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The influence of nanocellulose coating on saffron quality during storage

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ABSTRACT

Since saffron is an added-value product, and the most expensive agricultural product, it is necessary to increase its shelf life, prevent its quality loss during storage, and maintain its organoleptic properties, enabling producers to export saffron with higher quality and better consumer acceptability. So, in this research, saffron samples were coated through applying different carbohydrate biopolymers: maltodextrin with DE = 4 or DE = 20 (MD4 and MD20) or their combination with nanocellulose fibres (MDC4 and MDC20). Finally, the experiments were carried out to measure rehydration ratio, water activity, crocin content, color values, and sensory properties of saffron samples coated by different materials. MDC4 resulted in the lowest rehydration ratio among coated samples since, first, lower DE degrees of biopolymer complexes decreased moisture adsorption and solubility of maltodextrin and second, crystalline nanocellulose fibres increased tortuous and bended pathways in materials and reduced penetration possibilities of water molecules. MDC4 was the most effective treatment in preventing crocin decrease. Indeed, film forming characteristic of maltodextrin with low hydrolysis degree and special structure of nanocellulose led to the maintenance of crocin bioactive ingredient. SEM observations revealed coating on saffron surfaces as a thin clear and brilliant layer which enhanced saffron acceptability for our panelists.

1. Introduction

Saffron is of paramount importance in the cycle of non-oil export development for Iran and is considered among super strategic plants due to its job-creating and profitable advantages. Saffron is one of the most common and important spices consumed in the food industries, often in powder form for improving color, aroma and taste of food products and despite becoming more expensive recently, its consumption in pharmaceutical industries is developing. While the world's total annual saffron production is estimated to be 190 tons, Iran produces about 90% of the total rate (Maghsoodi, Kazemi, & Akhondi, 2012; Mahdavee Khazaei, Jafari, Ghorbani, & Hemmati Kakhki, 2014). Chemical composition analyses have revealed approximate composition of saffron: 10% moisture, 12% protein, 5% fat, 5% minerals, 5% crude fibre, and 63% sugars including starch, reducing sugars, pentosans, gums, pectins, and dextrins (Rajabi, Ghorbani, Jafari, Sadeghi Mahoonak, & Rajabzadeh, 2015). The four major bioactive compounds in saffron are crocin, crocetin, picrocrocin and safranal; crocin is broadly used as a natural food colorant due to an orange colored solution made by rapid dissolution of crocin in water (Mehrnia, Jafari, Makhmal-Zadeh, & Maghsoudlou, 2016; Mehrnia, Jafari, Makhmal-Zadeh, & Maghsoudlou, 2017). Apart from its high capacity to produce color, other beneficial properties of crocin are: antioxidant activity through quenching free radicals and protection of cells and tissues against oxidation (Shahi, Assadpour, & Jafari, 2016). Generally, saffron is useful to treat gastric disorders, prevent any damage to the stomach mucosa and improve protein digestion (Melnyk, Wang, & Marcone, 2016; Sarfarazi, Jafari, & Rajabzadeh, 2015).

It is always tried to maintain the best conditions for keeping saffron properties and increase its shelf life since fragrant materials of saffron are evaporable and in unsuitable conditions, its essence is evaporated and its flavor and odor are diminished and its quality is lessened. These days, the demands for food products with quality similar to fresh state and high shelf life are increasing. As a result, miscellaneous technologies emerged in food science to keep the quality and shelf life of food products as high as possible. Nowadays, edible films and coating are being applied which have its basis on polysaccharides, proteins, lipids or a combination of them. Edible coatings are thin layers of food products applied directly on the surface of materials going to be preserved or their quality to be improved. From the other side, nanoscience, as an example of novel technologies, has this potential to improve quality and safety of our food and owns the merits of higher efficiency and less cost, compared with common coating materials. This information convinced us to attempt for deploying biopolymers and nanoscience to coat

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saffron samples appropriately after designing a new equipment for this purpose.

By now, most researches have focused on evaluating effects of environmental factors on quality properties of saffron. Alonso, Varon, Gomez, Navarro, and Salinas, 1990 studied the effect of storage at 40 °C and 75%RH on oxidation of saffron through investigating into color and taste of those saffron samples. They concluded that color and taste followed dissimilar reaction order kinetics: first and second order, respectively. Morimoto (1994) studied post-harvest decomposition of carotenoids in saffron samples. They reported that indoor growth was more suitable for *Crocus sativus* L. than open field situations as far as the quality is concerned. The effects (presence or absence) of temperature, oxygen, light, and β-glucosidase were really crucial to the degradation of saffron during storage; furthermore, their research showed that −20 °C was an appropriate temperature to maintain medicinal properties of saffron during long-term storage of 2 years or more. Raina, Agarwal, Bhatia, and Gaur, 1996 analyzed alterations in ingredients responsible for color and flavor of saffron during different processing (drying) and storage conditions for saffron samples. Various drying methods, i.e. solar, oven, vacuum oven, at temperatures between 35 and 50 °C were used and unlike storage durations were examined. They found that while two drying approaches of solar and oven resulted in the development (up to 60%) of safranal, vacuum oven contributed to the promotion of 4-β-hydroxysafranal as the major ingredient. Their findings indicated that appropriate packaging and storage environment with only 5% water content can increase shelf-life of saffron samples substantially.

In another research, Tsimidou and Biliadris (1997) stored saffron powder at different water activities/temperatures and studied the kinetics of carotenoid loss. They found that kinetics of pigment degradation was similar to first-order type reactions; besides, the correlation between pigment deterioration and two variables was very strong. They also expressed that at room temperature, the medium water activities (0.43–0.53) could support appearance of aroma ingredients and suppress carotenoid degradation reactions more favorably. Bolandi, Shahidi, Sedaghat, Farhoush, & Mousavi-Nik, 2008 showed that storage period and drying conditions had significant effects on color, odor and flavor characteristics of saffron. Also, they stated that during storage period, crocin and safranal decreased and increased, respectively. Besides, they expressed that safranal rate raised at the beginning of the storage period but remained constant after 6 months of storage. Salari, Najafi, Karajian, & Vazirzadeh, 2010 evaluated physicochemical changes in saffron during one-year storage period and realized that storage length affected color strength and crocin rate decreased during this span. Besides, whereas moisture content, aqueous extract, crocin, picrocrocin, and other microbial properties of saffron decreased during storage period, safranal indicated an increasing trend. Jairmand, Rezaee, and Najafi Ashtiany (2010) monitored crocin contents of saffron stigma during long-term (20 months) storage conditions in different cities. They reported that dark storage conditions were more desirable for maintaining crocin content of saffron stigma than storage under the light or in refrigerator (0 °C).

This research aims to survey the effects of carbohydrate polymers on quality and physicochemical properties of saffron and its storage time; the carbohydrate resources selected for this research includes maltodextrin and nanocellulose as maltodextrin creates shiny surfaces and help drying of coating occur faster, and nanocellulose have outstanding optical and structural, including low density and high biodegradability rate, characteristics while both of them are cheaper than other fillers/nanofillers (Dehnad, Emam-Djomeh, Mirzaei, Jafari, & Dadashi, 2014; Dehnad, Mirzaei, Emam-Djomeh, Jafari, & Dadashi, 2014; Akhavan Mahdavi, Jafari, Assadpoor, & Dehnad, 2016). Since saffron is an added-value product, and the most expensive agricultural product, we hope to find a solution to increase qualitative properties of saffron, prevent its quality loss during storage, improve its organoleptic properties (by minimal expenditure), enabling us to export saffron with higher quality, and better consumer acceptability. It should be mentioned that effects of the selected carbohydrate biopolymers on saffron samples through spraying by the designed equipment have not been surveyed yet. Besides, this equipment was contrived for the first time.

2. Materials and methods

120 g Iranian Pushal Saffron grade 1 was purchased from Bahraman Co. (Mashhad, Iran) while packaged in vacuum and kept in dark at room temperature before experiments. Maltodextrin powders with DE = 16.5–19.5 and DE = 4–7 were purchased from Sigma-Aldrich Company, with product numbers of 419699 and 419672, respectively. Nanocellulose fibres with diameter below 100 nm were bought from Serva Group Company, USA.

2.1. Design and set-up procedures of coating equipment

For special coating of saffron, the required equipment was designed and made, facilitating coating operation by spraying of coating material on the food product. As follows, the equipment performance and set-up stages are explained in detail:

Different elements of the equipment could be categorized into two sections: main parts and minor parts. While main parts include air compressor (12 V, current intensity of 5 A, external power of 150 PSI, Tornado, China), gearbox motor (12 V, external speed of 50 RPM, 20GA, GTF Motors), SERVO motor (turning angle of 360°, MG995, Tower Pro.), pressure vessel, mist nozzle, connection hoses, screen drum (20 × 15 cm^2, cylindrical with 1 mm Mesh number), fan (12 V, high speed, 4 × 4 cm^2, Comdell, China), heater, operational control driver (all operations of the equipment including turning rate of motor, spraying amount of nozzles were controlled by the driver), and power supply (12 V, 30 A, industrial), minor parts included (metal) girth, aluminum leg, holding leg, cables and connection wires, automatic screw, wooden plate as the main frame plate of equipment (water-proof MDF wooden plates were used to avoid short-circuit, neutralize generated charge, and provide more safety).

In the first stage, air compressor and pressure vessel were used to generate and store pressure (Fig. 1). For this purpose, after filling the container with coating substance (its preparation method will be described later), connecting vessel to compressor was carried out and after ensuring from proper connection, compressor turned on and was adjusted at the required pressure; after reaching the required pressure monitored by the pressure gauge installed on the compressor, the compressor turned off.

In the next stage, saffron samples were located within the screen drum and distributed evenly. Then, spraying was carried out through nozzles by pressing S. button above the net-like chamber, having been contrived for this purpose. Total spraying duration was 1 s and it was retaliated another time to ensure spraying of the whole surface. During spraying operation, turning operations kept running with very low speed, adjusted by the volume button on the driver, to allow spreading of coating material on the whole surface. After finishing the work, stopping the spraying operation and ensuring the whole coverage of coating material, fan of the equipment turned on and the temperature was set between 0 and 150 °C by the volume button on the driver section, so blowing and drying were carried out at the same time (Fig. 1).

2.2. Preparation of coating materials

4% maltodextrin solution was prepared on weight basis: 4 g of maltodextrin with DE = 4–7 or DE = 16.5–19.5 was added to 96 g of distilled water and the complex was located on a water bath (Memmert, Germany) for 30 min at 60 °C. The 4% maltodextrin-nanocellulose solution was prepared similarly. For this purpose, 3 g of maltodextrin with DE = 4–7 or DE = 16.5–19.5 and 1 g of nanocellulose were added