained 0.9% cinnamon essential oil (3.22 log CFU/g). Since fungal species are aerobic and mainly grow on the surface of the crop, the mulches based on urban balango mucilage act as an oxygen barrier [13] and significantly reduce fungal growth on the crop. In addition, the antifungal activity of cinnamon essential oil has been proven in other studies [26 and 27]. Therefore, the lower growth rate of the fungus in the samples covered with mucilage containing cinnamon essential oil can be related to the low permeability of the edible coating to oxygen and the antifungal activity of cinnamon essential oil, which is consistent with the findings of other researchers [11].

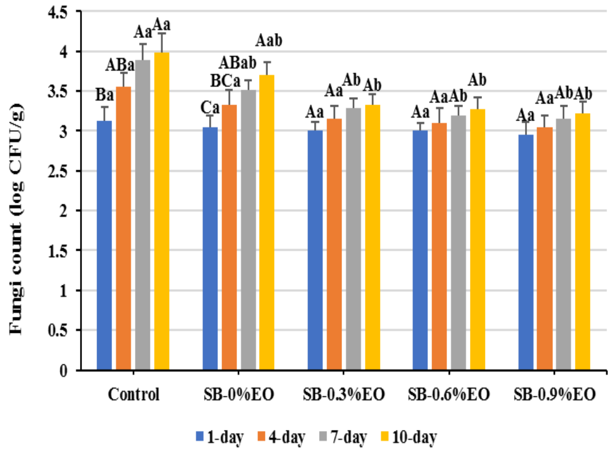

Fig 3 Changes in fungi count of strawberries during storage at 4 °C; SB, ShahriBalangu, EO, Essential oil.Significant small and capital letters indicate the effect of coating type and storage time, respectively ($p < 0.05$).

Figure 4 shows the changes in the hardness of the control and coated strawberry samples during the storage period under refrigerated conditions. All the samples experienced a decrease in hardness during the storage period, but this decrease was not significant in the samples covered with urban balangoi mucilage containing cinnamon essential oil ($p>0.05$) and increasing the concentration of essential oil in the edible coating prevented tissue destruction.

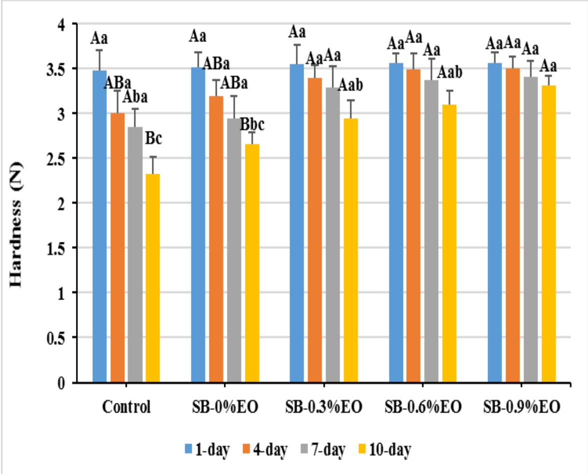

Fig 4 Changes in hardness of strawberries during storage at 4 °C; SB, ShahriBalangu, EO, Essential oil.Significant small and capital letters indicate the effect of coating type and storage time, respectively ($p < 0.05$).

In general, the amount of tissue decomposition in the control samples, covered with mucilage without essential oil and covered with mucilage of urban Balangoi containing concentrations of 0.3, 0.6 and 0.9% of cinnamon essential oil is 33.05, 43.05, respectively. 24, 16.90, 12.92 and

6.74 percent. The decrease in firmness of strawberry fruit during the storage period may be due to the dissolution of cell wall polysaccharides, enzyme activity, destruction of cell wall and parenchyma, as well as fungal spoilage [3, 28, 29]. Therefore, the higher degree of stiffness of the samples covered with mucilage containing essential oil after the storage period compared to the control sample can be caused by the lower intensity of respiration and the lower microbial load (fungi) in these samples. In accordance with the results of this study, Panji et al. [24] and Hernandez Munez et al. The control sample had a higher degree of tissue stiffness and strength.

Sensory characteristics of strawberry samples were changed during the storage period (Figure 5). Except for the sample covered with mucilage containing 0.9% essential oil, other samples experienced a significant decrease in color sensory index during storage ($p<0.05$). As the storage time increased, the sensory index of smell decreased significantly. Although all the samples underwent tissue decomposition during the storage period, this reduction was not significant in the sample covered with mucilage containing 0.9% essential oil, which is in line with the histological results (Figure 4).

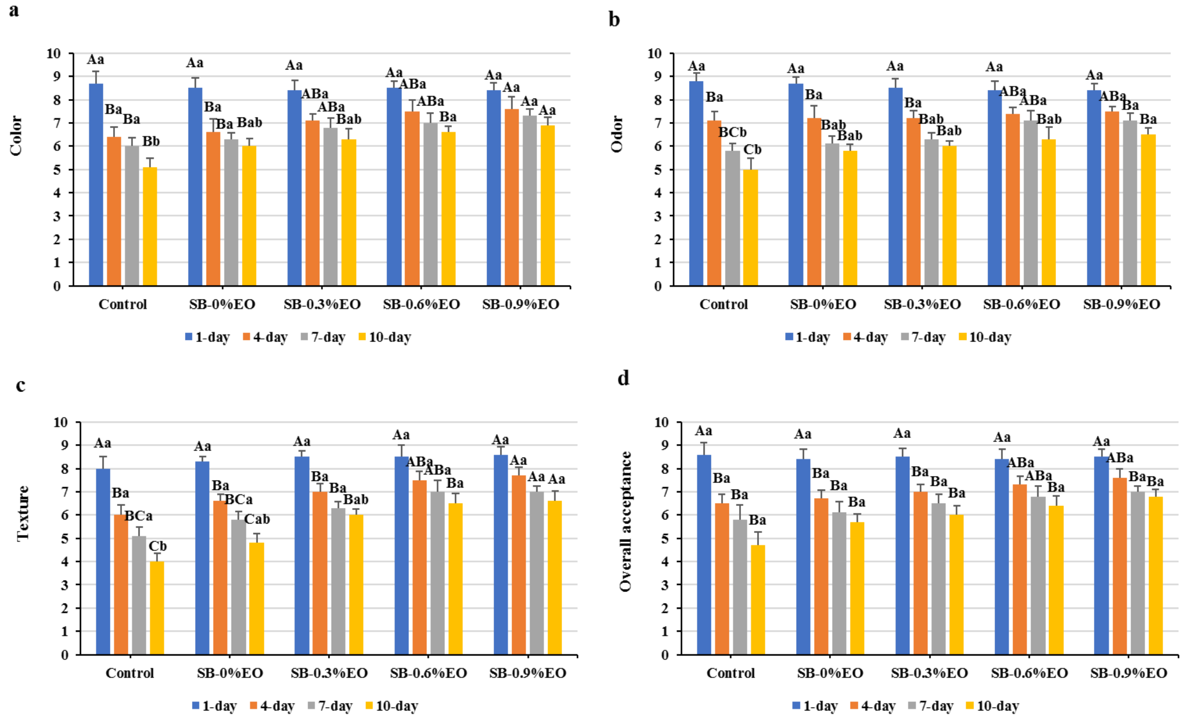

Fig 5 Changes in sensory parameters color (a), odor (b), texture (c), and overall acceptance (d) of strawberries during storage at 4 °C; SB, ShahriBalangu, EO, Essential oil.Significant small and capital letters indicate the effect of coating type and storage time, respectively ($p <0.05$).

A similar trend was observed in relation to the sensory index of overall acceptance. Thus, increasing the storage time from 1 to 10 days caused a significant decrease in this index. However, the severity of the overall acceptance drop in the coated samples, especially the types containing cinnamon essential oil, was less than other samples. In general, the control and coated samples with mucilage containing 0.9% cinnamon essential oil had the lowest and highest sensory scores, respectively, at the end of the storage time. It should be noted that the appearance and edible quality of the fruit (color, aroma and taste) decreases during the storage period due to the increase in respiration rate and enzyme activity [24]. The results of this study show that the samples treated with mucilage containing cinnamon essential oil had a higher overall acceptance than the control sample due to reduced respiration, preservation of tissue, low microbial load, and preservation of aroma and flavor compounds. Similar results have been reported by other researchers [24, 32-30].

4 - Conclusion

The results of the present study show that strawberries coated with mucilage of Balangou Shahri and cinnamon essential oil maintained the desired physicochemical and sensory characteristics during 10 days of storage at 4°C. Considering the antimicrobial effect of cinnamon essential oil against the fungal strains that cause strawberry spoilage, as well as the low permeability of the bioactive food coating based on the mucilage of urban balangoo seeds and cinnamon essential oil against oxygen, it is recommended to use this natural product on strawberries in the field. In addition, it is suggested to evaluate the effectiveness of the edible coating based on the mucilage of urban balangu seeds and cinnamon essence on other food and agricultural products in future studies.

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چکیده

پوشش‌های خوراکی ضد میکروب حاوی اسانس‌های گیاهی دارای مزایای مختلفی هستند و در حال حاضر برای طراحی بسته‌بندی‌های زیست تخریب‌پذیر استفاده می‌شوند. در این پژوهش، اسانس دارچین در غلظت‌های صفر، ۰/۳، ۰/٦ و ۰/۹ درصد به محلول موسیلاژ دانه بالنگوی شهری به منظور تولید پوشش خوراکی زیست فعال اضافه گردید. نمونه‌های توت‌فرنگی با پوشش خوراکی پوشش یافتند و تغییرات فیزیکوشیمیایی، میکروبی و حسی آن‌ها طی دوره نگهداری ۱۰ روزه در دمای ٤ درجه سانتی‌گراد بررسی گردید. در مقایسه با نمونه کنترل، استفاده از پوشش خوراکی مبتنی بر موسیلاژ دانه بالنگوی شهری حاوی ۰/۹ درصد اسانس دارچین، بطور معنی‌داری از تغییرات pH، اسیدیته، میزان مواد جامد محلول (۱۳/٦۹ درصد در برابر ٤۳/۵ درصد افزایش)، بارمیکروبی (log CFU/g ۳/۲۲ در برابر ۳/۹۸)، تجزیه بافت (٦/۷٤ در برابر ۳۳/۰۵ درصد) و ویژگی‌های حسی (رنگ، بو، بافت و پذیرش کلی) میوه توت‌فرنگی طی دوره نگهداری جلوگیری نمود. بنابراینپوشش خوراکی بر پایه موسیلاژ دانه بالنگوی شهری غنی شده با اسانس دارچین می‌تواند به‌عنوان یک بسته‌بندی فعال برای بهبود ویژگی‌های کیفی و ایمنی توت‌فرنگی استفاده شود.