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NIR Spectroscopy Assessment of Quality Index of Fermented Milk (Laban) Drink Flavored with Date Syrup during Cold Storage

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Abstract: Fermented milk (laban) with added date syrup can be an excellent candidate for a nutritious drink. Modeling with quality index (Q_i) can assist in assessing the quality of the drink's physiochemical properties. The properties of the laban drink fortified with date syrup were measured and modeled with Q_i during shelf life (7 days), and then analyzed with near-infrared spectra (NIR). The aim of this study was to develop a quality index model for the laban drink properties (objective and sensory assessments) and then to predict Q_i with a non-destructive measurement of NIR (with partial least-square regression (PLSR) and artificial neural network (ANN) analysis). The results revealed that the developed Q_i fits well with measured laban drink properties (viscosity, color, total soluble solids, pH, and sensory assessments during the shelf-life period with R^2 = 0.977). The NIR spectrum was efficient to estimate the quality index of the fortified laban drink. It was found that ANN is more appropriate than the PLSR model in estimating the Q_i of the Laban drink during cold storage. Thus, non-destructive NIR can predict Q_i and can be utilized with great success in the whole chain of production, processing, transportation, storage, and retail market to check the "quality" and "shelf life" of the product.

Keywords: fermented milk drink; date syrup; quality index; modeling; NIR

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1. Introduction

Increasing quantities of minimally processed foods are available in markets in response to a growing demand for natural products, which are perceived by consumers as more nutritious and healthy foods. Functional dairy beverages are among those foods that combine fruit syrup with dairy drinks fortified with vitamins, minerals, and fiber [1,2]. Several researchers, food producers and developers, and public health professionals, as well as consumers, are focusing on the concept of food quality to be healthier and nutritious. The concept of food quality is linked to several factors such as the person, place, and time [3].

The dairy products industry is one of the most advanced and successful sectors of the food industry in Saudi Arabia. Milk production in SA is estimated to be 2.55 million tons annually [4]. The most common products that are pasteurized and sterilized are milk, yogurt, labneh, and laban and their drinks. Flavored milk drinks (raw and fermented) are currently one of the largest expanding sectors in the dairy industry. Various additives and flavorings added to milk and milk products are in the markets such as chocolate, caramel, coffee, strawberry, vanilla, and banana [5–8]. Most of these flavors are artificial and the sweeteners lack nutritional value. It is essential to find an alternative to these artificial flavorings and sweeteners with products having a better nutritional value and suitable flavors and preferably being available locally, such as dates.

Dates can be one of the candidate fruits to fulfill both preferable flavor and natural sweetener. Saudi Arabia is the second-largest producer of dates in the world, exceeding 1.5 million tons/year from 33 million palm trees [4]. There is a surplus of dates in SA, estimated to be 15%, that can be utilized to achieve food security. There are several by-products from the date industry (produced from 156 date factories) including date syrup, paste, vinegar, and juice. Date syrup (concentrate of date juice) is one of the most important by-products of dates, it can be utilized as a sweetener, and has nutrition as well as flavor. Furthermore, it can also be introduced in the manufacturing of pastries, juices, ice cream, and others.

Date syrup, a traditional sweetener, is natural without additives and is a rich source of minerals, especially iron [9]. Yashaswini and Arunkumar [10] showed that date syrup is one of the best natural and nutritional additives to produce numerous flavored and sweetened dairy products and a safe alternative to sugar. They mixed yogurt with date syrup with the addition of 0, 8, 10, and 12% (date syrup: yogurt by weight). Measurements of the chemical components of the samples showed that the increase in the percentages of added date syrup led to an increase in proteins, total solids, and acidity (lactic acid %) in the range of 3.30–3.44%, 15.0–24.7%, and 0.85–1.09%, respectively; while it led to a decrease in fat in the range of 3.50–3.48%. Sensory evaluation revealed that the sample containing 10% syrup was the best and obtained general acceptance with a value of 8.7 out of 9.0 on the hedonic scale. Hamza et al. [11] examined the effect of gamma rays on the shelf life of yogurt flavored with date syrup. The obtained results showed that the treatment improved the microbiological quality of the samples as well as retained their physicochemical quality. Alhamdan et al. [12] examined the nutritional quality of laban drinks with added date syrup. Their results indicated that flavoring laban with date syrup affected the physicochemical, microbial, nutritional, and other quality attributes of the drinks. During storage, ash, acidity, and microbial load were increased, while fat, casein, total solids, and sugars showed a reduction with storage. There is a need for further extensive efforts to explore the utilization of date syrup in dairy products such as milk and laban.

The development of a theoretical/empirical model for overall quality properties can be described by the food quality index [3,13]. Instrument-based measurements (objective) are preferred over sensory evaluation in research and commercial applications. These tools are more accurate, reduce differences between arbitrators, and provide a common language between researchers, industry, and consumers [14]. There is a need to track food quality changes during the shelf life with a proper quality index model to help product developers as well as for the consumer's preference. Then, the quality index model can be further predicted utilizing non-destructive tests such as near-infrared spectroscopy (NIR).

Near-infrared spectroscopy (NIR) is a leading widespread non-destructive detecting approach for a possible quick appraisal of food properties. Numerous researchers attempted to predict the physical and chemical properties of various food products, either fresh or during processing or storing using NIR [15–22]. Moreover, other researchers have linked spectroscopy to sensory evaluation of foods [23–27]. NIR and statistical analysis can be powerful tools to express food properties and sensory evaluation. A combination of developing a quality index model for food properties and then expressing such Q_i with NIR will facilitate and speed up testing food quality within the food chain as well as during the shelf life of foods.

In recent studies, Tian et al. [28] developed an NIR model to predict three components of flavonoids (total flavonoids, phloridin, and trilobatin) in sweet tea leaves, as an alternative to time-consuming and expensive chemical analyses. The R^2 for all calibration, validation, and prediction sets of the NIR PLS models were 0.967, 0.858, and 0.818, respectively. They concluded that NIR was able to determine the flavonoid content of sweet tea quickly and conveniently. Furthermore, Zhang et al. [29] correlated green tea components (caffeine, epigallocatechin-3-gallate (EGCG), and moisture content) with NIR while production. They concluded that the model can be utilized to monitor tea product quality online in a productive process. They emphasized that NIR analysis is fast, non-destructive, and less sample volume is required, which is advantageous compared to traditional HPLC analysis. Pandiselvam et al. [30] examined different spectroscopic methods including NIR to determine the oxidative stability, adulteration, and detection of harmful additives, pathogens, and toxins in coconut products. Those non-destructive methods, including NIR, proved to be successful in authentication and quality determination of coconut products including the detection of adulterants in coconut oil. Araújo et al. [31] correlated experimental values of electrical conductivity and potassium leaching with NIR spectra of green coffee beans. The best model obtained for estimating electrical conductivity showed an R^2 of 0.97, whereas for potassium leaching, the R^2 was 0.88. Thus, NIR spectra gave a chemical fingerprint of the product correctively. Cano-Reinoso et al. [32] evaluated and correlated the chemical composition (α-guaiene and azulene) of 84 samples of patchouli aromatic oil in Indonesia by utilizing NIR. The best calibration model was the second derivative in which R^2 was higher than 0.90 and the coefficient of variation was less than 2.98%, which proved the applicability of NIR to the quality evaluation of patchouli oil. Ghooshkhaneh et al. [33] conducted an interesting study to examine the early detection of citrus black rot disease caused by fungi with NIR spectra. The oranges were inoculated with *Alternaria alternate* and inspected at 200–1100 nm in the first, second, and third weeks after inoculation. The accuracy in the detection of healthy and infected samples in the first week was 60%, in the second week was 60%, and in the third week was 100%.

To date, no published reports quantify both objective and subjective measurements of the properties of laban drinks flavored with date syrup during storage. The main objective of this study is to develop a quality index (Q_i) for flavored laban that combines objective and sensory assessment, and then examine the possibility of predicting this Q_i with a non-destructive measurement by means of NIR techniques. This will reduce time, cost, and effort in such sensory and routine analysis for fresh produce as well as during processing and storage.

2. Materials and Methods

2.1. Sample Preparation

Fermented milk (laban) drink flavored with date syrup was prepared by mixing laban samples (from local markets) with date syrup (80 °Brix) at different concentrations (Khlass variety) (2.5, 5, 7.5, 10, 12.5, and 15% date syrup/total weight of flavored laban) using a mixing apparatus (Coldream M2, Cofrimell S.a.s., Rome, Italy) in a water bath of 5 °C to simulate refrigeration temperature. The laban drink was stored in sealed sterilized containers for 7 days at 5 °C and the physical, nutritional, and sensory attributes of the product were assessed fresh and every day for 7 days of storage.

2.2. Sensory Evaluation of Laban Drinks

Thirty-six panelists consisting of students and staff of the College of Food and Agriculture Sciences, King Saud University, were engaged and instructed to perform the sensory evaluation. The evaluation was conducted in the sensory lab at the Department of Food Science and Nutrition. The samples were provided in white plastic cups under fluorescent light. All samples were marked with 3-digit codes, and the order of presentation of samples was randomized for each panelist. The panelists evaluated color, texture, taste, flavor, and overall acceptance using a 9-point hedonic scale (1 = dislike extremely and 9 = like extremely) as described by Lawless and Heymann [34]. The tests were conducted in two stages, the first was to select the most preferred percentage of syrup added to the laban to form the most preferred laban drink. The second stage is for the same panelists to examine the sensory evaluation of the selected laban drink during the shelf-life test daily for 7 days.

2.3. Measurements of Physicochemical Properties of Laban Drinks

The total soluble solids (TSS) of samples were measured using a refractometer (ABBE 5, Bellingham & Stanley Ltd., Longfield Rd, Tunbridge Wells TN2 3EY, UK). The pH was measured using a pH meter (Model 3510, Jenway, Bibby Scientific Ltd., Stone, Staffordshire, UK). After each measurement, the electrode was standardized using a pH 7.0 buffer.

Experiments to measure viscosity were carried out according to standard (DIN 53019-1) utilizing Anton Paar, Rheolab (C-PTD 180/Air/QC, Ankerstraße 6, Graz, Austria), and performed at cold storage temperature (5 °C) and at a shear rate 100 s^{-1}.

Basic color parameters (L*, a*, and b*) were measured using the Nix QC sensor (Nix Sensor Ltd., Ontario, Canada) with CIELAB international standard (ISO 11664-4). Other color parameters (total color difference (ΔE) and Browning index (BI)) were calculated as follows:

$$\Delta E = \sqrt{(L^*_0 - L^*)^2 + (a^*_0 - a^*)^2 + (b^*_0 - b^*)^2} \tag{1}$$

$$BI = \frac{[100 \times (x - 0.31)]}{0.17} \tag{2}$$

where:

$$x = \frac{(a^* + 1.75L^*)}{(5.645L^* + a^* - 3.012b^*)} \tag{3}$$

The basic color parameters for the fresh laban (no syrup added) were considered as the reference values.

2.4. Quality Index (Q_i) Assessment

The overall quality index (range 0 to 1) is a tool developed to normalize and model the variables examined with reference to the minimum value of the controlled variable; in which normalizations will help to have data compatibility of the quality index [35–38]. To normalize the parameters, the following formula can be used:

$$\hat{x_i} = \frac{x_i - x_{min}}{x_{max} - x_{min}} \tag{4}$$

where ($\hat{x_i}$) is the normalized value of the quality parameter (x), (x_i) is the measured value quality parameter, and x_{max}; x_{min} are the maximum and minimum values of the quality parameter (x), respectively. The quality index (Q_i) was calculated according to:

$$Q_i = \frac{\sum_{1=1}^{N} \hat{x_i}.}{N} \tag{5}$$

Thus, the developed Q_i will fit both normalized sample properties as well as overall sensory acceptance data. Next, those quality index data will be further evaluated utilizing NIR spectroscopy to non-destructively predict Q_i and food properties.

2.5. Quality Index Assessment Using NIR Technique

Near-infrared spectroscopy of food samples will non-destructively assist in evaluating food properties as well as Q_i by utilizing a handheld quality NIR meter (F-750, Firmware v.1.2.0 build 7041, Felix Instruments, Camas, WA, USA). The system was assembled with a Zeiss MMS1 VIS-NIR spectrometer in the range 310–1100 nm, every 3 nm. Optical shots of F-750 were conducted for all food samples prior to food measurements (sensory assessment and objective properties). The F-750 is equipped with a reference shutter which, when scanning with the lamp off, allows the effect of dark current and ambient light to be calculated with each measurement. For each sample, the spectrum for three scans was recorded and averaged. For the validation process, spectra were obtained for a separate set of samples for the same serving at 5 °C. After recording spectra, data were transferred from the F-750 SD-Card to a PC for analysis. The stored data were imported and saved as a comma-separated values file (CSV file) utilizing Data Viewer Software. Spectra were pre-processed using the second derivative of Savitzky–Golay.

Calibration models were then developed using the data set (252 samples and 272 spectra). The calibration models were developed using two analysis tools: a partial least squares regression (PLSR) and an artificial neural network (ANN). The PLSR method is used to analyze the spectra as a linear multivariate relationship [39]. PLSR works by finding latent variables (LVs) before executing a multiple regression model. Latent variables (LVs) are high-dimensional vectors that explain the most useful variance in the data. Latent variables are identified by exploring sub-spaces that increase the covariance between predictor and response variables [40].

Artificial neural networks (ANNs) are a highly developed nonlinear pattern recognition method that can model complicated biodiversity, and environmental and instrument variability [41]. In the present work, the estimated data were analyzed by AppBuilder v2.1.7 software (Felix Instruments, Camas, WA, USA). The prediction performance was assessed based on calibration and validation results according to the correlation coefficient (R^2), the root mean square error in calibration (RMSEC), and cross-validation (RMSECV) [22].

2.6. Statistical Analysis

All objective measured properties were analyzed using a statistical package (SAS software, Version 9.2, SAS Institute Inc., Cary, NC, USA). The prediction performance was assessed based on calibration and validation results utilizing AppBuilder v2.1.7 software (Felix Instruments, Camas, WA, USA). Graphs, plots, and other calculations were performed using Microsoft Office 365 package (Microsoft, Redmond, WA, USA).

3. Results and Discussions

The strategy of this study was to select the most acceptable laban drink percentage of added date syrup to the Laban for the arbitrators (which was 12.5%). Then, we perform the objective and subjective measurements of the drink shelf life, estimate the quality index, and build the NIR models based on the properties and Q_i of the drink chosen.

3.1. Sensory Evaluation

3.1.1. Best Sample Selection

Sensory evaluation (36 assessors) was performed for laban drinks flavored with added Khalass date syrup (2.5, 5, 7.5, 10, 12.5, and 15% date syrup/total weight of laban drink). Precautionary procedures and health measures were fulfilled to achieve the designed sensory evaluation. Table 1 shows the mean sensory values of the attributes of the laban drink by judges. It also displays the significant differences using Duncan's multiple choice at 0.05 ($p < 0.05$).

Table 1. Sensory evaluation of laban drinks at different added date syrup levels.

Added Date Syrup g/100 g Laban Drink	Texture	Flavor	Taste	Color	Acceptance
15	$7.92^A \pm 1.22$	$7.56^A \pm 1.18$	$7.67^A \pm 1.02$	$7.53^A \pm 1.20$	$7.72^A \pm 1.00$
12.5	$7.28^A \pm 1.79$	$6.67^A \pm 1.39$	$6.64^A \pm 1.11$	$7.11^A \pm 0.98$	$7.17^A \pm 1.08$
10	$6.72^A \pm 1.50$	$6.03^A \pm 1.40$	$6.25^A \pm 1.16$	$6.75^B \pm 1.11$	$6.00^B \pm 0.68$
7.5	$6.19^B \pm 1.50$	$5.39^B \pm 1.36$	$5.42^B \pm 1.00$	$6.50^B \pm 1.18$	$6.06^B \pm 1.01$
5	$5.39^C \pm 1.65$	$4.83^B \pm 1.36$	$4.53^C \pm 1.20$	$5.67^C \pm 1.20$	$5.28^C \pm 1.00$
2.5	$4.19^C \pm 1.02$	$3.67^B \pm 1.24$	$3.39^C \pm 1.45$	$4.78^C \pm 1.96$	$4.11^C \pm 1.09$

Mean values followed by different capital letters within the same column are significantly different at $p < 0.05$.

The results of the sensory evaluation of the samples revealed that, in general, the acceptance of the arbitrators decreases as the percentage of added date syrup decreases. This is in line with the increase of sweetness (thus, taste) of the laban drink by adding date syrup to the sour taste of the fresh laban. The addition of fruit pulps/syrup has been reported by Ryan et al. [2] in which the higher percentages of added mango fruit pulps usually result in better sensory profiles compared to the lower percentages of the fruit pulps. In this study, considering the average of the hedonic scale of 5, the results indicated that the addition ratio of 2.5% was the least favorable laban drink, as well as the flavor and taste characteristics of 5%.

It can be noted from Table 1 that the two preferred samples were 12.5 and 15% date syrup/total weight of laban drink. Economically, the mix (12.5%) would be the preferred laban drink compared to 15%. Consequently, the physical, sensory, and nutritional properties of this preferred Laban drink (12.5%) were chosen as candidates for the shelf life tests for 7 days.

3.1.2. Shelf-Life Sensory Evaluation

Table 2 shows the average sensory evaluation of the laban drink during the storage period of 7 days. In general, the characteristics did not change on the first day after storage compared to the fresh one. However, significant changes began to appear from the second day until the fourth day, which can be considered above average acceptance on the hedonic scale. It should be clarified that the addition of date syrup significantly reduced the total microbial counts as reported by Alhamdan et al. [12]. They suggested that date syrup exhibited antimicrobial effects in laban drink which can be attributed to the secondary formation of metabolites such as phenolic compounds, glycoproteins, and polypeptides.

Table 2. Analysis of variance for the effect of storage time on the sensory evaluation of laban drink.

Day	Texture	Flavor	Taste	Color	Acceptance
0	$7.31^{A} \pm 1.22$	$6.67^{A} \pm 1.18$	$6.67^{A} \pm 1.02$	$7.19^{A} \pm 1.20$	$7.17^{A} \pm 1.00$
1	$7.28^{A} \pm 1.79$	$6.64^{A} \pm 1.39$	$6.58^{A} \pm 1.11$	$7.11^{A} \pm 0.98$	$7.17^{A} \pm 1.08$
2	$6.11^{B} \pm 1.50$	$6.00^{B} \pm 1.40$	$6.00^{B} \pm 1.16$	$6.36^{B} \pm 1.11$	$6.00^{B} \pm 0.68$
3	$5.94^{B} \pm 1.50$	$5.86^{B} \pm 1.36$	$5.88^{B} \pm 1.00$	$6.14^{B} \pm 1.18$	$5.94^{B} \pm 1.01$
4	$5.25^{C} \pm 1.65$	$5.25^{C} \pm 1.36$	$5.33^{C} \pm 1.20$	$5.58^{C} \pm 1.20$	$5.28^{C} \pm 1.00$
5	$4.75^{D} \pm 1.02$	$4.81^{CD} \pm 1.24$	$4.81^{C} \pm 1.45$	$4.94^{D} \pm 1.96$	$4.78^{D} \pm 1.09$
6	$4.27^{E} \pm 1.12$	$4.33^{DE} \pm 1.17$	$4.25^{D} \pm 1.02$	$4.19^{E} \pm 1.22$	$4.25^{E} \pm 1.14$
7	$4.08^{E} \pm 1.08$	$4.19^{E} \pm 1.13$	$4.06^{D} \pm 1.52$	$4.03^{E} \pm 1.33$	$4.11^{E} \pm 1.17$

Mean values followed by different capital letters within the same column are significantly different at $p < 0.05$.

3.2. Physicochemical Properties during Shelf Life

Table 3 shows the effect of storage time on the physicochemical properties of the laban drink. TSS had no significant difference during storage. On the other hand, color parameters (Browning index (BI) and total color differences ΔE) showed a significant change during shelf life. This might be due to the bacterial activity of the laban drink affecting the pH, which influences the stability and color of the pigments of similar products [42–45]. A decrease in the apparent viscosity of the laban drink during storage was noted, probably due to the change of texture and other properties of the drink, as noted in Table 2. The tendency for these changes was similar to the changes in the apparent viscosity found for other fermented dairy products [46–49].

Table 3. Analysis of variance for the effect of storage time on the physicochemical properties of a laban drink.

Day	pH	TSS (Brix)	μ (mPas^{-1})	ΔE	BI
0	$4.76^{A} \pm 0.005$	$16.47^{A} \pm 0.001$	$240.65^{A} \pm 0.01$	$0.00^{A} \pm 0.000$	$1.01^{D} \pm 0.001$
1	$4.76^{B} \pm 0.005$	$16.47^{A} \pm 0.001$	$240.65^{A} \pm 0.01$	$1.11^{G} \pm 0.002$	$1.11^{B} \pm 0.002$
2	$4.75^{B} \pm 0.006$	$16.47^{A} \pm 0.001$	$239.48^{B} \pm 0.02$	$1.30^{F} \pm 0.010$	$1.30^{C} \pm 0.010$
3	$4.73^{C} \pm 0.005$	$16.47^{A} \pm 0.001$	$235.36^{C} \pm 0.01$	$2.59^{E} \pm 0.014$	$2.59^{h} \pm 0.014$
4	$4.71^{C} \pm 0.005$	$16.46^{A} \pm 0.001$	$235.00^{C} \pm 0.01$	$3.38^{D} \pm 0.002$	$3.38^{F} \pm 0.002$
5	$4.69^{D} \pm 0.006$	$16.46^{A} \pm 0.001$	$234.35^{D} \pm 0.03$	$3.79^{D} \pm 0.001$	$3.79^{C} \pm 0.001$
6	$4.67^{E} \pm 0.005$	$16.46^{A} \pm 0.001$	$232.34^{E} \pm 0.03$	$4.58^{C} \pm 0.004$	$4.58^{A} \pm 0.004$
7	$4.61^{F} \pm 0.033$	$16.40^{A} \pm 0.001$	$229.70^{F} \pm 0.01$	$4.62^{B} \pm 0.008$	$4.62^{E} \pm 0.008$

Mean values followed by different letters within the same column are significantly different at $p < 0.05$.

3.3. Quality Index Modeling

The quality index (Q_i) for the laban drink assesses the average quality of 10 parameters: five for sensory and five for physicochemical properties. During the storage period, the laban drink showed gradual and consistent changes for all evaluated parameters as shown in Figure 1. The modeled quality index of the laban drink started with a value of 0.8 but reached 0.2 at the end of the storage period.

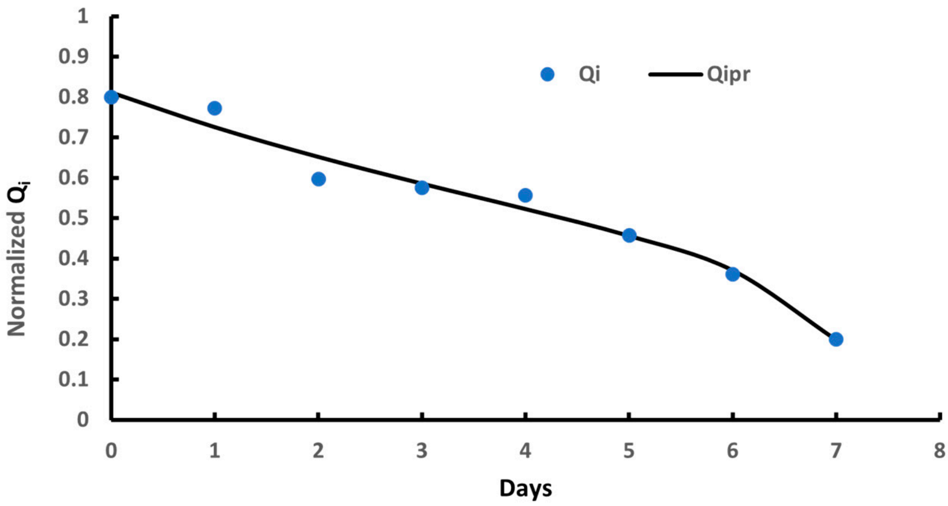

Figure 1. Experimental and predicted normalized quality index (Q_i) of the laban drink during storage.

A relation between the normalized quality index and shelf-life period (days) was established in the following model (with R^2 = 0.977):

$$Q_i = \frac{0.810545 - 0.109204 \times \text{Days}}{1 - 0.019771 \times \text{Days} - 0.012851 \times \text{Days}^2} \quad (6)$$

Furthermore, the power law model may describe and evaluate the sensory evaluation of a food product [50]. In this sense, the correlation between overall sensory acceptance (y) and the normalized quality index is:

$$y = 7.4188{Q_i}^{0.4384} \quad (7)$$

The acceptable correlation coefficient was (R^2 = 0.8683). The exponent of the power function which determines its curvature is less than 1.0; thus, the overall acceptance has downward curvature with respect to the normalized quality index, and the overall acceptance increased less rapidly with an increasing quality index.

It can be concluded that the quality index assisted to be a reference of the actual shelf life of laban drink, and can be examined with dairy and other products. Furthermore, authorities can utilize Q_i to check and calculate the actual quality and shelf life of liquid and dairy products along the chain of storage, production, transportation, and retail, with reasonable accuracy.

With the success of modeling quality index with sensory and physiochemical properties into a single value, it will be helpful to evaluate and model this Q_i further with a non-destructive and easy-to-measure instrument such as NIR.

3.4. Modeling Quality Index Using the NIR Technique

Recently, the NIR technique gained more popularity in food applications to link the reflectance/absorbance of the measured spectrophotometer waves with the physiochemical properties of food products. Pre-processing NIR spectrum data is necessary to obtain strong models with good performance. To remove some extraneous signals from the spectra, the derivatives can be very useful in (NIR) spectroscopy [51,52]. In this study, the second derivative of NIR spectra was performed. The mean second absorbance derivative spectra for laban drinks during the shelf-life period of 7 days (36 samples each day) at the wavelength region (729–975 nm) were determined and shown in Figure 2.

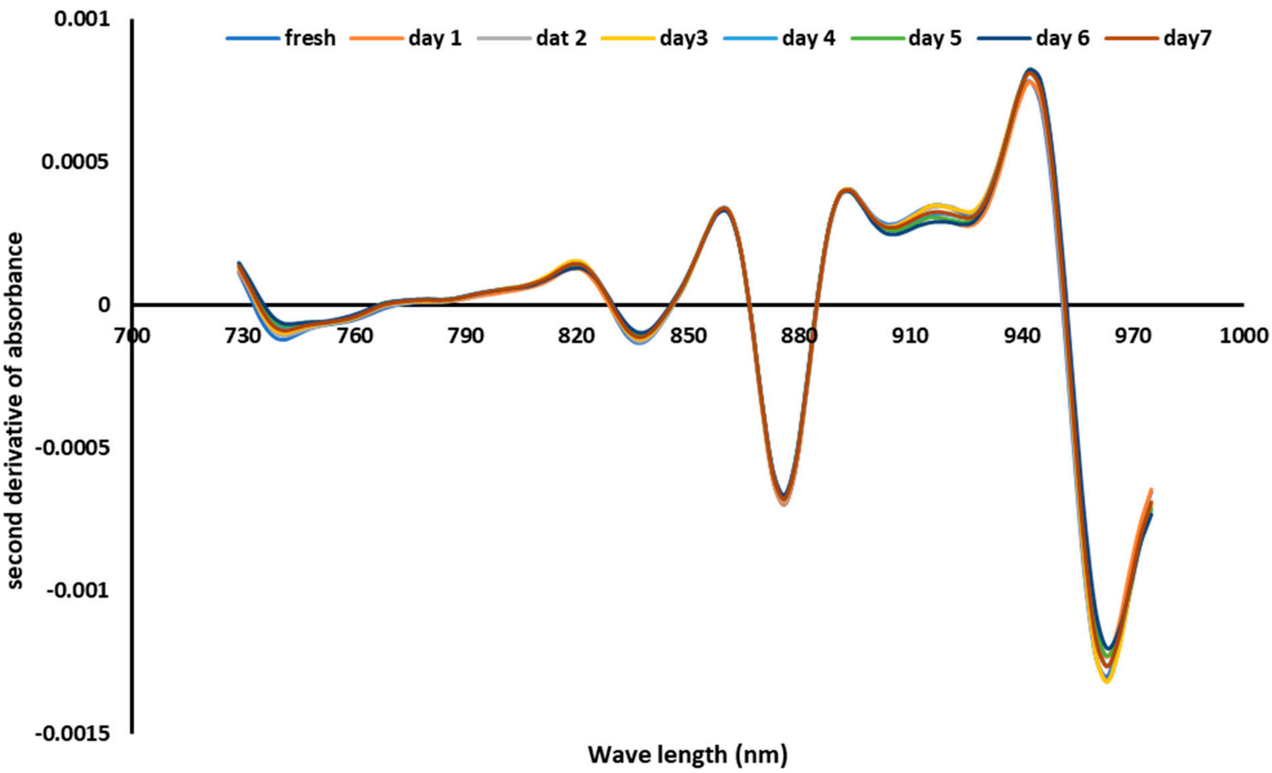

Figure 2. The mean second derivative of absorbance in the wavelength range (729–975 nm) for the shelf-life period of the stored laban drink.

Several methods of pre-processing can be implemented prior to modeling [16,53]. After NIR experiments were performed, two analysis tools were utilized: PLSR and ANN.

3.4.1. Partial Least Squares Regression (PLSR)

PLSR performance of calibration and cross-validation for TSS, pH, μ, ΔE, BI, and Q_i properties are shown in Table 4. In the calibration models, R^2 and RMSEC values were 0.989 and 0.666 for TSS; 0.912 and 0.715 for pH; 0.911 and 2.14 for apparent viscosity μ; 0.971 and 1.004 for ΔE; 0.89 and 0.988 for BI; 0.801 and 0.11 for Q_i, respectively.

Table 4. PLSR performance for TSS, pH, μ, ΔE, BI, and Q_I of flavored laban drinks for both calibration and cross-validation models.

Parameter	Calibration		Cross-Validation	
	R^2	RMSRC	R^2	RMSECV
TSS	0.989	0.666	0.919	0.766
pH	0.912	0.715	0.902	0.785
μ	0.911	2.140	0.910	1.940
ΔE	0.971	1.004	0.921	0.989
BI	0.890	0.988	0.891	0.911
Q_i	0.801	0.111	0.791	0.301

In cross-validation performance, R^2 and RMSECV values were 0.919 and 0.766 for TSS; 0.902 and 0.785 for pH; 0.91 and 1.94 for apparent viscosity μ; 0.921 and 0.989 for ΔE; 0.891 and 0.911 for BI; 0.791 and 0.301 for Q_i, respectively.

It can be noted that the correlation coefficient (R^2) values ranged from 0.79 to 0.92. This range indicates a very good model performance; in which an R^2 higher than 0.70 in NIR models is considered to be satisfactory [54–56]. This suggests that the PLSR technique is a powerful statistical tool for predicting both objective properties and subjective evaluation of the laban drink.

3.4.2. Artificial Neural Networks (ANN)

The ANN's performance for calibration and cross-validation for the laban drink properties is presented in Table 5. In calibration models, R^2 and RMSEC values were 0.992 and 0.866 for TSS; 0.9 and 0.755 for pH; 0.91 and 1.84 for apparent viscosity μ, 0.96 and 1.104 for ΔE; 0.9 and 0.688 for BI; 0.921 and 0.311 for Q_i, respectively. In cross-validation performance, R^2 and RMSECV values were 0.989 and 0.712 for TSS; 0.902 and 0.715 for pH; 0.91 and 1.14 for apparent viscosity μ; 0.959 and 999 for ΔE; 0.898 and 0.611 for BI; 0.921 and 0.311 for Q_i, respectively. The results support that the ANN technique is an excellent tool for predicting the properties of the laban drink. Furthermore, the ANN model is, generally, more suitable for laban drink properties prediction compared to the PLSR model. It is evident that the correlation coefficients of the ANN model are higher than those of PLSR, more clearly with the normalized quality index parameter. Hence, under the conditions of this study, it is recommended for Q_i to use the ANN technique (R^2 = 0.921) rather than that of PLSR (R^2 = 0.890).

Table 5. ANN performance for TSS, pH, μ, ΔE, BI, and Q_I of flavored laban drinks for both calibration and cross-validation models.

Parameter	Calibration		Cross-Validation	
	R^2	RMSRC	R^2	RMSECV
TSS	0.991	0.866	0.989	0.712
pH	0.900	0.755	0.902	0.715
μ	0.910	1.840	0.910	1.140
ΔE	0.960	1.104	0.959	0.999
BI	0.900	0.688	0.898	0.611
Q_i	0.921	0.311	0.921	0.311

RMSEC is a measure of how well the calibration model fits the calibration set. It is always decreasing as the number of factors increases. However, the RMSECV occasionally increases when more factors are added. RMSECV is a better estimate of the future performance of model prediction than RMSEC [57].

Thus, the two techniques of analysis (PLSR and ANN) proved to be powerful tools to model NIR data in terms of calibration and cross-validation. Moreover, the ANN model is preferable compared to PLSR due to the higher correlation coefficients. Therefore, with those analyses, NIR correlated well with the Q_i and thus with the individual properties of the laban drink as well.

In principle, Q_i can be determined during storage and in retail up to the shelf life of flavored laban drinks set by standard authorities [58]. For applications in fields, a non-destructive handheld NIR spectrophotometry meter can be used with great success by food producers, processors, and authorities in the whole chain of production, processing, transportation, storage, and retail market to check the "quality" and "shelf life" of the produce.

4. Conclusions

The quality index (Q_i) developed for the laban drink flavored with date syrup allows a reliable and relatively accurate estimation of the drink's shelf life. This method offers a fast and reliable quality assessment procedure that can be easily utilized in all transportation, storage, and marketing chain during the shelf-life period. The NIR technique linked the reflectance/absorbance of the measured spectrophotometer waves with the physiochemical properties of food products. Both sensory and objective assessment can be tracked and measured with the quality index (Q_i) during the shelf life and measured directly by an NIR analyzer. NIR was analyzed utilizing both partial least-square regression (PLSR) and artificial neural network (ANN) analysis.

NIR satisfactorily predicted Q_i and fits well with normalized measured sample properties (viscosity (μ), color (color difference ΔE and Browning index Bi), total soluble solids (TSS), the potential of hydrogen (pH), and sensory assessments (five attributes) during the shelf-life period with R^2 = 0.977. NIR technology was efficient in estimating the quality index of Laban drink flavored with date syrup in calibration and cross-validation with an R^2 ranging from 0.79 to 0.99.

In conclusion, Q_i can be estimated during storage and in retail up to the shelf life of the flavored laban drink. As a result, non-destructive NIR spectrophotometry can predict Q_i and thus can be utilized with great success by food producers, processors, and authorities in the whole chain of production, processing, transportation, storage, and retail market to check the "quality" and "shelf life" of the product set by standard authorities (SFDA.FD 150-1/2018).

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