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Impact of Substituting Sugar with Date Juice on the Sensory and Physicochemical Characteristics of Uncoated Chewing Gum

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ABSTRACT: In contemporary confectionery industry, manufacturing of dietary and low-calorie products, notably in the realm of chewing gum production, stands as a significant challenge. Sweeteners are integral components in confectionery products, with applications extending to chewing gum as well. This research utilizes the established advantageous characteristics of dates to investigate the potential use of date juice as a replacement for sugar in the manufacturing of dietary gum. The substitution ratios tested in the experiment are, 10, 20, and 30%. The findings of the experiment indicated that the gum supplemented with date juice at a substitution rate of 20% exhibited superior quality and shelf life, as evidenced by its enhanced moisture retention, texture, and sensory attributes, particularly taste. Conversely, a higher substitution rate of 30% led to a decline in both quality and sensory characteristics, with values falling below those of the control treatment. The study encompassed physicochemical and sensory examinations, encompassing the analysis of gum content, determination of reducing sugars following hydrolysis, measurement of ash content, assessment of texture, evaluation of sensory attributes, and investigation of colorimetric properties. The findings indicated that the quantity of gum and sugar obtained following the hydrolysis of the product was consistent across all experimental treatments, displaying no statistically significant variance as compared to the control treatment. Additionally, there was a notable increase in the ash percentage index with higher levels of date juice replacement. The adhesion indices demonstrated a notable increase, while both chewability and springiness exhibited a decrease.

Keywords: Diet Chewing Gum, Date Juice, Sensory and Physicochemical Properties, Sugar Substitute.

Introduction

The use of sucrose as a natural sweetener offers numerous advantages. The link between sugar consumption and health issues, including hypertension, cardiovascular disease, dental caries, obesity, and elevated levels of blood glucose and insulin, as well as the economic and technological challenges associated with sugar production, has prompted extensive research into the potential use of alternative natural sweeteners. This line of inquiry has been explored by Alsenaien *et al*. (2015). Carocho *et al*. (2017) noted that consumers generally exhibit a preference for confectionery products that are sweetened with sugar substitutes. This preference is largely attributed to the desire to reduce calorie intake and control

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body weight. Furthermore, sugar substitutes are recognized for their potential role in managing diseases such as diabetes and lowering blood sugar levels the study by Kazemi *et al*. (2001) provide valuable insights into the topic. Iran has historically been regarded as a prominent producer of dates. As of 2013, Iran holds a prominent position in global date production with an annual output of 1,490,000 tons, as reported by statistical data. Approximately 30% of the dates cultivated in the country do not meet the quality standards required for consumption and therefore are unsuitable for the consumer market. Consequently, these dates are redirected to processing industries where they are converted into valuable products such as date juice. Date juice is considered to be a highly significant byproduct of dates, characterized by its high content of natural sugars such as fructose and glucose, while containing low levels of sucrose. In terms of physiological processes, it is notable that absorption of fructose sugar in the body does not require the presence of insulin. Hence, sugar is considered to be appropriate for individuals with diabetes and is a source of significant energy. Furthermore, date juice is rich in potassium, calcium, phosphorus, and iron, making it a valuable dietary option for supporting the nutritional needs of children, breastfeeding women, and the elderly. It is important to exercise caution when using these sweeteners and adhere to the recommended permissible limits set by authoritative organizations. The incorporation of date juice into food formulations not only serves as a viable alternative to sugar and artificial sweeteners, but also contributes to enhancing the nutritional profile of the end product (Gohari *et al*., 2005; Razavi *et al*., 2006; Mardani *et al*., 2014).

Materials and Methods

- Product Formulation

The initial step in the production of strip chewing gum involved transferring the gum base to a laboratory mixer, where it was kneaded for a duration of 30 minutes until a viscid and malleable dough was achieved. Subsequently, date juice was incorporated into each sample according to the specified weight ratios outlined in the accompanying table. The softener was incrementally introduced to the solution. The gum paste was prepared by mixing, kneading, and spreading it, and subsequently divided into small square pieces through shaping. Following the preparation of three distinct varieties of chewing gum, they were subsequently packaged in nylon bags and subjected to sensory and quality evaluations subsequent to random coding. Tables 1 and 2 present chewing gum formulation and treatments given respectively.

Table 1. Chewing gum formulation

Raw materials	%
Date syrup	In three propositions 10,20,30
Glucose	15
Gum	20-62
Glycerin	0.5
Essential oil	2
Sorbitol	1.5

Table 2- Treatment's codding(%)

Raw materials	T	T_1	T_2	T_3
Sugar	55	45	35	25
Gum	26	26	26	26
Glucose Bx=82	15	15	15	15
Date syrup	0	10	20	30
Essential oil	2	2	2	2
Glycerin	0.5	0.5	0.5	0.5
Sorbitol	1.5	1.5	1.5	1.5

- Strip Chewing Gum tests

The present study aimed to investigate several key parameters including Brix measurement of date juice, reduction sugar measurement, total gum content, sucrose

percentage, ash percentage, and moisture percentage.

- Brix measurement of date syrup

The Brix content of the date juice was quantified using a refractometer prior to conducting the experiment.

- Sugar measurement (Lin Aynon Method)

The assessment of sucrose content is a customary procedure in product analysis, and was conducted as outlined below to ascertain the presence of sucrose in the end product.

A precise measurement of 9. 5 grams of sucrose of laboratory purity was meticulously weighed and subsequently dissolved in a suitable volume of water. Subsequently, 5 milliliters of concentrated hydrochloric acid was introduced into the solution, followed by the addition of distilled water until the volume reached approximately 100 milliliters. The solution was subjected to ambient room temperature conditions for an extended duration. The experiment involved subjecting the specimens to a temperature of 12-15 degrees Celsius for a duration of 7 days, followed by a temperature of 20-25 degrees Celsius for a period of 3 days. Upon the completion of the cooling process, the resultant solution achieved a final volume of 100 milliliters. The solution referred to is the standard 10% sugar acid solution, which can maintain its efficacy for a period of up to 2 months when stored at normal ambient temperature, approximately 20 degrees Celsius.

- Measurement of reducing sugar after hydrolysis

A 10-milliliter aliquot of a 4% gum solution was transferred into a 100-milliliter flask, to which distilled water and 2. 5 milliliters of concentrated hydrochloric acid were added. The resulting mixture was subsequently subjected to a bain-marie at 70 degrees Celsius for a total duration of 10 minutes, during which time it was agitated for 3 minutes and then maintained at a constant temperature for 7 minutes. Following the cooling process, the solution was neutralized using a phenolphthalein indicator, then concentrated sodium hydroxide and one-tenth normal sodium hydroxide were added to bring the volume to 100 milliliters. The resultant solution was subsequently transferred to a burette and a titration procedure was executed. The quantity of sugar regenerated following hydrolysis in a 100-gram specimen was determined using equation 1 and expressed in units of dextrose (glucose) (Anon, 1995).

$$E = [(T \times 100 \times 100)/(\mathrm{V} \times \mathrm{W} \times 1000) \times 10)] \times 100 \quad (1)$$

where,

T= Corrected Fehling's titer in terms of dextrose in milligrams

V= The used volume of the sample solution for Fehling neutralization

W= Weight of gum in grams

- Measurement of sucrose

The quantitative analysis of the sucrose content in the sample was determined using the provided equation (Anon, 1995).

$$\text{Percentage of sucrose} = 0.95 \times (\text{Sugar before hydrolysis} - \text{Sugar after hydrolysis}) \quad (2)$$

- Total gum measurement

Approximately 2 grams of the gum sample in crushed form was precisely measured and then transferred into a beaker, using a small glass rod for

agitation. The beaker had previously been weighed and had reached a stable weight. Boiling water was incorporated into the mixture and agitated until its complete dissolution. Upon the precipitation of the insoluble material at the base of the flask, the subsequent extraction of the blue layer ensued, followed by multiple iterations of rinsing the residual contents within the flask. Subsequently, the remaining substance is to be transferred into a beaker and subjected to an oven temperature of 105 degrees Celsius, until complete desiccation is achieved. The ensuing dried substance is then allowed to cool and subsequently weighed. The percentage of total gum, defined as the sum of the gum and its filler, was determined using Equation 3 as outlined in the Iranian Standard (Anon, 1995).

$$\text{Gum} = (\,(\text{B} - \text{A})/\text{m}) \times 100 \qquad (3)$$

where,
B= The weight of the beaker with the glass rod and its dried residue
A= Weight of empty beaker with glass rod
C= Sample weight

- Moisture measurement

Initially, the plate was placed in an oven for a duration of 30 minutes at a temperature range of 100-105 degrees Celsius. Subsequently, the plate was withdrawn from the oven and transferred to a cold desiccator until it equilibrated to ambient temperature, following which its mass was determined. A specified quantity (minimum of 2 grams) of the pulverized specimen of the gum under investigation was subsequently added to the plate, and the plate was re-weighed with the sample content. The plate containing the sample content was then subjected to a temperature range of 100-105 degrees Celsius until a consistent weight was achieved. The sample was placed in a desiccator for cooling and subsequently weighed. The procedure is iterated, involving the sequential application of heat, cooling, and weighing, with the aim of achieving a consistent and stable weight. According to the Iranian Standard (Anon, 1995), it is expected that the difference in the final weight between two consecutive tests should not exceed 2 mg. Equation 4 was employed to determine the moisture content.

$$Moisture\ \% = (\text{W1} - \text{W2}/\text{W1} - \text{W}) \times 100 \qquad (4)$$

where,
W_1 = Initial weighing
W_2 = Secondary weighing
W= The total weight of the sample

- Ash measurement

The amount of ash was analysed by a furnace set at a temperature of 550-500 °C. The quantitative analysis of the ash content in the samples was determined by using a furnace set at a temperature of 500-550 °C according to equation 5 (Anon, 1995).

$$\text{Ash}\ \% = (\text{W2} - \text{W}/\text{W1} - \text{W}) \times 100 \qquad (5)$$

where,
W= Crucible weight
W_1 = The weight of the Crucible with the sample before incineration
W_2 = Crucible weight with ash

- Texture analysis

The analysis of texture was carried out utilizing the TA-XT2i Texture Analyzer Stable Micro System, which was equipped with a 5 mm cylindrical probe. The texture profile analysis parameters were measured using a compression force of 25%, and the parameters of hardness, gumminess, springiness and chewability were analyzed

with Expression PC V. 21 software, as described in a study conducted by Razavi *et al*. (2006).

- Hardness

The process of compression and deformation consists of two stages. Initially, the moving jaw of the machine compresses the sample to a degree of 70% and then returns to its original state. Subsequently, after a brief interval, the sample undergoes a second compression of 70%. Ultimately, two distinct peaks are derived, and the size of these peaks varies according to the type and properties of the products. Furthermore, the maximum force experienced during the initial stage of product compression is denoted as texture hardness (Razavi *et al*., 2006).

- Cohesiveness

The assessment of the product's second deformation in relation to its behavior during the initial deformation provides insight into the adhesion state of the sample. This analysis was conducted by dividing level 2 into level 1, as indicated in the diagram (Razavi *et al*., 2006).

- Springiness

The capacity for a product to revert to its original state following compression can be determined by calculating the ratio between the height of the peak hardness at stage 2 and the height of the peak hardness at stage 1 (Razavi *et al*., 2006).

- Chewiness

The chewing properties are derived from the combined effects of hardness, adhesion, and springness (Razavi *et al*., 2006).

Result and Discussion

- Brix measurement results of date juice

The findings of the Brix assessment of date juice indicated a numerical value of approximately 74.

- Sensory evaluation results

The analysis of the sensory evaluation results are presented in Figures 1 to 4 and indicate notable variances in the sensory attributes of the treatments subsequent to the production period and throughout a six-week storage period. The utilization of date juice in composition of chewing gum has been demonstrated to have a notable impact on enhancing taste and texture, with the results showing improvement up to 20% in the parameters studied, as illustrated in Figure 1. Elevating the substitution rate of date juice beyond 20% is anticipated to adversely affect the sensory attributes, particularly the texture of the gum, ultimately influencing overall acceptability. There were notable variations in both the aroma and flavor of the gums utilized in the post-production, as indicated by a statistically significant difference between them ($p<0.05$). The researchers conducted an evaluation in which treatments containing a 30% replacement of date juice were found to receive the lowest scores in terms of aroma and smell. Conversely, the control treatment and those with 10% and 20% replacement were deemed to have higher scores as compared to the control treatment. The influence of different periods of storage on the sensory qualities of the products showed a significant level of importance. Extending the storage time also had significant effects on the sensory characteristics of the treatments. The control group showed no significant differences as compared to the other groups until the fourth week of preservation, as evidenced by a p-value below 0.05. The extension of preservation time did not yield statistically significant differences in the treatments employing

10% and 20% preservation, particularly in terms of texture characteristics, as well as in the treatment involving a 20% replacement of date juice. The product has effectively maintained its textural attributes, flavor profiles, and olfactory properties, and has garnered the highest ratings from assessors in terms of overall acceptance. The definitive order of the treatments is as follows:

$$T_2>T_1>T>T_3$$

The findings depicted in Figure 1 demonstrate that the evaluation of the taste of the gum treatments indicates a positive correlation between the acceptability of the gum treatments and the rising percentage of date juice. As the Brix level increases, there is a corresponding increase in the acceptability of taste. The score related to taste also increases up to a 20% replacement level. This suggests that in terms of texture, particularly in juice sugar, there is potential to emulate properties similar to sugar solutions in products. The item possesses nourishment and is capable of serving as a suitable substitute in this regard (Mardani *et al*., 2014; Milani *et al*., 2011). The assessment of various chemical and sensory attributes of juice, concentrate, and juice date sugar in comparison to sugar solution revealed that the sensory evaluation indicated the juice sugar solution to possess characteristics more closely aligned with those typically sought, rendering it a more suitable product. In substitution of sucrose, an alternative consistent with the findings of the current study is sugar as suggested by (Homayouni *et al*., 2014).

A primary objective in the production of packaged food is to minimize alterations during the period of storage. The findings of the investigation demonstrate that there were no discernible alterations in the sensory attributes of treatments T1 (0% date juice) and T2 (10% date juice) over the course of a six-week storage period. The findings from the assessment of the physicochemical, rheological, microbial, and sensory properties of date juice indicated that there were no notable alterations in dates throughout the storage duration in juice form, which aligns with the outcomes of the current investigation by Homayouni in accordance with the findings of (Homayouni *et al*., 2014). The assessment of texture revealed that substituting 30% of date juice resulted in a loss of the gummy consistency in gum formulations. The findings of the texture evaluation and total gum measurement indicate a significant reduction in texture scores for all treatment groups ($p<0.05$). Furthermore, the reduction in the sensory attribute ratings of the treatments demonstrates that the substantial replacement of date juice has resulted in a decline in the overall acceptance of the treatments. The judges' overall assessment of the sample under study is influenced by its various characteristics such as texture, flavor, and taste. This overall acceptance is a reflection of the judges' feelings towards the sample, indicating the importance of these specific attributes in determining the overall evaluation. The study utilized a comparison of mean scores of sensory characteristics to ascertain that the sample containing a 30% date juice substitute exhibited the lowest overall acceptance score. The findings of this study are congruent with those of previous researchers according to the study conducted by (Gohari et al., 2005). The research conducted by the authors titled "Investigation of the Impact of Replacing Sugar with Date Juice on the Physical and Sensory Characteristics of Soft Ice Cream" revealed that the substitution of 100% date

juice for sugar resulted in the lowest total acceptance score. This decrease in score was found to be highly significant, amounting to approximately 42%. One of the primary functions of sucrose, beyond its role as a sweetening agent, is to contribute to the crispness and texture of a product. However, increasing the percentage of sucrose replacement has been shown to result in a substantial decrease in these sensory characteristics, thereby significantly impacting overall consumer acceptance (Mardani, 2014). The works conducted by researchers (Mardani *et al*., 2014; Labbe *et al*., 2007) are of particular academic relevance. The function of sugar in chewing gum extends beyond imparting sweetness, as sucrose crystals also play a pivotal role in establishing a desirable texture for products like chewing gum, where textural attributes hold significance. The findings from the assessment of the flavor of the gum treatments demonstrated that the acceptability of the gum treatments increased in conjunction with higher concentrations of date juice. The rise in Brix content is positively correlated with the enhancement of taste acceptability. The score associated with taste increases significantly up to a level of 20% replacement. Specifically, in terms of texture, particularly in juice sugar there is an increased ability to replicate properties typically found in sugar solutions in products. The item possesses nutritional value and can serve as a viable alternative in the realm of sustenance. The experimental findings pertaining to gum treatments, as well as laboratory-scale gum production, indicate that the utilization of a 20% date juice substitute yields superior outcomes. This observation aligns with prior studies conducted on various products.

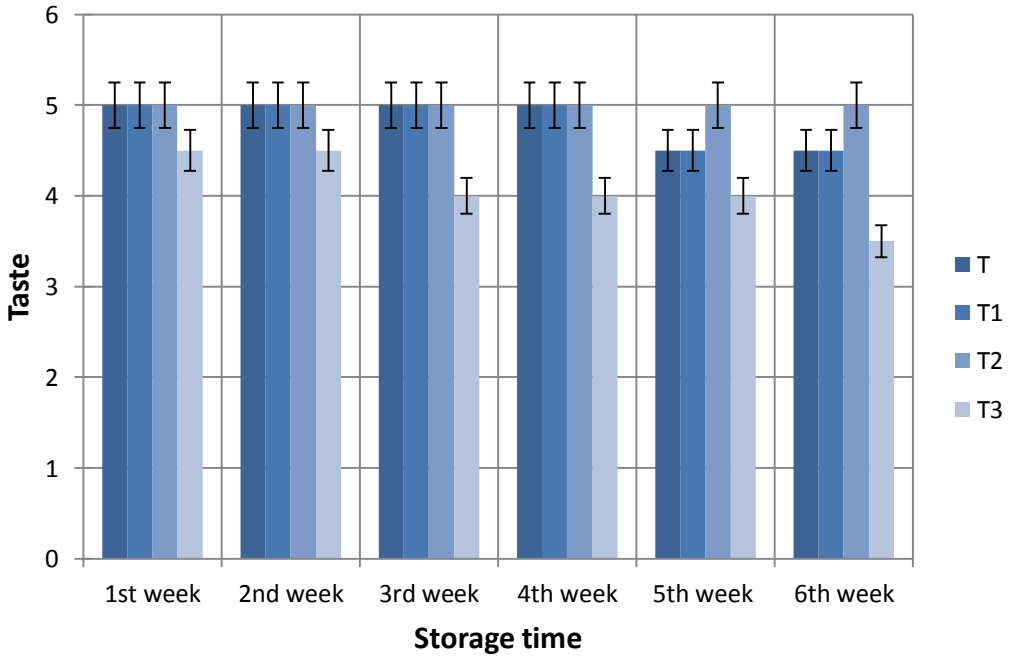

Fig. 1. The results of comparison of the average sensory evaluation index (taste) during six weeks of storage ($p<0.05$).

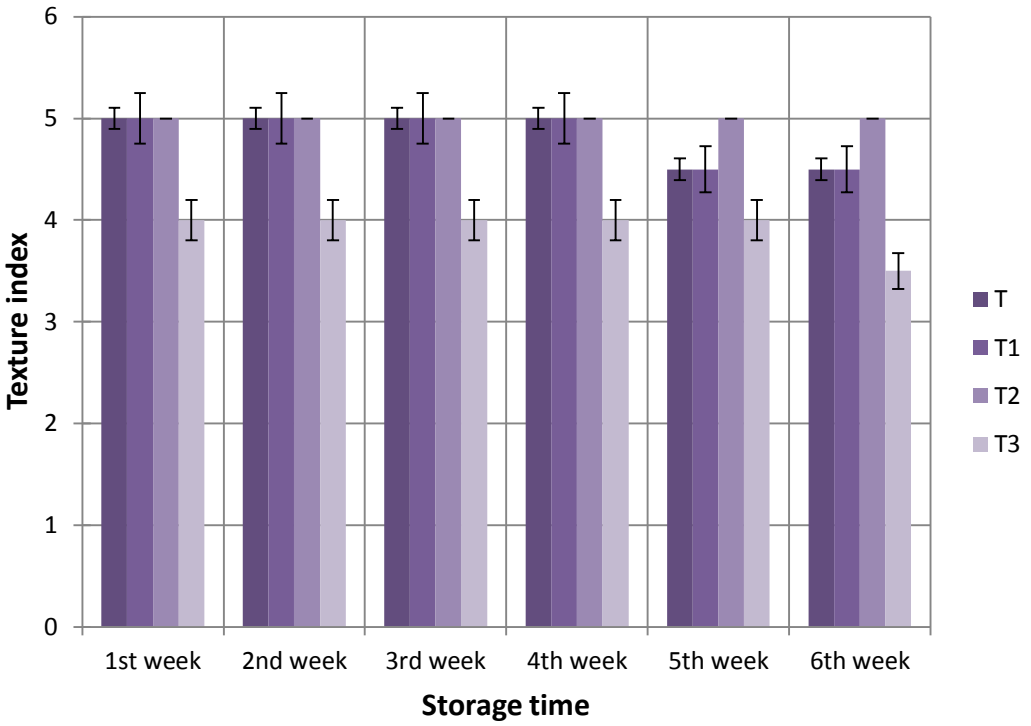

Fig. 2. The results of comparison of average sensory evaluation index (texture) during six weeks of storage ($p<0.05$).

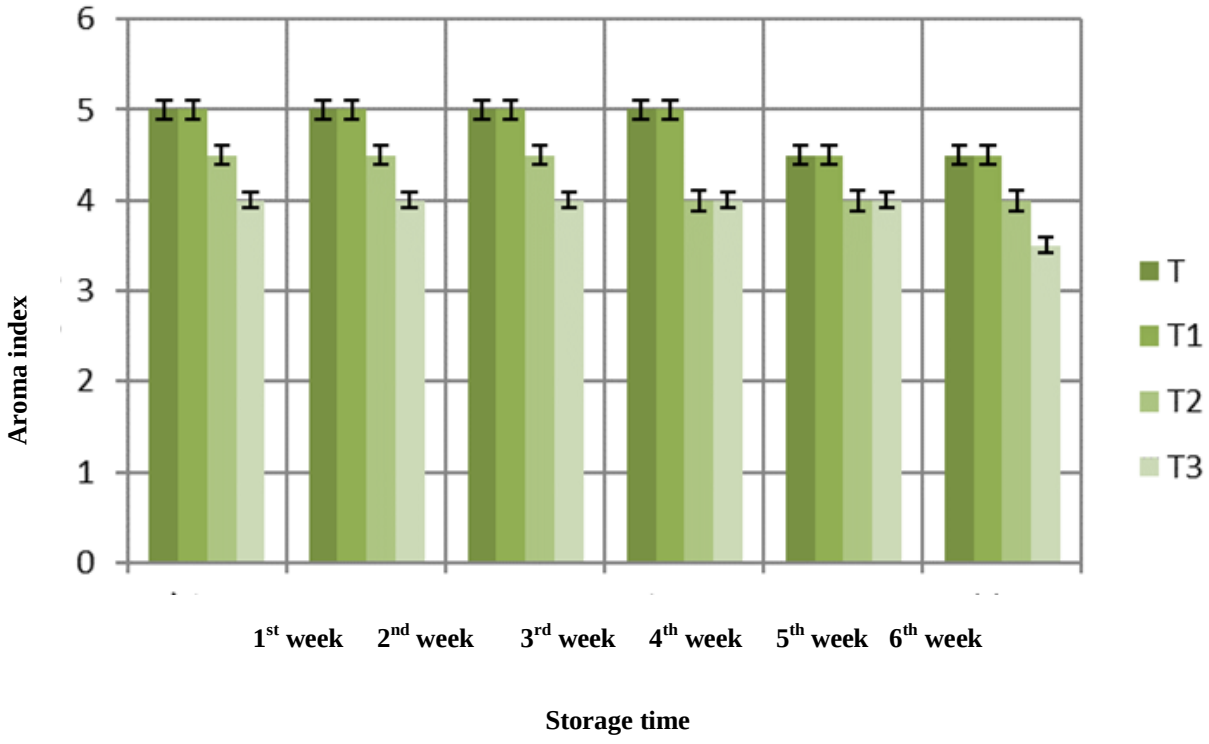

Fig. 3. The comparison results of the average sensory evaluation index (smell and aroma) during six weeks of storage ($p<0.05$).

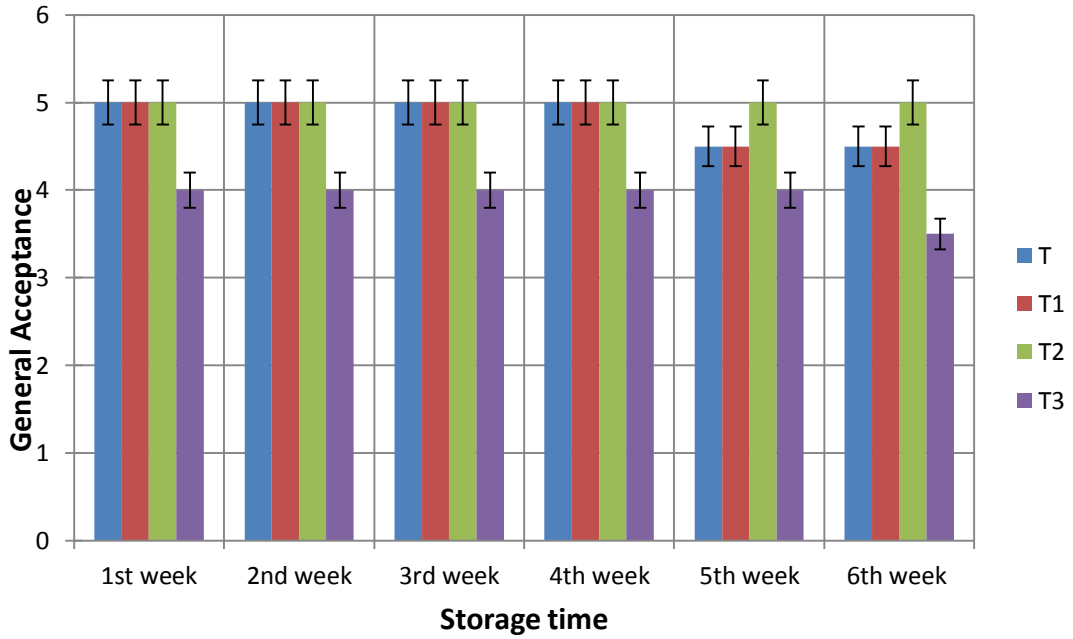

Fig. 4. The results of comparing the average sensory evaluation index (overall acceptance) during six weeks of storage ($p<0.05$).

- Color Parameters Results

The subsequent Figures (5-7) illustrate the variations in color indices within different treatments and across varying time intervals subsequent to storage. The findings indicate that the inclusion of date juice in the treatment formulations leads to a considerable reduction in the brightness index across all treatments. Consequently, there are notable distinctions between each treatment and the control group in this aspect. The a* index is observed to exhibit a color ranging from green to red, with no statistically significant changes evident post-production and throughout the duration of storage ($p<0.05$). Significant variations in redness index were observed among the different treatments, particularly in relation to the type of treatments. Furthermore, a noteworthy increase in redness index was observed with higher proportions of date juice replacing sugar, displaying a statistically significant correlation ($p<0.05$). The b* index demonstrated notable alterations in color, shifting from blue to yellow as the proportion of date juice used to replace sucrose in the gum formulation increased. This increase in date juice substitution resulted in a statistically significant rise in the yellow color index (b*) ($p<0.05$). However, the progression of time did not demonstrate any significant impact on the b* index.

The findings indicated a correlation between the augmented proportion of date juice substitution and a deepening of the coloration of the gum, as well as a rise in the yellowness index and a reduction in the brightness index. The observed phenomenon can be attributed to the Maillard reaction occurring within the simple sugars present in dates, as well as the intensity of color present in date juice.

The study "Investigation of the effect of replacing date juice sugar with invert sugar in layer cakes" determined that the substitution resulted in darker coloration of the samples as compared to the control group is in line with the present research

findings (Ishurd *et al*., 2005; Ahmadi *et al*., 2011).

The study focused on the substitution of liquid sugar with date juice in varying proportions (0, 20, 40, 60, 80, and 100%) within a biscuit formula, and its impact on the physicochemical and sensory attributes of the resulting product, determined that as the percentage of date juice replacement increased, there was a significant decrease in the L* index, which aligns with previous research findings. Mansouri (2013) and Edwards *et al*. (2018) have both contributed valuable insights to the field.

The study investigated the effects of substituting sugar with date powder and date syrup in the production of cookies. It was observed that the red index a* exhibited a significant increase, while the yellowness index showed a significant decrease as a result of the direct use of date powder and syrup. Concurrently, the current investigation exposes a contradiction in the formulation put forth by Milani *et al.* (2011).

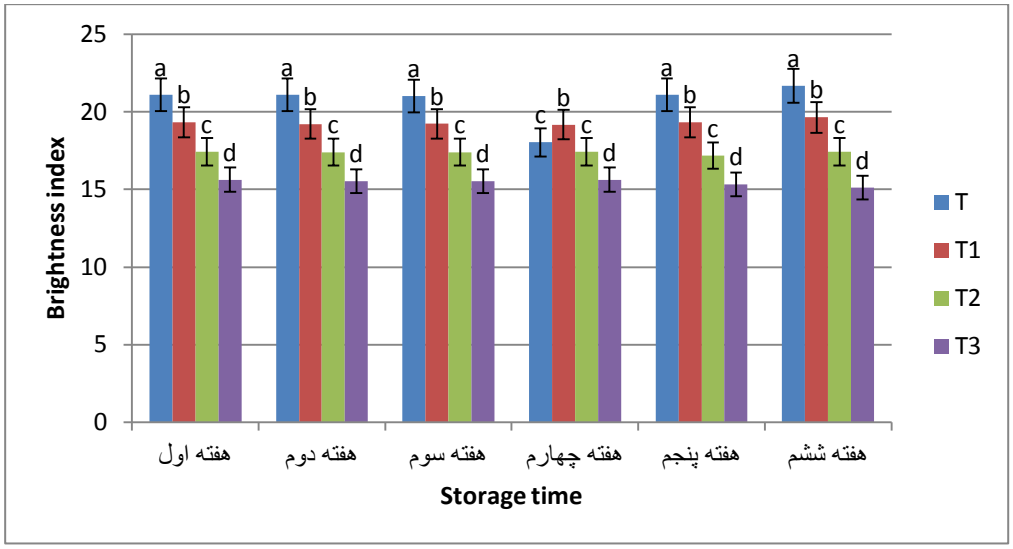

Fig. 5. The results of evaluating the brightness index of chewing gum treatments during six weeks of storage ($p<0.05$).

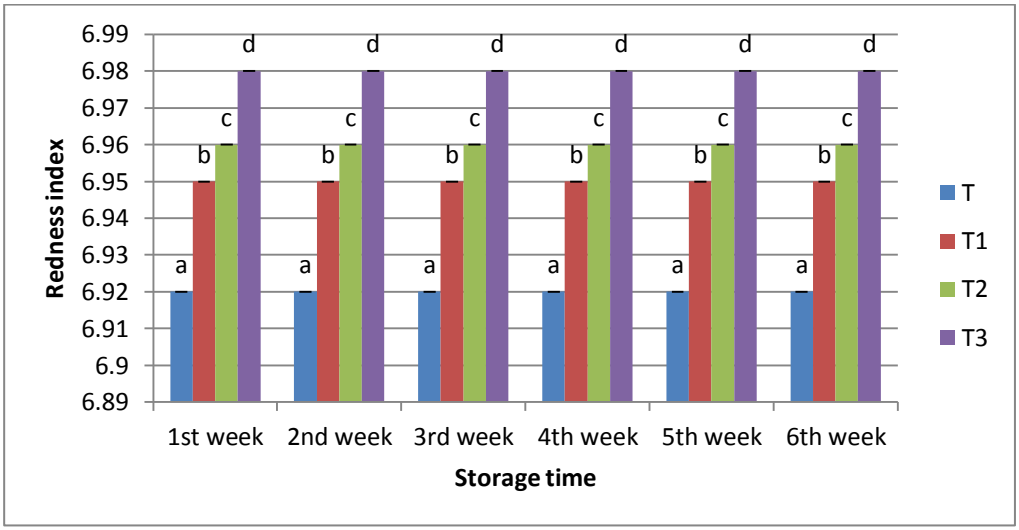

Fig. 6. Evaluation results of redness index of chewing gum treatments during six weeks of storage ($p<0.05$).

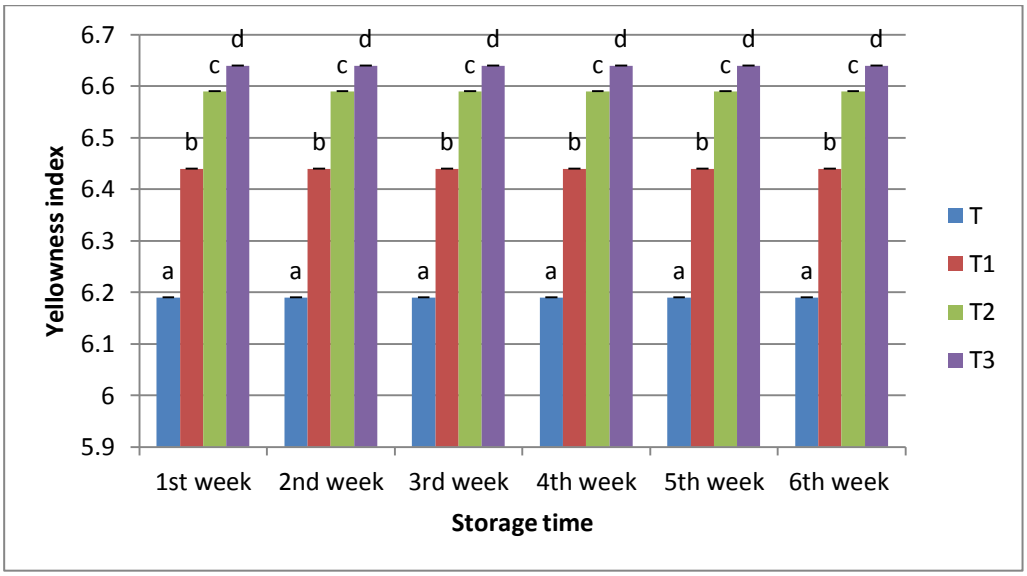

Fig. 7. Evaluation results of yellowness index of chewing gum treatments during six weeks of storage ($p<0.05$).

- Sugar measurement

Figure 8 presents various treatments in comparison to each other and the control. However, extending the duration of storage has not obtained significant impacts on any of the interventions. By augmenting the proportion of date juice replacement in the formulation of the experiment, there was a notable decrease in the total sugar percentage of the treatments ($p<0.05$). The total sugar percentage refers to the proportion of sucrose within a given sample. Date juice is found to contain a low level of sucrose, while also containing fructose and glucose. As the percentage of date juice in the formulation of chewing gums increases, the overall sugar content decreases notably. Furthermore, this reduction in sugar content becomes more pronounced with a higher percentage of substitution with date juice. The primary objective of achieving a lower sucrose content in chewing gum production is achieved more expeditiously with a formulation containing 20% date juice, as determined through experiments across various treatments. The study investigated the impact of substituting honey and date juice on the physicochemical properties, texture, and viscosity of low-fat orange yogurt ice cream dessert (Jafarpour *et al*., 2017). The findings revealed that the utilization of date juice as a substitute for sugar led to a more pronounced reduction in sugar content, attributable to the presence of reducing sugars in the date juice which enhances the activity of the starter cultures. These outcomes align with the overall decline in sugar content observed in the present study.

Researchers carried out a study to examine how replacing sucrose with date palm pulp affects the taste, physical and chemical characteristics, and ability to be stored of bread. The results of the study are consistent with earlier research carried out by Hashim *et al*., 2013; Aleid *et al*., 2013; Ghnimi *et al*., 2017).

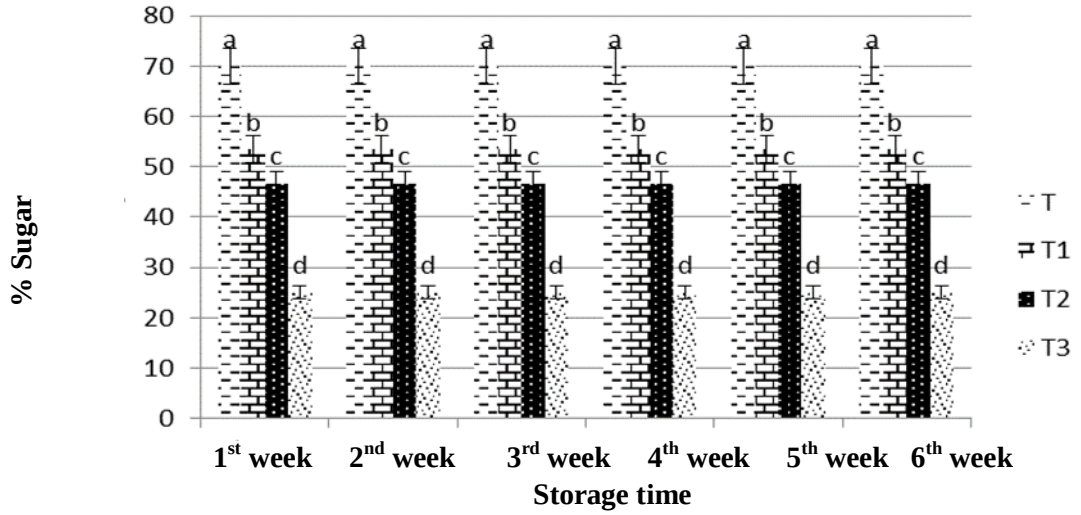

Fig. 8. Comparison of the average results of measuring sugar percentage during six weeks of storage ($p<0.05$).

- Measurement of glucose after hydrolysis

Based on the data presented in Figure 9, it can be observed that there are statistically significant variations in the levels of reducing sugars following hydrolysis in gum treatments post-production when compared to the control sample ($p<0.05$). An elevation in the sucrose substitution percentage within the treatment formulation led to a significant increase in the percentage of reducing sugar concerning the treatment T_3 demonstrate the highest percentage. Meanwhile, treatments T_2 and T_1 followed suit with lower percentages. However, there were no notable changes in the percentage of reducing sugar following hydrolysis across all treatments over a six-week maintenance period ($p<0.05$). The extent of sugar reduction following hydrolysis is contingent upon the specific sugar type and its constituent components. Date juice contains a notable proportion of rejuvenating sugars, namely glucose and fructose. The manipulation of the percentage of date juice in the formulations resulted in a significant increase in the percentage of reducing sugar after hydrolysis with an increase of 30%. This effect was found to be statistically significant at $p<0.05$ level.

The control treatment exhibited a significant decrease in reduced sugar percentage after hydrolysis as compared to other treatments, likely is attributed to the high sucrose content in the formulation. This difference was found to be statistically significant at a confidence level of $p<0.05$ and aligns with findings from previous research studies.

- Total gum measurement

Figure 10 indicates that the proportion of overall gum content in the gum treatments remained constant on the production and throughout a six-week storage period. The substitution of date juice does not result in statistically significant alterations in the quantity of total gum ($p<0.05$). Furthermore, it was observed that the duration of time had no impact on the total of gum present and the quantity of gum remained constant. The analysis of the outcomes related to alterations in the quantity of gum in chewing gum revealed that there was no significant variance in the proportion of

gum between the control group and the other experimental groups ($p<0.05$). The utilization of date juice as a sucrose substitute in the formulation has resulted in an equal percentage of base gum being used in all gum compounds. Additionally, the duration of storage for six weeks did not result in any alterations in the overall composition of the gum treatments. Thus, it can be concluded that there is no statistically significant variance between the various gum treatments. The study investigated the impact of various liquid syrups of DE grade on achieving a consistent percentage of total gum across all treatments. This finding is in accordance with the outcomes of the current study as documented by Yuda *et al*. (2018) and Mehta *et al*. (2012).

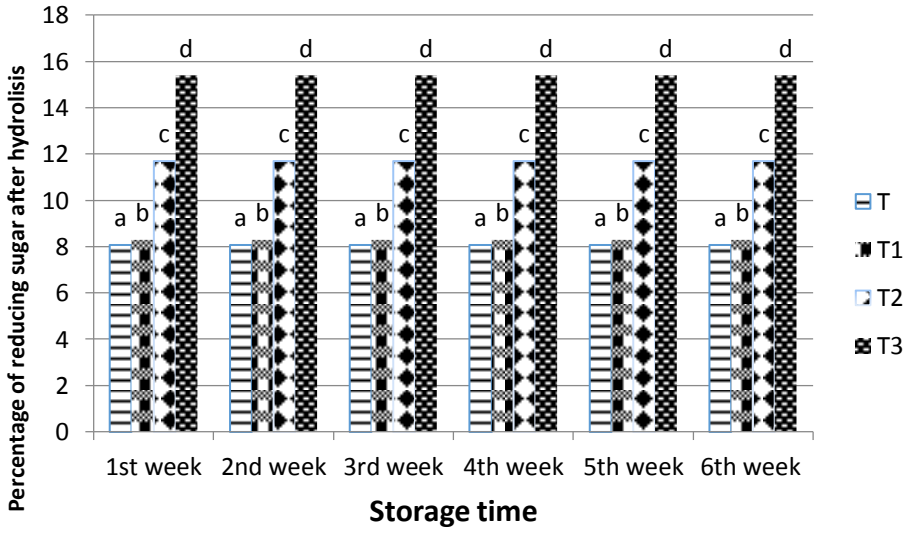

Fig. 9. Comparing the average results of measuring the percentage of reduced sugar after hydrolysis during six weeks of storage ($p<0.05$).

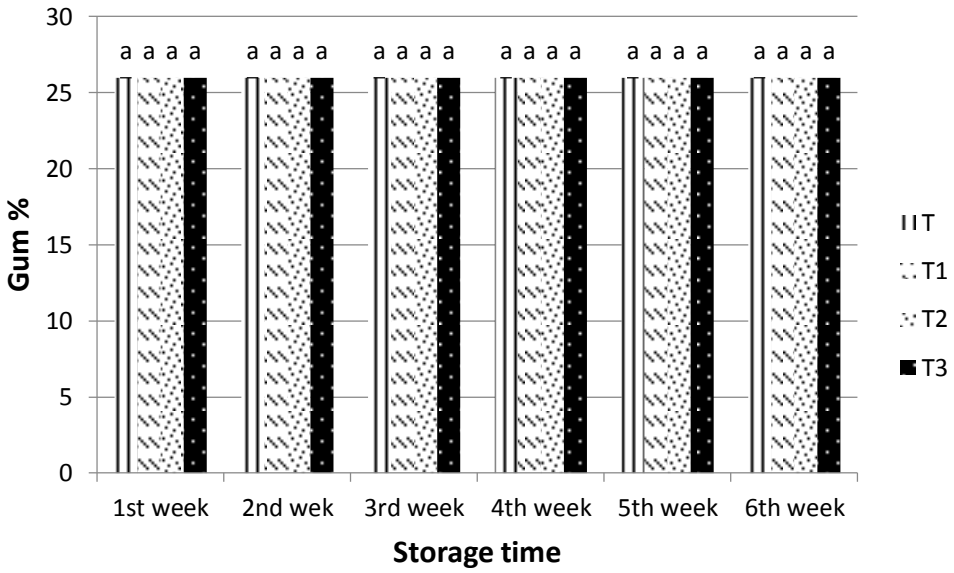

Fig. 10. Comparison of the average results of measuring the percentage of total gum during six weeks of storage ($p<0.05$)

- Moisture measurement

The analysis of the findings depicted in Figure 11 indicates that there were statistically significant variations in the moisture contents among the treatments starting from the initial day of production ($p<0.05$). During the initial three weeks of storage, there were no notable variations in the moisture content among the treatments. However, starting from the third week of storage, a significant decrease in moisture content was observed in the treatments. Notably, treatments with a higher concentration of date juice exhibited a slower rate of moisture loss. The statistical analysis of the mean values revealed a statistically significant difference in moisture content between the different gum treatments, as indicated by a p-value of less than 0.05. The findings from the Duncan's test indicated that there were significant variations in the moisture content of the samples in comparison to the control sample. Moreover, it was observed that the moisture content increased proportionally with the rise in the substitution of date juice sugar in the chewing gum. The elevation in moisture can likely be attributed to the competitive nature of water absorbent compounds present in the formulation. It appears that altering the variety of sugar has proven to be successful in modifying the moisture content of the product. The majority of the sugar present in date juice consists of regenerating monosaccharide sugars (glucose and fructose) and negligible quantities of sucrose. In general, the majority of sugars produce solutions with high viscosity due to their strong hydrophilic nature and ability to dissolve. The presence of the hydroxyl group facilitates the potential for hydrogen bond formation with molecules of water. An examination of the molecular compositions of sucrose, fructose, and glucose suggests that the elevated concentration of functional groups in the sugars found in date juice, as compared to sucrose, contributes to heightened hydrogen bond formation. The consequent reduction in the mobility of unbound water leads to increased absorption and retention of moisture, ultimately resulting in higher moisture content in the treated materials. The substitution of sucrose with date juice in gum formulations has been the focus of research in studies carried out by Damodaran *et al*. (2007), Mäkinen *et al*. (2014), and Amerine *et al*. (2013).

The results of the study are consistent with those reported by the researchers in their examination of the effects of replacing liquid sugar with invert sugar in layer cakes. Ishurd *et al*. (2005) and Haahr *et al*. (2003) have noted that a rise in the proportion of invert sugar used as a substitute is linked with a concomitant increase in the level of moisture in cakes.

The incorporation of date powder in the production of chocolate toffee resulted in similar findings. The conclusions drawn from the study suggest that the substitution of more than 25% of date juice in the chocolate toffee recipe results in significant changes in the moisture characteristics of the chocolates. Furthermore, the findings of the experiments carried out in this study align with the outcomes reported by Ahmadnia and Sahari in their previous research (Hull *et al.* 2010), Al Hagbani *et al.* 2018, and Ahmadnia *et al*. conducted an examination of multiple topics within their individual areas of expertise.

- Ash measurement

Figure 12 presents the ash content during examined period. The correlation between the percentage of ash in the treatments and the extent of date juice replacement in the treatment formulations

was found to be directly proportional. As depicted in Figure 12, the augmentation of the replacement percentage of date juice in the gum formulation resulted in a notable escalation in the ash content of the treatments post-production. The duration of storage of the treatments did not have a statistically significant impact on the percentage of ash. Additionally, as the storage time increased, none of the treatments exhibited any significant deviations from the ash percentage observed on the day after production ($p<0.05$). The ash content of the product is significantly influenced by the fiber and pectin compounds, with variations based on the purification and extraction methods employed. The findings indicate a notable increase in the percentage of ash with the incorporation of a higher proportion of date juice in the treatment formulations. The control treatment yielded lower ash content attributed to the presence of sucrose. Conversely, the incorporation of date juice and fiber at increased proportions led to a substantial rise in the percentage of these compounds. The elevation of the ash percentage of the product demonstrates a concurrent increase. Previous studies have reported a noteworthy rise in the ash percentage of the treatments, correlating with higher levels of date juice replacement (Sahari *et al*., 2008; Yuda *et al*., 2018).

- Texture analysis

The assessment of gum texture interventions is presented in Table 3. The findings indicate that there were notable distinctions in chewing capability between the various gum treatments, as well as in comparison to the control treatment, as evidenced by the statistical significance ($p<0.05$). The findings indicate that the substitution of date juice in place of sucrose at concentrations of 10% and 20% resulted in a significant increase in the chewability of gum treatments ($p<0.05$). A notable increase in chewability is observed with the implementation of a 30% sucrose substitution. The treatment with T_3 resulted in a decrease. The duration of storage for six weeks did not produce statistically significant effects on the quantity of chewing gum ability ($p<0.05$).

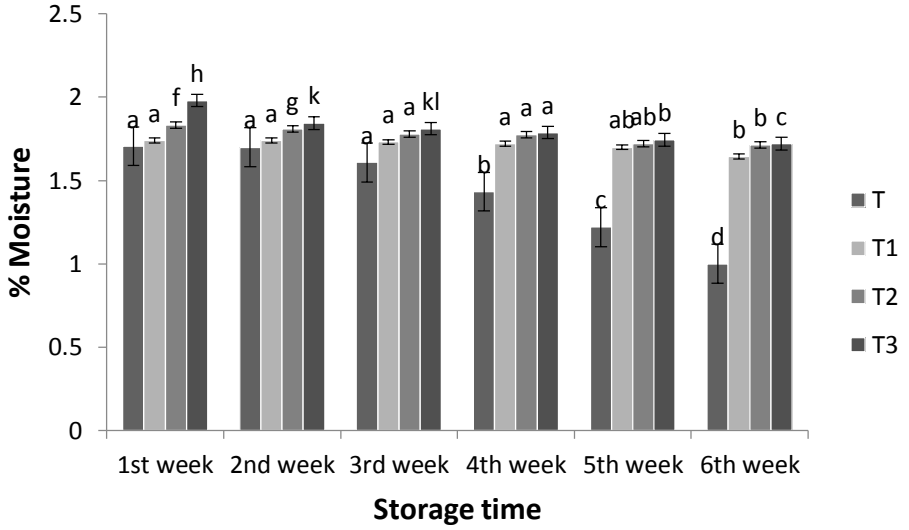

Fig. 11. The results of comparing the average moisture percentage of gum treatments during six weeks of storage ($p<0.05$)

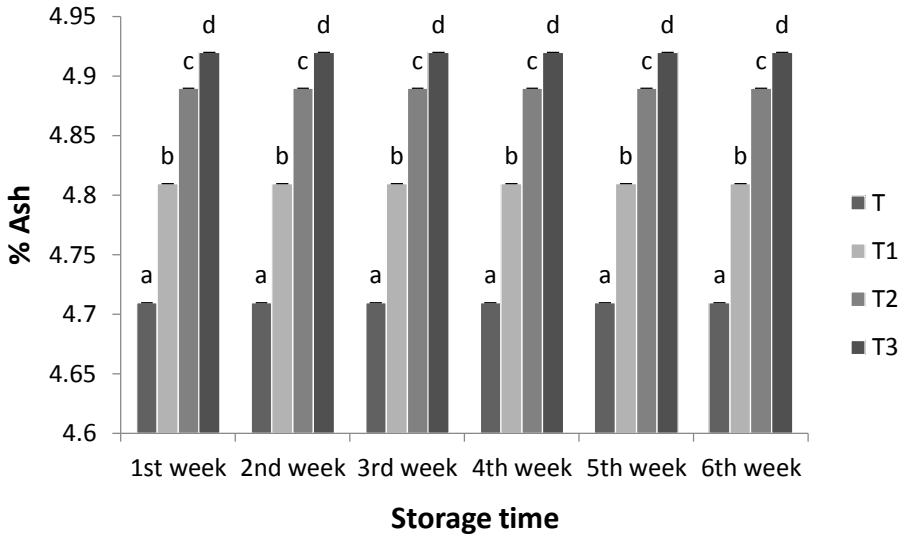

Fig. 12. The results of comparing the average ash percentage of chewing gum treatments during six weeks of storage ($p<0.05$)

The analysis of the hardness of chewing gum treatments indicates that an increase in the percentage of sucrose substitution in the gum formulation leads to a reduction in the hardness of the gum treatments post-production ($p<0.05$) Furthermore, over a six-week storage period, the hardness of the gums remains constant at the same ratio. The minimum level of hardness is found to be correlated with T_3 treatment, while the maximum level of hardness is observed in the control treatment.

Substituting sucrose with date juice resulted in notable alterations in the adhesion index across the various treatments. As demonstrated in Table 3, the incorporation of date juice in the composition of the treatments resulted in a significant increase in adhesion. Specifically, the treatment utilizing a 30% replacement of date juice exhibited the highest adhesion rate, whereas the control treatment yielded the lowest adhesion rate. The treatments employing 10% and 20% substitution of date juice exhibited minimal distinctions from the control treatment. Specifically, substituting sucrose with date juice at a 20% level did not result in substantial variances in treatment adhesion ($p<0.05$).

The capacity for springiness is influenced by additional texture properties, including hardness and adhesion. There is a significant decrease in the springiness of treatments by increasing adhesion and reducing hardness. The decline in springiness becomes apparent at the replacement level of 20% and above. The treatment with the highest level of adhesion (T_3 treatment) exhibits the least degree of springiness. The springiness of T_1 and T_2 treatments shows a significant increase when the hardness of these treatments is reduced through the substitution of 10% and 20% ($p<0.05$). Furthermore, over a six-week period of storage, no statistically significant differences were observed between the various treatments on the first day following production ($p<0.05$).

The findings of the texture assessment demonstrate alterations in the gum's texture as a consequence of substituting sugar with date juice. The textual alterations can be attributed to the inherent properties of date juice. Date juice, as a

sweetener, can contribute to the viscosity, shape retention, and elasticity of gum due to its high solids content. This phenomenon has been demonstrated in various studies (Al Hagbani *et al*., 2018; Sultan *et al*., 2016; Apar *et al.*, 2004). The findings presented in Table 3 demonstrate that the retention of elevated levels of moisture results in a reduction in the hardness of gum treatments. This issue relates to improving the chewiness of date juice gum treatments by substituting 10 and 20% of the original ingredients used. The augmentation of adhesion in elevated concentrations of date juice corresponds to a 30% reduction in the elasticity and resilience of the texture, resulting in a subsequent diminution in masticatory function. Furthermore, the resilience of the gum experiences a notable reduction as the percentage of adhesion increases, due to its correlation with the rise in moisture content in the T_3 treatment. The preservation of chewing gum treatments through packaging and limited moisture exchange with the surrounding environment prevents notable alterations in the texture attributes of chewing gum within the initial six weeks of storage following production ($p<0.05$). Several studies have shown consistent findings regarding the impact of liquid syrup consumption on the gum production process and the assessment of gum quality characteristics (Al Hagbani *et al*., 2018; Haahr *et al*., 2003).

Table 3. Comparing the average results of evaluation of histometric indicators of treatments during six weeks of storage ($p<0.05$)

Storage time	Treatments	Chewing ability ($N.mm^{-1}$)	Hardness (N)	Cohesiveness	Springiness (mm)
1st week	T	6±0.01 a	7.8±0.02 a	1±0.02 a	0.9±0.02 a
	T_1	6.3±0.02 b	7.4±0.01 b	1±0.49 a	0.92±0.01 b
	T_2	6.6± 0.04 c	7.2±0.04 c	1±0.98 a	0.94±0.02 c
	T_3	5.8± 0.2 d	7±0.02 d	1.5±0.02 b	0.7±0.02 d
2nd week	T	6±0.01 a	7.8±0.02 a	1±0.02 a	0.9±0.02 a
	T_1	6.03±0.1 b	7.4±0.01 b	1±0.09 a	0.92±0.03 b
	T_2	6.6±0.02 c	7.2±0.04 c	1±0.53 a	0.94±0.01 c
	T_3	5.8±0.02 d	7±0.02 c	1.5±0.88 b	0.7 ±0.02 d
3rd week	T	6±0.01 a	7.8±0.02 a	1±0.02 a	0.9±0.02 a
	T_1	6.3±0.03 b	7.4±0.01 b	1±0.04 a	0.92±0.03 b
	T_2	6.6±0.03 c	7.2±0.04 c	1±0.03 a	0.94±0.03 c
	T_3	5.8±0.02 d	7±0.02 d	1.5±0.94 b	0.7±0.02 d
4th week	T	7.8±0.02 a	7.8±0.02 a	1±0.02 a	0.9±0.02 a
	T_1	7.4±0.01 b	7.4±0.01 b	1±0.04 a	0.92±0.02 b
	T_2	7.2±0.05 c	7.2±0.04 a	1±0.02 a	0.94±0.03 a
	T_3	7±0.02 d	7±0.02 d	1.5±0.9 4 b	07±0.02 d
5th week	T	6±0.01 a	7.8±0.02 a	1±0.02 a	0.9±0.02 a
	T_1	6.3±0.02 b	7.4±0.01 b	1±0.29 a	0.92±0.02 b
	T_2	6.6±0.06 c	7.2±0.04 c	1±0.76 a	0.94±0.04 c
	T_3	5.8±0.02 d	7±0.02 d	1.5±0.96 b	0.7±0.02 d
6th week	T	6±0.01 a	7.8±0.02 a	1±0.02 a	0.9±0.01 a
	T_1	6.3±0.03 b	7.4±0.01 b	1±0.02 a	0.92±0.03 b
	T_2	6.6±0.04 c	7.2±0.04 c	0.99	094±0.05 c
	T_3	5.8±0.02 d	7±0.02 d	1.5 b	0.7±0.02 d

Conclusion

Sucrose is celebrated for its natural sweetness and robust functional properties, making it a widely utilized ingredient across various food products. Nevertheless, the prevalent use of sucrose in food items has been found to diminish the intake of essential nutrients such as vitamins, minerals, amino acids, and fatty acids. Conversely, the correlation between sugar consumption and various health ailments such as elevated glucose and blood sugar levels, cardiac conditions, dental caries, and obesity, along with concomitant economic and technological factors, has prompted an upsurge in research efforts to identify a viable sugar substitute to be used as alternative. Concurrently, there is a concerted effort to develop value-added products in this aspect.

Cereal-based products, including bread, cakes, biscuits, and confectionery items like chewing gum, are extensively utilized worldwide and have become integral components of the contemporary diet. Many of these products, particularly chewing gum, contain excessive quantities of sugar. Various agricultural products, including corn, date fruit, figs, and grapes, have been identified as potential natural and viable alternatives to sucrose. Furthermore, incorporating date juice in food formulation not only decreases the sucrose content, but also offers various advantages such as enhancing the nutritional profile of food items, generating high-value products, utilizing cost-effective and easily accessible raw materials, and consequently aiding local processing sectors. The sensory (taste) and tactile (firmness and mouthfeel) attributes of the product are of considerable importance. Several issues pertaining to optimization arise when substituting sucrose in food products, including negative impacts on taste, physical attributes of the product, consumer acceptance, and legal restrictions within this domain. This research examined the sensory and physicochemical attributes, including texture, chewability, elasticity, and flavor, of chewing gum treated with different levels of date juice replacements. The treatments that replaced 20% and 10% of date juice were found to be the most favorable based on the mentioned characteristics.

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