JRIFST
Original Paper

https://journals.rifst.ac.ir
ISSN: 2252-0937(print), 2538-2357(online)
Journal of Research and Innovation in Food Science and Technology
11 (2022) 3, 233-246
https://doi.org/10.22101/JRIFST.2022.306907.1279

Research Institute of Food Science and Technology

Extending Shelf Life of Noughl by Modifying Relative Humidity of the Container: Study of Physicochemical and Textural Properties

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Abstract
Dehydration of Noughl, as a sugar-based confectionary product, negatively affects its texture which can be hindered by increasing relative humidity (RH) of atmosphere of storage container. In this research, glucose syrup (GS) and its mixture with salt at different ratios (8:1, 4:1 and 2:1) was utilized as RH-modifier inside the storage container in order to prevent hardness of Noughl. The effect of RH-modifiers on moisture, hardness, area and color of samples was investigated during 30 days. Color and area changes of samples were measured using image processing. According to the findings, the lowest change in moisture content, color and area of saffron Noughls was observed when GS-salt mixture was used at the ratio of 8:1. It is found that the RH-modifier could re-increase the RH of container internal space after opening and reclosing lid of the container for 29 times. Furthermore, hardness of Noughls was hindered since the average hardness values were 32.40 and 23.38 N on zero and 30 days, respectively. However, hardness of control sample reached to 149.85 N on day 5. Based on sensory evaluation, there was no significant difference between the overall acceptability of fresh Noughls and those stored for 30 days ($P<0.05$). The introduced low-cost RH-modifier can be applicable for different foodstuffs to prevent dehydration.

Received: 2021.09.28
Revised: 2022.01.21
Accepted: 2022.01.22
Online publishing: 2022.04.11

Keywords
Glucose syrup
Image processing
Moisture loss
Noughl
Relative humidity-modifier

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Introduction
As a fact, when a fresh food is located in an atmosphere with low RH it becomes dehydrated via escaping of water molecules from the surface to the fluid which is called desorption. Once a food comes into equilibrium with the surrounding atmosphere, the water activity (a_w) of the food becomes equal to and RH of the surrounding atmosphere divided by 100 (Eq. 1). In other words, after reaching equilibrium, the food sample neither gain nor lose moisture over time (Figura & Teixeira, 2007; Sahin & Sumnu, 2006).

$$a_w = \frac{RH}{100} \quad (1)$$

There are some reports showing different attempts on modifying of RH to maintain the quality of products. In this regard, a humidity controlled package was introduced by Klann (2018) which is equipped with a sensitive valve with the capability of being opened and re-closed to control RH via air flow. Furthermore, a group of researchers developed a cellulose-based film to regulate humidity by preventing water vapor condensation on the film surface to increase the storage life of broccoli which respires and produces H_2O during storage (Caleb *et al.*, 2016). Panda & Townsend (2014) used a water nozzle in order to increase the RH of a container to a defined value. Besides, to control the RH of a container, evaporator fans of the refrigeration system have been applied (Thogersen & Dyrmose, 2017). As stated, different apparatus might be needed to modify the RH of a container which makes it costly to provide energy and to purchase the necessary equipment. Hence, it seems that finding a non-expensive method to modify the RH of atmosphere of a container would be a new approach for avoiding moisture loss and hardening of food products.

Generally, to gain a specific RH value for speeding up chemical reactions, it is possible to use saturated salt (e.g. NaCl, KCl, K_2CO_3), glycerol or sulfuric acid solutions (Sahin & Sumnu, 2006). As an example, it is common to use saturated KBr to enhance RH to 79% to accelerate Maillard reaction for synthesis of glycoprotein (Miralles *et al.*, 2007; Wong *et al.*, 2011; Xu *et al.*, 2012). However, without any doubt, a RH-modifier for foods must be non-toxic and highly viscose to assure there is no flow toward food during transport and also a movement of storage container; therefore, the saturated solutions used for chemical reactions are not suitable for foods.

Noughl is an Iranian traditional confectionary product which is a sugar coated almond/walnut that suffers from dehydration in a short time. It contains sugar, water, herbal distillates (such as Salix aegyptiaca distillate), citric acid, vanilla, cardamom and sometimes saffron, cinnamon or dried damask rose (Azarikia, 2019).

To the best of authors' knowledge, there is no report on using a food-grade viscous material as a RH-modifier to increase RH for preventing food hardening. Thereupon, the purposes of the present study were: (1) to modify RH of a storage container using edible materials (mixture of GS and salt) with high viscosity to assure that the formulated compound will not be thrown toward the food during transporting-despite being edible, (2) to investigate the capability of the formulated RH-modifier on re-increasing RH of container atmosphere after opening and re-closing container lid for 29 times, (3) to identify the effect of RH-modifier on physic-mechanical properties (moisture, hardness, color, area and sensory properties) of Noughl during storage for 30 days.

Materials and methods

Materials

The glucose syrup (GS), with a dextrose equivalent of 42 obtained from hydrolysis of corn starch, was donated by Zar Fructose Co. (Hashtgerd, Iran). Refined salt (Golha food industry, Iran), was prepared from a local grocery store (Tehran, Iran). Noughls were bought from a confectionary store (Tarkhan, Iran) in Urmia.

Preparation of GS-salt mixture to prevent dehydration of Noughl

To find an appropriate formulation for RH modification, GS and salt was mixed at the ratios of 8:1, 4:1 and 2:1. In this regard, salt was gradually added to glucose syrup and mixed gently by continuous stirring at 50 °C for 1 h. Then, it was poured inside a small polypropylene container (220 mL) that was stuck to a bigger cubic polypropylene container (3.7 L). A digital RH-meter (TFA, Germany) was also put inside the bigger container to monitor the RH of its atmosphere. The next day, when the equilibrium was reached and RH remained constant, RH data were collected at ambient temperature. To peruse the ability of GS-salt mixture in re-increasing of RH of container atmosphere, the lid of container was opened and reclosed when the digital RH-meter showed that RH of container reduced to the room RH. Measurements were done during 30 days.

To study the effect of RH-modifiers on the properties of Noughls, 500 g of saffron Noughls were located inside the polypropylene container containing RH-modifier (Fig. 1). As a control sample (C), Noughls were stored at ambient condition. To study the efficiency of storing inside a container without a RH-modifier, Noughls were also stored inside a container with no RH-modifier and it was called sealed-control samples (SC).

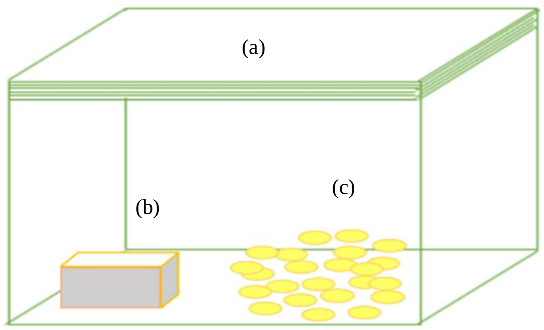

Fig. 1. Schematic of active storage container: (a) polypropylene container (3.7 L), (b) GS-salt mixture inside a small container (220 mL), and (c) Noughls (500 g).

Monitoring of GS and GS-salt mixture level during time

In order to determine surface evaporation from GS and GS-salt mixture, a system consists of an ultrasonic sensor (SRF04, China), a digital humidity sensor (HTU21, China), a data logging module (Catalex, China) and OLED display (Adafruit, SSD1306, China) was designed. To control the system, all the components were connected to a micro-controller (AVR, ATmega32, China). The main aim of this system was to clarify RH-modifiers role on RH rise. To do so, surface evaporation was monitored through the determination of RH-modifier level using the ultrasonic sensor for 29 days.

Characterization of Noughls

Moisture content was determined according to the method reported by AOAC (2002). To evaluate the hardness of Noughls stored at different conditions, a texture analyzer (Hounsfield, H5KS Model, UK) equipped with a 50 mm cylindrical probe and a load cell of 500 N was used. To accomplish the uniaxial compression test, samples with an intermediate diameter of 17±1 mm were chosen and the probe speed was 25 mm/min. The hardness was determined where the peak in the force-distance curve was observed. Additionally, breakage energy (E), the energy absorbed by the sample at the peak point, was defined by calculating the area under the force -distance curve using the following, (Hassan-Beygi *et al.*, 2009):

$$E = \frac{1}{2} FD \qquad (2)$$

Where, F: is the force and D: is the distance at peak point. Hardness and breakage energy were studied for 30 days by testing at least 5 samples. In the case of C samples, the evaluation was carried out only for 15 days due to being too hard and obtaining unreliable curves in the next days.

To study the changes of color and area of Noughl samples, image acquisition and processing were applied. In this regard, the optical image capturing and processing system included: a digital camera (Nikon, D3400, USA) fixed at a constant distance from the samples (25 cm) perpendicular to the imaging surface, two 25 w LEDs which were mounted at a 45^{o} angle with respect to the horizontal plane for eradicating shadows and a laptop with MATLAB software (2013, Version. 8.1). After taking images, they were transferred to the laptop, following by a preliminary preprocessing (i.e. contrast enhancement and noise removing). Furthermore, image segmentation was conducted using Otsu method (Zhao *et al.*, 2020). Afterwards, area opening and closing operators were used to remove the background noises and fill the deleted area inside the object, respectively. After that, segmented images were transformed to Lab color space using the method proposed by Soltanikazemi & Abdanan Mehdizadeh (2017). Finally, the binary image was multiplied to each R, G, B, L*, a* and b* color bands to determine the average of each color channel during the storage period.

As the next step, the obtained a* and b* values were documented and utilized to calculate hue angle (h°) based on the method described by a group of researchers (McLellan *et al.*, 1995). Briefly, when both a* and b* values were positive Eq. (3) was used for calculation of h°; whilst, Eq. (4) was applied when a* value was negative. To report changes of hue angle after storage for 30 days (Δh°) the Eq. (5) was utilized, where $h°_0$ and $h°_{30}$ are the hue angle on the 1st and 30th days, respectively:

$$\text{Hue angle} = \arctan(b^*/a^*) \quad (3)$$

$$\text{Hue angle} = 180 + \arctan(b^*/a^*) \quad (4)$$

$$\Delta h° = h°_{30} - h°_0 \quad (5)$$

For sensory evaluation, sensory attributes including taste, texture, color, odor and overall acceptability of the samples stored at different storage conditions were appraised by 20 semi-trained panelists during 30 days. The 3 digit coded samples were presented to panelists in random order along with drinking water for mouth rinsing to prevent carry-over flavor after each stage of sensory evaluation. A 5-point hedonic test was applied for evaluation in which 5 stood for excellent and desirable quality, while 1 for poor and undesirable quality.

Statistical analysis

The obtained data were analyzed using one-way ANOVA. The least significant difference (LSD) was also utilized to determine significant differences between mean values using SPSS software (Version 14.0). Image processing was accomplished via MATLAB software (2013, Version. 8.1). All experiments were performed at least in triplicate.

Results and discussion

Effect of salt on RH of container atmosphere

It is found that RH of atmosphere of containers containing GS or GS-salt mixture at the ratios of 8:1, 4:1 and 2:1 were 81±1, 73±1, 67±1 and 60±2%, respectively. It indicates that the addition of salt led to a decline of RH: the higher the salt concentration, the less the RH value. This reduction might be related to hydration of NaCl leading to the formation of Na^+ and Cl^- followed by dipole binding between Cl^- ions of salt and H^+ ions of water molecules at the surface of GS-salt mixture (Figura & Teixeira, 2007) which diminished desorption; in other words, lower number of water molecules escaped from GS to the container atmosphere due to salt addition.

Notably, adding salt at different ratios not only altered the RH of atmosphere of containers, but also changed the apparent viscosity of RH-modifiers. Although rheological properties of GS-salt mixtures will be discussed in another report, it is noteworthy to mention that the apparent viscosity of GS and GS-salt mixture at the ratios of 8:1, 4:1 and 2:1 at a shear rate of 42.9 1/s were 225, 396, 618 and 725 Pa.s, respectively (data are not shown). This indicates that salt addition caused an increment of apparent viscosity which is attributed to attractive interaction between glucose syrup and salt molecules (Deumier & Bohuon, 2005).

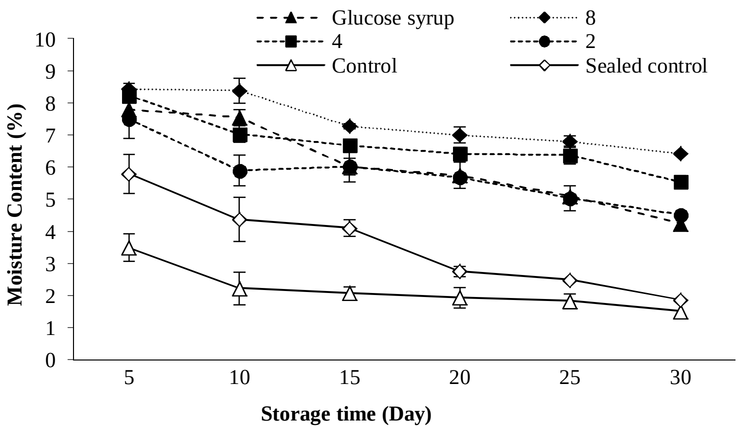

Fig. 2. Moisture content of Noughls stored at various storage conditions

Effect of storage condition on moisture of Nough during storage time

Fig. (2) represents the moisture content of Noughls stored at different conditions for 30 days. With respect to the initial moisture content of Nougls that was 8.6±0.4%, SC and C samples showed a moderate and dramatic reduction in moisture content in the first 5 days of storage, respectively. Transfer of water molecules between Noughl and the surrounding fluid atmosphere took place in two steps: (1) diffusion of water out of the interior tissue structure of Noughl, and (2) escaping of water across the sample surface boundary that is known as desorption. Notbly, only "free water" molecules have the ability to leave food and escape into the surrounding atmosphere. Ionic and hydrogen bonds are responsible for interaction between food component and water molecules; hence, the lower the number of ionic or polar molecules in the food, the less water is held (Figura & Teixeira, 2007). Therefore, Noughl which is composed of sugar, water and little amount of vanilla, herbal distillates, citric acid and cardamom was sensitive to dehydration in a short time. Although both C and SC samples had lower moisture content in comparison with samples stored with RH-modifiers during storage, the moisture content in the case of SC Noughls was higher than C which indicates the positive impact of closing the lid of the container in delaying loss of free water. More likely, the approximate constant moisture level seen in Fig. (2) for both C and SC on day 30 corresponded to presence of "bound water".

On the other hand, in samples stored inside the containers containing GS and GS-salt mixture a slight decline was observed, confirming the capability of RH-modifiers in the reduction of moisture loss. This capability was attributed to exit of water molecules from GS of RH-modifiers toward the surrounding atmosphere. As stated before, RH-modifiers considerably raised the RH of atmosphere of container to values higher than room RH (40±2%). Hence, when RH of container atmosphere was higher than room RH, fewer water molecules tended to escape from the surface of Noughl toward the surrounding fluid phase. Based on Fig. (2), although there was a reducing trend in moisture content in the whole samples during storage time, the samples stored in the presence of GS-salt mixture at the ratio of 8:1 had the lowest moisture loss after storing for 30 days. The reason for the better effectiveness of this RH-modifier will be discussed in the next section.

Effect of opening and re-closing of container lid on RH value during time

In order to determine the effectiveness of GS and GS-salt mixture at the ratio of 8:1 on increasing RH of container atmosphere after opening and re-closing the lid, RH and the changes of RH-modifier level were measured during 29 days (Table 1). According to the outcomes, it is observed that the RH of container containing GS was remarkably higher than room RH until day 11. That is to say that GS was able to sharply enhance RH after opening and re -closing the lid of the container 10 times (1 time a day, 10 days). Reduction of RH-modifier level after opening and re-closing for 10 times (0.14 cm) confirmed mass transfer from GS to the gas phase. However, from day 13 to 21, only a slight increase in RH was observed. Afterwards, from day 21 to 29, RH magnitude was near to room RH, attributing to the formation of a thick layer on GS surface based on visual observations. Since there was no alteration in the level of GS from day 13 to 25, it seems this barrier layer completely formed on the 13th day and prevented mas transfer from GS to gas. Besides, the change in RH-modifier level increased from day 25 to 27 probably due to shrinkage of the barrier layer. Interestingly, focusing on the moisture content of Noughls stored in the presence of GS shows a sharp decrement on day 15 (Fig. 2). Undoubtedly, formation of a barrier layer was responsible for the dehydration of Noughl on the 15th day.

Contrary, continuous change of GS-salt mixture level at the ratio of 8:1 was evidence of water molecules migration toward the atmosphere, indicating no barrier layer formed on the surface. It clarifies the importance of salt present in the formulation of the RH-modifier. Probably, dipole bonds between Cl^- of salt in RH-modifier and H^+ of water molecules of surrounding air might keep water molecules near the surface of GS-salt mixture which could hinder case-hardening. Similarly, NaCl solution used for osmotic dehydration prevents case-hardening of foods during dehydration (Torringa *et al*., 2001).

Since a_w of Noughls are almost 0.51 (Azarikia, 2019), dehydration of Noughls can be prevented when the RH of atmosphere becomes 51 or higher, based on Eq. (1). Therefore, Table (1) affirms that GS-salt mixture at the ratio of 8:1 were able to provide appropriate RH (higher than 51%) after opening and reclosing the container lid for 29 days which was the reason for a positive effect of this RH-modifier on the prevention of dehydration discussed earlier.

Table 1. Relative humidity of the container atmosphere containing GS or GS-salt mixture at the ratio of 8:1 as well as change of the RH-modifier level as a function of time

Days	GS		Mixture of GS-salt (8:1)	
	RH (%)	Level change (cm)	RH (%)	Level change (cm)
1	80.86	0.00	73.01	0.00
3	78.23	0.07	72.28	0.00
5	75.71	0.10	70.66	0.00
7	74.02	0.10	69.24	0.08
9	72.87	0.12	67.73	0.46
11	68.36	0.14	66.98	0.48
13	50.86	0.18	62.93	1.09
15	47.11	0.18	62.11	1.15
17	46.04	0.18	61.84	1.15
19	44.18	0.18	60.82	1.18
21	43.31	0.18	56.09	1.19
23	42.00	0.18	55.75	1.22
25	42.00	0.18	55.24	1.22
27	40.54	0.48	54.23	1.24
29	40.19	0.48	52.94	1.24

Effect of storing condition on area of Noughls

Foods could be shrunken, hard and brittle due to losing of free water (Cybulska, 2006). Fig. (3) shows area changes of Noughls stored at different conditions after 30 days. Based on the findings, storing the samples inside a container containing GS-salt mixture at the ratio of 8:1 had the lowest effect on reduction of the product area, followed by GS-salt mixture at the ratio of 4:1. Intrestingly, there was a coordination between area changes and moisture content results. The highest shrinkage caused by desorption belonged to C, SC, GS and GS-salt mixture at the ratio of 2:1. Similarly, there are several reports confirming that shrinkage increased with a decrease in moisture content (Dissa *et al*., 2010; Koua *et al*., 2019; Mercier *et al*., 2011; Zogzas *et al*., 1994).

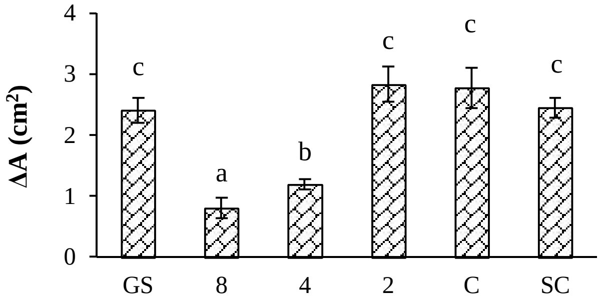

Fig. 3. Efficiency of different storage conditions on the changes of area of Noughls on 1 and 30 days (ΔA) (P<0.05). GS: Glucose syrup, 2: GS-salt mixture at the ratio of 2:1, 4: GS-salt mixture at the ratio of 4:1, 8: GS-salt mixture at the ratio of 8:1, C: control sample, SC: sealed-control sample. Various letters show significant difference at P<0.05.

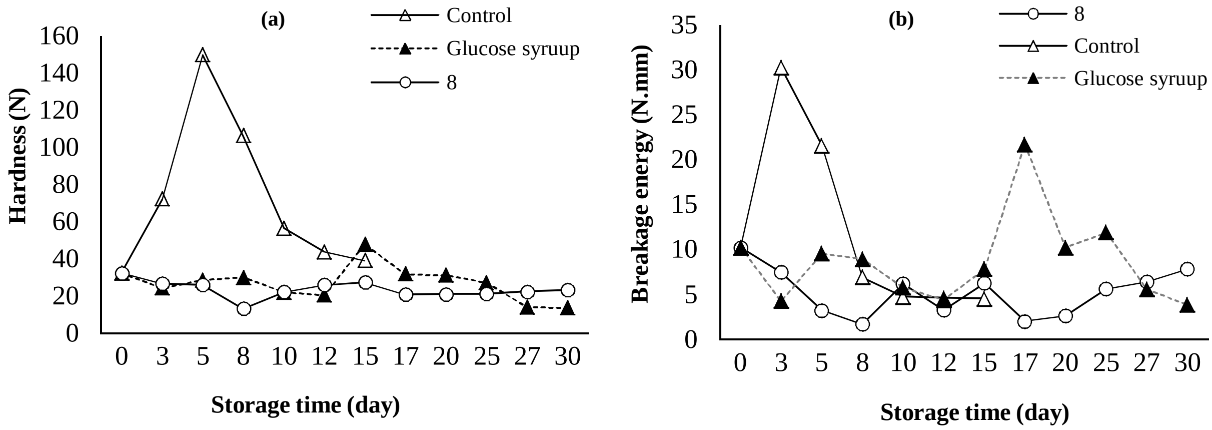

Fig. 4. (a) Hardness and (b) breakage energy of Noughls at different storage conditions

Effect of storing condition on hardness of Noughl

In the C sample, there was a sharp increase in hardness from day zero to day 5 of storage which was attributed to dehydration (Fig. 4a). Previously, the increment of hardness due to water loss has been found for different types of Noughls (cinnamon, damask rose, vanilla and saffron) stored at room RH (Azarikia, 2019). Likewise, other researchers also reported hardening of mortadella due to reduction of moisture content (Viuda-Martos *et al.*, 2010). However, after the peak on day 5, a downward trend was observed in C sample: a dramatic fall from day 5 (149.85 N) to day 10 (56.57 N), following by a moderate decrease from day 10 (56.57 N) to day 15 (39.10 N). This reducing trend seems to be due to the formation of porous structure on the product surface which could result in less persistency of Noughls against the applied force. It has been proved that the porosity of foods increased as the water was removed during dehydration (Dissa *et al.*, 2010; Koua *et al.*, 2019; Mercier *et al.*, 2011; Zogzas *et al.*, 1994).

On the other hand, it was found that the hardness of Noughls stored in the presence of GS did not increase until day 12, while a rise was observed from day 12 (20.5 N) to day 15 (47.93 N) followed by a decreasing trend, similar to C sample. As stated, GS was able to modify the RH of container atmosphere to values higher than 51% before day 13. However, in future days, formation of the barrier layer on GS surface inhibited escaping of water molecules from GS-gas boundary surface. For this reason, texture hardening was enhanced after storing for 12 days via dehydration. Similar to the pattern found for hardness-time curve of C sample, after the upward trend of GS sample from day 12 to 15, a downward trend was observed until day 30. As stated, formation of pores on the product surface was responsible for hardness reduction. However, hardness of the Noughls stored in the presence of GS-salt at the ratio of 8:1 not only did not increase during storage for 30 days, but also it was slightly lower than hardness of fresh Noughl. Actually, from day 1 to 8, there was a detectable reduction in hardness attributing to adsorption (Fig. 4a). Since RH values of the container during these days were approximately 70% or higher (Table 1) and a_w of Noughls were 0.51, to reach an equilibrium according to Eq. (1), water molecules of gas phase could link to Noughls' surface via weak hydrogen bonds (Figura & Teixeira, 2007). These results were in agreement with the data obtained from studying of the area because the area of Noughls stored in the presence of GS-salt at the ratio of 8:1 increased during storing for 10 days (data are not shown). Howsoever, according to both area and textural data, it seems the weak hydrogen bonds between GS-gas phases did not exist during further days. The reason probably can be attributed to the fact that, although GS-salt mixture had the capability of re-increasing the RH after re-closing the container, RH values were not the same in all storage days and it gradually decreased during 30 days of storage (Table 1).

Studying the breakage energy of C Noughls as a function of time showed a rising trend followed by a falling one, similar to harness. By comparing Fig. (4b) and Fig. (4a), it is found that breaking energy reached its maximum value on day 3, while the maximum value in hardness was seen on day 5. As well, a comparison of breakage energy of these 2 days declared that more energy was needed to break Noughls on day 3 (30.30 N.mm) than day 5 (21.59 N.mm). Therefore, it can be concluded that probably formation of porous structure in C samples started after day 3 and the newly formed pores were not effective on reduction of hardness on day 5.

Comparison of breakage energy of 30-day-old Noughl stored inside the container containing GS-salt at the ratio of 8:1 with fresh product demonstrated no increase during storage. By focusing on both moisture content and breakage energy data, it could be concluded that the Noughls with higher moisture content had lower breakage energy which indicates that lower the breakage energy, softer the Noughl.

Effect of storing condition on color of Noughl

Fig. (5) represents the appearance of saffron Noughls stored under different conditions for 30 days. As can be seen, discoloration occurred in saffron Noughls stored under the whole storage conditions, except the samples stored in the presence of GS-salt mixture at the ratio of 8:1. Since RH of GS-salt mixture at the ratio of 8:1 was higher than other storage conditions, it seems that discoloration due to saffron oxidation can be hindered at RH values above 51%. Saffron, the additive used as a colorant in the formulation of Noughls, contains the water-soluble pigment crocin, zeaxanthin, and β-carotene (Wilska-Jeszka, 2006). It has been previously reported that a_w and temperature highly affected the degradation of saffron carotenoid, mainly crocins (Tsimidou & Biliaderis, 1997). It seems that our results about the dependency of discoloration upon RH were in agreement with the previous report referring to the relation between RH of container and food a_w according to Eq. (1).

Moreover, the visual property of samples also was negatively affected by sugar bloom. On day 10, white chalky spots were detectable on the surface of the Noughls stored in the presence of GS. As a fact, sugar bloom happens by the deposition of water from the air onto the product, followed by dissolving sugar on the surface. Once water diffuses back into the air, spotty appearance forms because of sugar recrystallization on the surface (Andrae-Nightingale *et al.*, 2009).

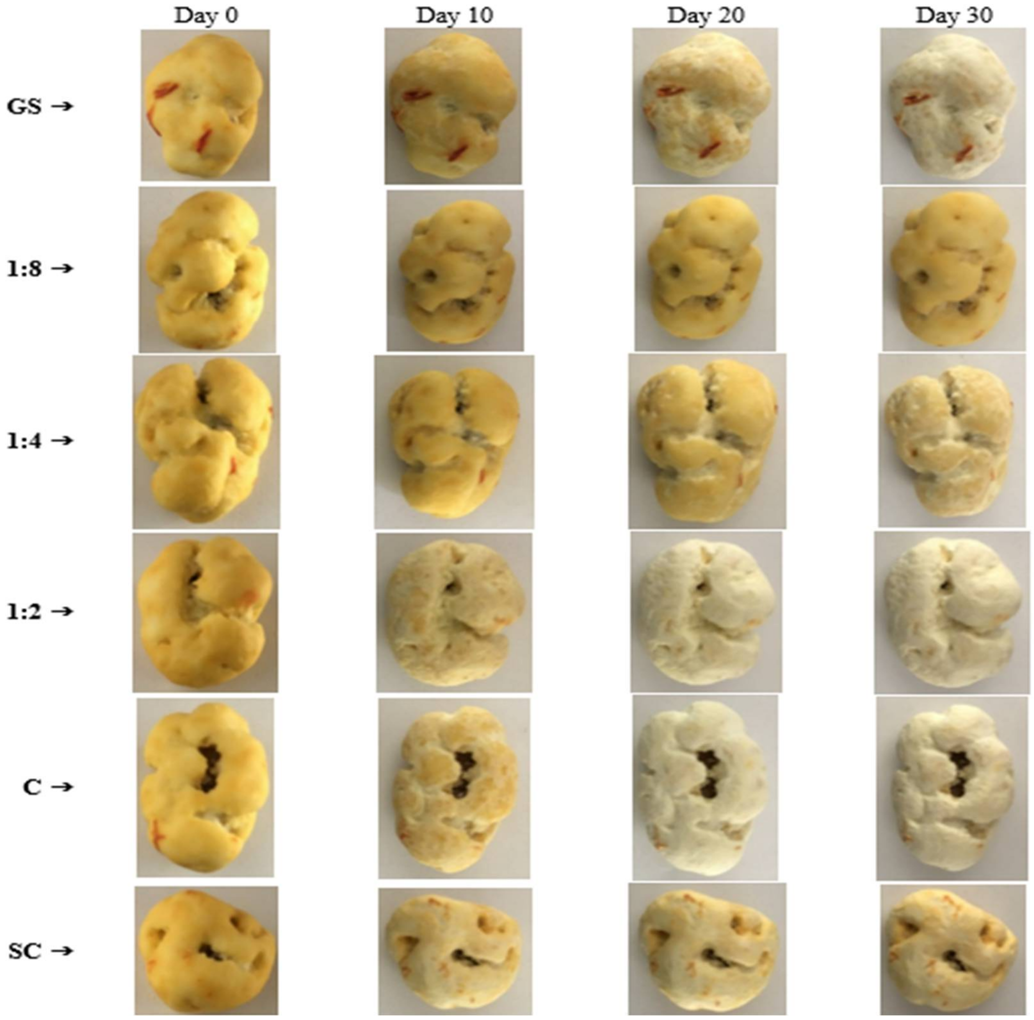

Fig. 5. Appearance of saffron Noughls stored under different conditions on different storage days. GS: Glucose syrup, 8: GS-salt mixture at the ratio of 8:1, 4: GS-salt mixture at the ratio of 4:1, 2: GS-salt mixture at the ratio of 2:1, C: control sample, SC: sealed-control sample.

According to Table (1), RH of container atmosphere in the presence of GS was found to be higher than the container containing GS-salt mixture at the ratio of 8:1 until day 11, this higher RH might be effective on the absorption of water from the air to Noughls and sugar recrystallization in GS samples Fig. (6) illustrates a*, b* and L* values of Noughls during storage for 30 days. It shows that a* values shifted from positive to negative values, except in the case of Noughls stored in the presence of GS-salt mixture at the ratio of 8:1, in which a* remained on positive values with a negligible change during storage for 30 days. The shift from positive to negative values can be due to saffron oxidation. Furthermore, b* and L* values increased with a fluctuated trend. Increment of b* values in Noughls (except the ones stored in the presence of GS-salt mixture at the ratio of 8:1) was evidence of domination of yellowness and decrement of redness caused by oxidation of saffron pigments.

It is also found that, on days 20 and 30, the lowest L* belonged to GS-salt mixture at the ratio of 8:1, confirming the fact that storing under the other conditions led to higher L* because of whitening. On day 20, the highest L* value which represented the highest lightness, belonged to the C sample. Interestingly, its L* value decreased on day 30 which probably was attributed to an accumulation of dust particles on the surface of Noughls stored in the room with without packaging.

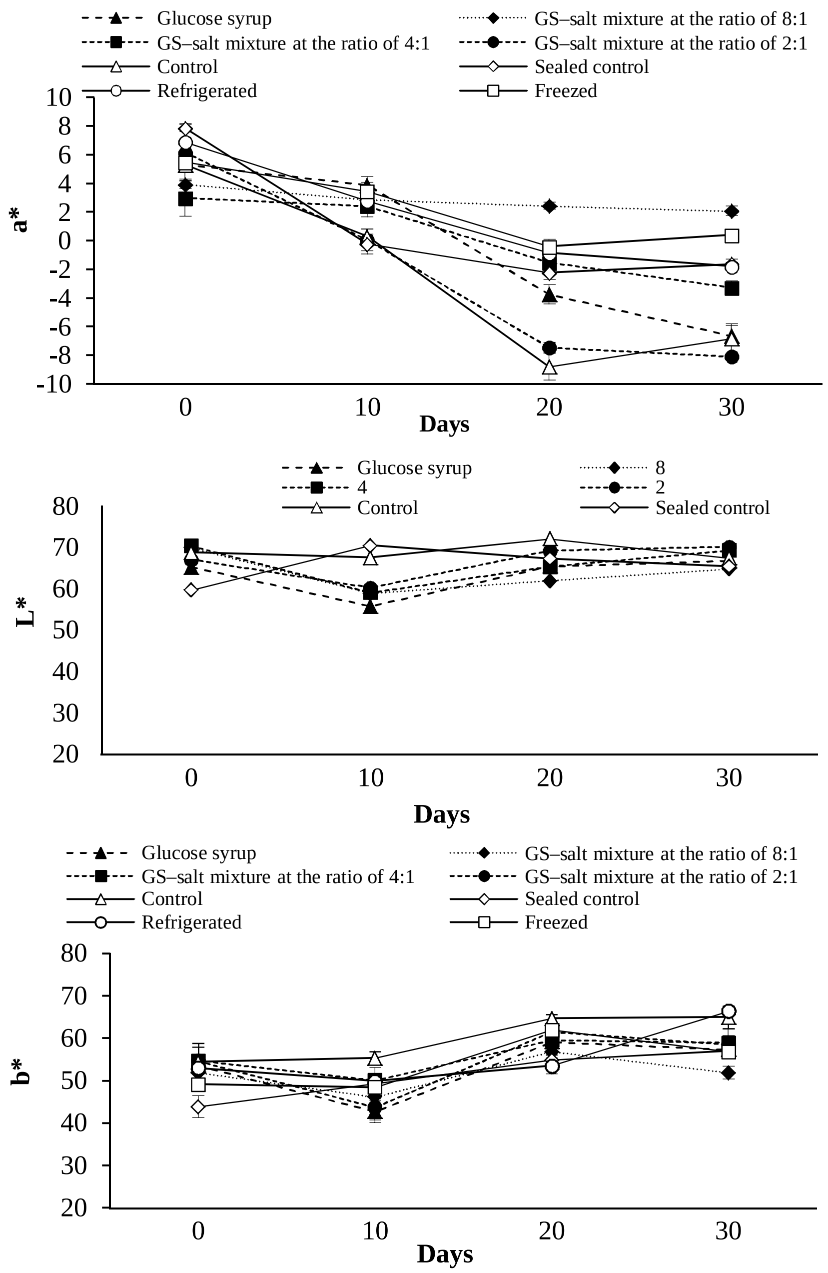

Fig. 6. a*, L* and b* values as a function of storage time for the Noughls stored under different conditions

Comparison of the uniform trend of a* changes and the fluctuated trend of b* and L* alterations might administrate that, according to image processing analyses, the most suitable indicator to show color changes during time for saffron Noughl containing little saffron particles on the product was a*. Although b* and L* color channels were previously found to be appropriate to study color changes for saffron Noughls without saffron particles on their surface (Azarikia, 2019). Hue angle (h°) is the most favorable way to report color when visual attributes should be presented (McLellan *et al.*, 1995). The changes of hue angle (Δh°) after storing the Noughls for 30 days for the sample stored in the presence of GS, GS-salt at the ratios of 8:1, 4:1, 2:1 were 11.48±0.69, 2.03±0.24, 6.20±1.58 and 12.90±1.89 degree, respectively. Therefore, in the presence of GS-salt at the ratio of 8:1, Δh° was significantly lower than the changes of hue angle for the other storage conditions demonstrating the effectiveness of GS-salt at the ratio of 8:1 on preserving the stability of Noughl color. The difference between the functionality of RH-modifiers highlighted the importance of RH of surrounding atmosphere on prevention of carotenoids degradation. Our results were in agreement with a previously published report, stating that the stability of maize carotenoids during storage was dependent on RH and temperature (Ortiz *et al.*, 2016).

Effect of different RH-modifiers on sensory properties

To evaluate the degree of preference for samples stored in containers containing GS or GS-salt mixtures as well as the Noughls stored at ambient condition (C or SC), a preliminary test was firstly accomplished after storing the samples for 5 days. Based on the preliminary evaluation, there was no difference between sensory properties of days zero and 5 in the case of Noughls stored in active storage containers containing GS and mixtures of GS-salt. However, a significant diminish in sensory attributes of C and SC Noughls was observed (data are not shown). Thereupon, to monitor sensory properties for 30 days, only the Noughls stored in the presence of RH-modifiers were considered. The results of the sensory comparison of RH-modifiers are represented in Table (2). Based on the results, GS-salt mixture at the ratio of 8:1 considerably had the highest score in the whole tested properties after storing for 30 days. Comparison of the ability of different RH-modifiers in maintaining the quality of product revealed that, in the case of taste of Noughls, a significant difference was observed between different used RH-modifiers after storing for 20 days. GS-salt mixture at the ratio of 8:1 had the highest score, while the samples stored in the presence of GS-salt mixture at the ratio of 2:1 could not be tested by panelists because of being too hard to be bitten. Similarly, in color evaluation, a significant difference between GS-salt at the ratio of 8:1 with other treatments was also observed on day 20. However, in texture and odor evaluations significant difference was seen on day 15 (P<0.05).

Table 2. Sensory properties of Noughls stored at different conditions during storage time

Sensory property	Sample type	Storage time (days) 5	10	15	20	25	30
Taste	GS	$4.63\pm0.48^{a*A}$	$4.47\pm0.59^{aA**}$	3.89 ± 0.62^{abA}	3.57 ± 0.67^{bAB}	NP	NP
	8	4.74 ± 0.43^{aA}	4.63 ± 0.47^{aA}	4.58 ± 0.58^{aA}	4.52 ± 0.49^{aA}	4.36 ± 0.58^{aA}	4.16 ± 0.54^{aA}
	4	4.58 ± 0.58^{aA}	4.42 ± 0.59^{aA}	3.79 ± 0.62^{abA}	3.10 ± 0.42^{bcB}	1.79 ± 0.68^{cB}	NP
	2	4.37 ± 0.73^{aA}	4.05 ± 0.70^{aA}	2.70 ± 0.62^{bB}	NP	NP	NP
Softness (Texture)	GS	4.80 ± 0.40^{aA}	4.73 ± 0.43^{aA}	3.35 ± 0.88^{bB}	3.10 ± 0.61^{bB}	1.40 ± 0.72^{cBC}	1.00 ± 0.00^{cC}
	8	4.84 ± 0.36^{aA}	4.79 ± 0.40^{aA}	4.63 ± 0.48^{aA}	4.53 ± 0.48^{aA}	4.47 ± 0.50^{aA}	4.05 ± 0.54^{aA}
	4	4.79 ± 0.40^{aA}	4.68 ± 0.48^{aA}	3.90 ± 0.54^{abB}	2.75 ± 0.75^{bcB}	2.63 ± 0.43^{cB}	1.50 ± 0.48^{dB}
	2	3.25 ± 0.52^{aB}	3.10 ± 0.53^{aB}	1.05 ± 0.22^{bC}	1.05 ± 0.22^{bC}	1.00 ± 0.00^{bC}	1.00 ± 0.00^{bC}
Color	GS	4.90 ± 0.30^{aA}	4.79 ± 0.40^{aA}	3.95 ± 0.44^{abB}	3.32 ± 0.71^{bB}	1.21 ± 0.53^{cC}	1.05 ± 0.3^{cC}
	8	4.95 ± 0.22^{aA}	4.89 ± 0.30^{aA}	4.84 ± 0.40^{aA}	4.79 ± 0.43^{aA}	4.73 ± 0.46^{aA}	4.68 ± 0.48^{aA}
	4	4.84 ± 0.36^{aA}	4.74 ± 0.43^{aA}	4.47 ± 0.59^{abA}	3.32 ± 0.71^{bB}	2.16 ± 0.73^{bcC}	1.79 ± 0.67^{cC}
	2	4.63 ± 0.48^{aA}	4.26 ± 0.69^{abB}	3.65 ± 0.47^{bB}	2.26 ± 0.43^{cC}	1.00 ± 0.00^{dC}	1.00 ± 0.00^{dC}
Odor (aroma)	GS	4.74 ± 0.43^{aA}	4.58 ± 0.58^{aA}	3.40 ± 0.57^{bB}	2.21 ± 0.77^{bB}	1.00 ± 0.00^{cC}	1.00 ± 0.00^{cB}
	8	4.79 ± 0.40^{aA}	4.63 ± 0.48^{aA}	4.53 ± 0.50^{aA}	4.11 ± 0.54^{abA}	3.95 ± 0.44^{abA}	3.26 ± 0.70^{bA}
	4	4.84 ± 0.40^{aA}	4.21 ± 0.68^{abA}	3.53 ± 0.49^{bB}	2.84 ± 0.65^{bcB}	2.15 ± 0.79^{cB}	1.05 ± 0.22^{dB}
	2	4.47 ± 0.59^{aA}	3.68 ± 0.64^{abA}	3.32 ± 0.41^{bB}	1.00 ± 0.00^{cC}	1.00 ± 0.00^{cC}	1.00 ± 0.00^{cB}
Overall acceptability	GS	4.79 ± 0.40^{aA}	4.42 ± 0.57^{abA}	3.35 ± 0.56^{bcB}	2.79 ± 0.89^{cB}	1.00 ± 0.00^{dC}	1.00 ± 0.00^{dB}
	8	4.84 ± 0.40^{aA}	4.74 ± 0.46^{aA}	4.58 ± 0.49^{aA}	4.47 ± 0.60^{aA}	4.26 ± 0.71^{aA}	4.05 ± 0.70^{aA}
	4	4.63 ± 0.48^{aA}	4.11 ± 0.54^{aA}	3.79 ± 0.65^{aAB}	2.63 ± 0.43^{bB}	1.60 ± 0.57^{cB}	1.00 ± 0.00^{dB}
	2	4.32 ± 0.56^{aA}	3.01 ± 0.53^{bB}	1.74 ± 0.70^{cC}	1.00 ± 0.00^{dC}	1.00 ± 0.00^{dC}	1.00 ± 0.00^{cB}

GS: Glucose syrup, 8: GS-salt mixture at the ratio of 8:1, 4: GS-salt mixture at the ratio of 4:1, 2: GS-salt mixture at the ratio of 2:1.

***** Different superscript letters show significant difference between mean values in each row (P<0.05).

****** Different superscript capital letters in each column show significant difference between different storage conditions (P<0.05).

In addition, aroma (odor) was found to be the only factor that was statistically different between the fresh product and the Noughls stored in the presence of GS -salt at the ratio of 8:1 for 30 days. Since herbal distillates, especially Salix aegyptiaca distillate, are amongst the ingredients of Noughls, it seems that evaporation of the aromatic compound during storage time led to a reduction in odor score on day 30. Probably, the odor reduction may be hindered by addition of Salix aegyptiaca distillate to GS-salt mixture formulation which may cause release of aromatic molecules to surrounding atmosphere. It may decrease release of aromatic molecules from Noughls surface via mass transfer. However, it is just a suggestion and can be studied in future researches.

Besides, according to overall acceptability, the sensory quality of Noughls in the presence of GS-salt at the ratio of 2:1, GS, GS-salt at the ratio of 4:1 and GS-salt at the ratio of 8:1 was as acceptable as fresh product after storing for 10, 15, 20 and 30 days, respectively. This indicates that the presence of GS-salt at the ratio of 8:1 inside a container preserved sensory properties of Noughls for a longer time than other RH-modifiers.

Conclusions

In this research a novel approach to use edible materials for enhancing RH was developed. Regardingly, a mixture of GS and salt was used as food grade, viscose and low cost RH-modifier. The RH-modifier had the capability of re-increasing RH via migration of water molecules from GS-gas boundary surface toward the container atmosphere. This mass transfer was confirmed by reduction of the RH-modifier level during storage time. Moreover, it is found that salt addition hindered barrier layer formation on GS, which prevented mass transfer. Hence, GS-salt mixture at the ratio of 8:1 had the capability of re-increasing RH of the container 29 times after opening and re-closing the container lid. Comparison of the differences between moisture content, hardness, area, color and sensory properties of samples stored in the presence of GS-salt mixture with control sample proved the effectiveness of RH-modifier to enhance shelf life of Noughls. Consequently, the introduced RH-modifier can be useful to prevent moisture loss and degradation of saffron carotenoid during storage time. As a suggestion, the RH-modifier can either be packaged in sachet form to be put inside a storage container or should be poured inside the intermediate part of a coaxial cylinders form container followed by sealing with a plastic film. Migration of water molecules from the RH-modifier to the container atmosphere can be possible by punching some holes in plastic film.

Acknowledgments

The authors gratefully acknowledge funding from University of Tehran Science and Technology Park for financial support of the research.

Author contributions

Fatemeh Azarikia: Data collection, Writing the draft of the manuscript, Data analysis and interpretation, Presenting the research idea and study design, Revising and editing the manuscript, Supervising the study, Approval of the final version; **Saman Abdanan Mehdizadeh**: Data analysis.

Conflict of interest

There is no conflict of interest based on the writers.

References

Andrae-Nightingale, L. M., Lee, S. Y., & Engeseth, N. J. (2009). Textural changes in chocolate characterized by instrumental and sensory techniques. *Journal of Texture Studies*, *40*(4), 427-444 .

AOAC. (2002). Official methods of analysis of AOAC (4th ed) . In: Washington, DC: Association of Analytical Chemists.

Azarikia, F. (2019). Investigation of changes in physico-mechanical properties of walnut noughl during storage time: Studying of additives' effect. *Journal of food science and technology(Iran), 16,* 149-161. http://fsct.modares.ac.ir/article-7-22901-en.html (in Persian)

Caleb, O. J., Ilte, K., Fröhling, A., Geyer, M., & Mahajan, P. V. (2016). Integrated modified atmosphere and humidity package design for minimally processed Broccoli (Brassica oleracea L. var. italica). *Postharvest Biology and Technology*, *121*, 87-100. https://doi.org/10.1016/j.postharvbio.2016.07.016

Cybulska, E. B. (2006). Chapter 3- Water and Food Quality. In A. E. Sikorski (Ed.), *Chemical and functional properties of food components* (pp. 29-60). Taylor & Francis group, LLC, CRC Press .

Deumier, F., & Bohuon, P. (2005). Densities, viscosities and water activities of ternary NaCl–glucose syrup–water systems from 283.1 to 298.1 K. *Journal of Food Engineering*, *68*(3), 377-383 .https://doi.org/10.1016/j.jfoodeng.2004.06.013

Dissa, A. O., Desmorieux, H., Savadogo, P. W., Segda, B. G., & Koulidiati, J. (2010). Shrinkage, porosity and density behaviour during convective drying of spirulina. *Journal of Food Engineering*, *97*(3), 410-418. https://doi.org/10.1016/j.jfoodeng.2009.10.036

Figura, L., & Teixeira, A. A. (2007). *Food physics: physical properties-measurement and applications*. Springer Science & Business Media .

Hassan-Beygi, S. R ,.Ghaebi, S. M., & Arabhosseini, A. (2009). Some physico-mechanical properties of apricot fruit, pit and kernel of ordubad variety. *Agricultural Engineering International: CIGR Journal*, *XI* .

Klann, K. (2018). *Humidity Control Package, U.S. Patent No. 9,896,240*. Washington, DC: U.S. Patent and Trademark Office. https://assignment.uspto.gov/patent/index.html#/patent/search/resultAbstract?id=9896240&type=patNum

Koua, B. K., Koffi, P. M. E., & Gbaha, P. (2019). Evolution of shrinkage, real density, porosity, heat and mass transfer coefficients during indirect solar drying of cocoa beans. *Journal of the Saudi Society of Agricultural Sciences*, *18*(1), 72-82. https://doi.org/10.1016/j.jssas.2017.01.002

McLellan, M., Lind, L., & Kime, R. (1995). Hue angle determinations and statistical analysis for multiquadrant Hunter L, a, b data. *Journal of food quality*, *18*(3), 235-240 .

Mercier, S., Villeneuve, S., Mondor, M., & Des Marchais, L.-P. (2011). Evolution of porosity, shrinkage and density of pasta fortified with pea protein concentrate during drying. *LWT - Food Science and Technology*, *44*(4), 883-890. https://doi.org/10.1016/j.lwt.2010.11.032

Miralles, B., Martínez-Rodríguez, A., Santiago, A., van de Lagemaat, J., & Heras, A. (2007). The occurrence of a Maillard-type protein-polysaccharide reaction between β-lactoglobulin and chitosan. *Food Chemistry*, *100*(3), 1071-1075. https://doi.org/10.1016/j.foodchem.2005.11.009

Ortiz, D., Rocheford, T., & Ferruzzi, M. G. (2016). Influence of temperature and humidity on the stability of carotenoids in biofortified maize (Zea mays L.) genotypes during controlled postharvest storage. *Journal of Agricultural and Food Chemistry*, *64*(13), 2727-2736 .

Panda, N. C., & Townsend, C. W. (2014). *Humidity Generator, U.S. Patent No. 8,814,149*. Washington, DC: U.S. Patent and Trademark Office. https://assignment.uspto.gov/patent/index.html#/patent/search/resultAbstract?id=8814149&type=patNum

Sahin, S., & Sumnu, S. G. (2006). *Physical properties of foods*. Springer Science & Business Media .

Soltanikazemi, M., & Abdanan Mehdizadeh, S. (2017). Classification of bitter and sweet olives using image processing and artificial neural networks during curing process in brine and water environments. *International Journal of Food Properties*, *20*(sup2), 1954-1964. https://doi.org/10.1080/10942912.2017.1360904

Thogersen, O., & Dyrmose, A. (2017). *Apparatus for controlling relative humidity in a container, U.S. Patent No. 9,557,084*. Washington, DC: U.S. Patent and Trademark Office. https://patents.google.com/patent/US9557084B2/en

Torringa, E., Esveld, E., Scheewe, I., van den Berg, R., & Bartels, P. (2001). Osmotic dehydration as a pre-treatment before combined microwave-hot-air drying of mushrooms. *Journal of Food Engineering*, *49*(2), 185-191. https://doi.org/10.1016/S0260-8774(00)00212-0

Tsimidou, M., & Biliaderis, C. G. (1997). Kinetic studies of saffron (Crocus sativus L.) quality deterioration. *Journal of Agricultural and Food Chemistry*, *45*(8), 2890-2898 .

Viuda-Martos, M., Ruiz-Navajas ,Y., Fernández-López, J., & Pérez-Alvarez, J. A. (2010). Effect of added citrus fibre and spice essential oils on quality characteristics and shelf-life of mortadella. *Meat Sci*, *85*(3), 568-576. https://doi.org/10.1016/j.meatsci.2010.03.007

Wilska-Jeszka ,J. (2006). Chapter 9- Food colorants. In Z. E. Sikorski (Ed.), *Chemical and functional properties of food components* (pp. 245-274). Taylor & Francis group, LLC, CRC Press .

Wong, B. T., Day, L., & Augustin, M. A. (2011). Deamidated wheat protein–dextran Maillard conjugates: Effect of size and location of polysaccharide conjugated on steric stabilization of emulsions at acidic pH. *Food Hydrocolloids*, *25*(6), 1424-1432. https://doi.org/10.1016/j.foodhyd.2011.01.017

Xu, D., Wang, X., Jiang ,J., Yuan, F., & Gao, Y. (2012). Impact of whey protein – Beet pectin conjugation on the physicochemical stability of β-carotene emulsions. *Food Hydrocolloids*, *28*(2), 258-266. https://doi.org/10.1016/j.foodhyd.2012.01.002

Zhao, Y., Liu, S ,.Hu, Z., Bai, Y., Shen, C., & Shi, X. (2020). Separate degree based Otsu and signed similarity driven level set for segmenting and counting anthrax spores. *Computers and Electronics in Agriculture*, *169*, 105230. https://doi.org/10.1016/j.compag.2020.105230

Zogzas, N. P., Maroulis, Z. B., & Marinos-Kouris, D. (1994). DENSITIES, SHRINKAGE AND POROSITY OF SOME VEGETABLES DURING AIR DRYING. *Drying Technology*, *12*(7), 1653-1666. https://doi.org/10.1080/07373939408962191

افزایش مدت زمان ماندگاری نُقل ازطریق اصلاح رطوبت نسبی ظرف نگهداری: مطالعهٔ ویژگی‌های فیزیکوشیمیایی و بافتی

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چکیده

خشک‌شدن نُقل بر ویژگی‌های بافتی آن تأثیر منفی دارد که این روند می‌تواند با افزایش میزان رطوبت نسبی اتمسفر ظرف نگهداری مرتفع گردد. در این تحقیق، از ترکیب شربت گلوکز و نمک طعام در نسبت‌های مختلف (8:1، 4:1 و 2:1) به‌عنوان ترکیب اصلاح‌کنندهٔ رطوبت نسبی جهت جلوگیری از سفت‌شدن نُقل استفاده شد. تأثیر این اصلاح‌کننده‌های رطوبت نسبی بر میزان رطوبت، سختی، مساحت، رنگ و ویژگی‌های حسی نمونه‌ها طی نگهداری به مدت 30 روز مورد پایش قرار گرفت. برای اندازه‌گیری میزان تغییرات مساحت و رنگ نمونه‌ها از پردازش تصویر استفاده شد. براساس نتایج کمترین تغییر در میزان رطوبت، رنگ و مساحت نُقل‌های زعفرانی زمانی مشاهده گردید که مخلوط شربت گلوکز-نمک به نسبت 8:1 به‌عنوان اصلاح‌کنندهٔ رطوبت نسبی استفاده شده بود. نتایج نشان داد که حضور این اصلاح‌کننده در ظرف نگهداری نُقل قادر است پس از 29 روز باز و بسته‌کردن درب ظرف، رطوبت نسبی فضای داخل ظرف را افزایش دهد. به‌علاوه، حضور این ترکیب اصلاح‌کنندهٔ رطوبت باعث جلوگیری از سفت‌شدن نُقل طی 30 روز نگهداری شد؛ به‌طوری‌که، میانگین میزان سختی در روز صفر و 30 به‌ترتیب 32/4 و 23/38 نیوتن بود. درحالی‌که، سختی نمونهٔ شاهد در روز 5 به 149/85 نیوتن رسید. همچنین، براساس ارزیابی حسی، بین نُقل تازه و نُقل نگهداری‌شده به مدت 30 روز تفاوت معنی‌داری ازنظر میزان پذیرش کلی مشاهده نشد (P<0/05). این روش اصلاح رطوبت نسبی اتمسفر داخل ظرف نگهداری می‌تواند به‌عنوان یک روش کم‌هزینه در جلوگیری از خشک‌شدن سایر مواد غذایی نیز کاربرد داشته باشد.

واژه‌های کلیدی: ازدست‌دادن رطوبت، اصلاح‌کنندهٔ رطوبت نسبی، پردازش تصویر، شربت گلوکز، نُقل