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Application of Tragacanth gum impregnated with *Satureja khuzistanica* essential oil as a natural coating for enhancement of postharvest quality and shelf life of button mushroom (*Agaricus bisporus*)

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ABSTRACT

The effect of Tragacanth gum (TG) coating incorporated with 100, 500 and 1000 ppm *Satureja khuzistanica* essential oil (SEO) on the postharvest quality and shelf life of button mushroom (*Agaricus bisporus*) stored at $4 \pm 1\,^{\circ}C$ for 16 days was investigated. Weight loss, firmness, browning index (BI), total phenolics, ascorbic acid, microbial and sensory quality were measured. The results indicated that treatment with TG containing SEO (TGSEO) maintained 92.4% tissue firmness, and reduced microorganism counts, such as yeasts and molds and *Pseudomonas*, compared to uncoated samples. Furthermore, mushrooms treated with TGSEO coating exhibited up to 57.1% decreased in BI, significantly higher levels of total phenolics (85.6%) and ascorbic acid accumulation (71.8%) than control and its efficiency was better than that TG coating alone. Sensory evaluation demonstrated the capability of TGSEO coating for preserving the quality of mushroom during the storage. The results obtained endorse that application of TGSEO coating might be a simple and effective technique for prolonging their postharvest shelf life of mushroom by up to 16 days.

1. Introduction

Since ancient times, mushrooms have been consumed by humans not only as a part of the normal diet but also as a delicacy because they have a highly desirable taste and aroma [1]. As much as 10,378,163 t of mushrooms were produced in the world [2]. White bottom mushroom (*Agaricus bisporus*) is one of the most popular and most widely consumed edible mushroom species in the world [3]. There are number of reasons behind the success of this species which include relatively inexpensive cultivation methods using organic substrates and nutritional profile: high content of riboflavin, niacin and minerals, particularly phosphorus. Moreover, *A. bisporus* has been considered as functional food due to the free radical scavenging and antioxidant activities [4,5].

The short shelf life of mushrooms, typically one to three days at room temperature, is a serious problem in postharvest distribution [6]. They lose their commercial value within a few days. Loss of qualities for mushrooms include browning, softening, cap development, off-flavour and secondary mould growth [5]. The short shelf-life of mushroom is an impediment to the distribution and marketing of the fresh product. Thus, prolonging postharvest storage while preserving their quality would benefit the mushroom industry as well as consumers [7]. To slow down the rate of postharvest deterioration in the fresh mushrooms, there are a number of preservative methods that could be used, such as low temperature storage, chemical treatments, γ-irradiation, and modified atmosphere packaging [8]. Application of semipermeable edible coating can give the same effect as modified atmosphere storage in improving the shelf life of perishable fruits [9,10]. Edible coatings act as a barrier, decline gas exchange between fruit and the surrounding atmosphere, result in modified interior atmosphere (high CO_2 and low O_2), as well as reduced water loss [11]. Preservation of fruit quality has been achieved by using a number of edible coatings, such as chitosan in strawberries [12], carrageenan in banana [13], gum Arabic in tomato [14] and gum cordia in chilgoza [15].

Tragacanth gum (TG) is a natural and acidic polysaccharide with an ancient history that mostly found in certain areas of Asia and in the semi desert and mountainous regions of Iran, Syria,

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Turkey and other near Eastern countries [16,17]. TG is defined by Joint FAO/WHO Expert Committee on Food Additives (JECFA) as: "a dried exudation obtained from the stems and branches of *Astragalus gummifer* Labillardière and other Asiatic species of *Astragalus* (Fam. Leguminosae)" [18]. TG biopolymer is a very complex heterogeneous anionic branched polysaccharide with a high molecular weight (approximately 8.4 × 105 Da) and has been widely used as a stabilizer, thickener, emulsifier, fat replacer and cross-linking agent in the food systems for many years [19]. It has unique chemical and biological properties such as non-toxicity and safe for oral intake, biocompatibility and eco-friendliness, stability over wide pH range. Moreover, TG has been accepted since 1961 as Generally Recognized as Safe (GRAS) at the level of 0.2–1.3% and in Europe has E-number E413 on the list of additives approved by the scientific committee for food of the European community [20,21].

In recent years, there has been an increased interest in the use of natural antimicrobial agents instead of chemical ones. Previous research has shown that essential oils (EOs) and extracts of many herbs and spices are known to have antimicrobial activity which can be used as natural food preservatives. Tragacanth gum and the other biopolymers can be used as a suitable carrier for natural antimicrobial and antioxidant compounds [22,23].

The genus *Satureja* (Lamiaceae, subfamily Nepetoideae and tribe *Satureja*) constitutes about 200 species of herbs and shrubs, often aromatic, widely distributed in Mediterranean area, Asia and boreal America [24]. *Satureja khuzistanica*, "Marzeh khuzestani" in Persian, is an endemic traditional herbal medicine among the nomadic inhabitants of southwestern of Iran including Ilam, Lorestan and Khuzestan Provinces. It used as herbal tea for its analgesic, antiseptic and anti-inflammatory properties, especially in toothache problems [25,26]. *S. khuzistanica* has also been reported to be antispasmodic, antidiarrhea, vasodilator, antihyperlipidemic, and antioxidant and possess antifungal, antiviral and antimicrobial properties [27]. In previous researches *S. khuzistanica* essential oil (SEO) used as natural antioxidants in soybean oil [28], safflower oil [29] and sunflower oil [25] and antifungal agent in liquid medium and tomato paste [30] and strawberry fruit [24]. According to our literature review, the use of Tragacanth gum either solitary or accompanied by *Satureja khuzistanica* essential oil in fresh button mushrooms has not been studied until now.

The aim of this study was to assess the impact of TG coating with or without different concentrations of SEO on postharvest quality of button mushroom during storage at 4 °C for 16 days.

2. Materials and methods

2.1. Plant material

Button mushrooms used in this study were harvested from a local farm in Shiraz, Iran. Mushrooms were picked from the same flower and from the same area of the shelf so as to reduce possible variations caused by cultivation and environmental conditions. The mushrooms were transferred to the laboratory within one hour of harvesting, and then stored in darkness at 4 ± 1 °C and 90% relative humidity (RH). The mushrooms were screened for their uniformity in size and colour and absence of mechanical damage prior to their final processing and packaging in high density polyethylene (HDPE) box.

2.2. Satureja khuzistanica essential oil

SEO (having purity of at least 98% as indicated in its specification sheet), was provided by a local commercial producer of plant essential oils.

2.3. Tragacanth gum and coating treatments

The high quality ribbon type TG (food grade) used in this study was purchased from a local herbalist store, washed with water thoroughly and dried in a vacuum oven at 70 °C. The dried gum was ground into fine powder for subsequent experiments. In a preliminary experiment, numerous concentrations of TG, namely, 0.2, 0.4, 0.6 and 0.75% (w/v) containing 1.0% sorbitol (as a plasticizer) were prepared and coated on button mushrooms. To optimize concentration of TG solution, colorimetric test, weight loss and phenolic contents were evaluated on each sample. Three concentrations of SEO (100, 500 and 1000 ppm) were dissolved in 100 mL purified water at 70 °C that containing 0.6% TG and 1.0% sorbitol. The solution was homogenized to achieve complete dispersion. Five different treatments were applied: (1) control (water); (2) Tragacanth gum coating (TG); (3) TG coating containing 100 ppm SEO (TGSEO1), (4) TG containing 500 ppm (TGSEO5), (5) TG containing 1000 ppm (TGSEO10). Mushrooms were dipped into their respective solutions for 5 min. The coating treatments were selected according to the preliminary experiments on mushrooms to assure adherence and uniformity of the coatings. The coated and control samples were kept over a plastic strainer for 30 min and a fan generating low-speed air was used to speed up drying. The treated samples were packaged in 18 × 20 cm high density polyethylene (0.04 mm thickness) containers. Finally, samples were stored for 16 days at 4 ± 1 °C and 95% RH for further analysis. Fifteen replicates were included in each treatment group, and subsequently every 4 days, three replicates from each treatment group were analyzed.

2.4. Weight loss and texture analysis of samples

Weight loss was represented as the percentage of loss of weight concerning the initial weight. In order to estimate the weight loss content of the packages before and after the storage period was weighed. A penetration test was implemented on the mushroom cap using a CT3 texture analyzer (Brookfield, US), using a 5 mm diameter cylindrical probe (TA35). Samples were penetrated 5 mm in depth. The speed of the probe was 2.0 mm s^{-1} during the pretest and penetration. From the force vs. time curve, firmness was defined as the maximum force [31].

2.5. Colour

The surface colour of mushroom caps was measured with using digital imaging and software analysis under controlled conditions (illumination, distance between camera and sample, camera angle and light source). The method has a good correlation with Hunter colorimeter [32]. A white wall box without permeability to surrounding light was used. A digital camera (Canon SX220 with 12.1 Mega Pixels) placed vertically at 25 cm distance from the samples. The angle between the axis of the lens and the sample was approximately 45°. The images were taken at maximum resolution and L* (light/dark), a* (red/green) and b* (yellow/blue) values of mushroom caps measured by filter/blur/average command in CS6 Photoshop software and compared to the ideal mushroom colour values of L* = 97, a* = −2 and b* = 0 using ΔE as described by the following equation [33]:

$$\Delta E = \left[(L-97)^2 + (a-(-2))^2 + b^2\right]^{\frac{1}{2}} \quad (1)$$

where ΔE indicates the degree of overall colour change in comparison to the colour values of an ideal mushroom.

The browning index (BI), which represents the purity of brown colour [34], was calculated according to the following equations:

$$BI = [100\,(x-0.31)]\,/0.172 \quad (2)$$

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