Physicochemical properties, nutritional value, and sensory attributes of a nectar developed using date palm puree and spirulina

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ABSTRACT
The aim was to develop nutritious drinks using date nectar with the two most popular Saudi date cultivars (Khalas and Sukkari) and spirulina at different substitution rates. The date puree was prepared with different concentrations of pectin enzymes. The approximate composition, microbiological quality, sugars, vitamins, and minerals of date puree and spirulina, as well as the contaminants, physical properties, fatty acids, and phytopigments of spirulina were evaluated. Chemical composition and sensory properties of the developed date drinks were also assessed. The results showed that spirulina is safe, free from contaminants and heavy metals, and appeared to contain appreciable amounts of essential fatty acids, amino acids, vitamins, minerals, and phytopigments. The microbiological loads of date puree and spirulina were very low, and there were no pathogenic microbes were found. Spirulina contained higher amounts of total solids, ash, protein, minerals, fiber, fat, and vitamins, than date puree, indicating its suitability as a rich source of nutrients for food fortification. In both date types, treatment of puree with 400 ppm enzyme yielded nectar with higher scores in all sensory attributes, indicating that this is a suitable concentration to yield acceptable juice amounts. The substitution of date nectar with 10% spirulina gave the highest scores for sensory attributes; consequently, this concentration was used for the formulation of functional nectar from date nectar and spirulina. Incorporation of 10% spirulina in date nectars showed a significant increase in the contents of total solids, protein, essential amino acids, ash, fat, sugars, carotenoids, and chlorophyll in the date nectars, thereby improving its nutritional and health properties.

INTRODUCTION
The date palm (Phoenix dactylifera L.) is one of the oldest trees (5500–3000 BC) and has a variety of uses. Its cultivation has widely expanded in recent years due to its great capacity to adapt to harsh environmental conditions, such as drought, salinity, and hot environments. [1] Date palm fruits, leaves, pits, and pollen have been used for food and in pharmaceutical applications because of their high amounts of carbohydrates, dietary fibers, vitamins, minerals, anthocyanins, phenolics, sterols, carotenoids, procyanidins, and flavonoids. [2,3] Thus, the consumption of date fruits and their products has been recommended by several nutritionists and health workers to overcome several health problems and nutritional disorders. [2–4] The development of food products from date fruits is a major focus of the food industry in date palm producing countries in the Middle East and North Africa. In this regard, several packaging and perseveration techniques for dates have been practiced, and numerous
products such as dry dates, powders, bars, cubes, syrups, juice concentrates, jams, jellies, butters, candies, chutney, relish, pickles, vinegar, alcohol, probiotic drinks, and beverages have been made from dates on both traditional and industrial scales. Furthermore, the processing of dates into nutritious and functional food products is still progressing.

The United Nations’ World Food Conference recognized *Spirulina platensis* as a nutritious food because of the high amounts of protein, minerals, vitamins, and phytochemicals that it contains; therefore, it is considered to be a superfood by many food producers, nutritionists, and health workers. This alga is utilized as a dietary supplement because of its high nutritional value and its potential to be an antioxidant, antimicrobial, anticancer, and anti-inflammatory agent. *Spirulina* has also been used in specialty food bars, powdered nutritional drinks, popcorn, beverages, fruit and fruit juices, frozen desserts, and condiments. Moreover, recent studies have indicated that the supplementation of food products with different concentrations of spirulina improved the nutritional quality, health properties, functional properties, and sensory attributes of the products. Furthermore, it has also been used in the development of specialty foods for elderly peoples. The formulation of specialty foods and drinks using spirulina as a supplement is of high importance from both nutritional and health standpoints. In this regard, the current study was conducted to develop specialty nectar for babies, pregnant women, and athletes, using date fruit puree and spirulina. Optimization of the processing conditions and the supplementation ratio was also studied, while the impact of these conditions on the nutritional and sensory attributes of the developed products was investigated.

**MATERIALS AND METHODS**

**Materials**

Mature date fruits of Sukkari and Khalas cultivars of uniform size were obtained from date palm farms in Riyadh, Saudi Arabia, in the 2019 season. Pectinex Ultra SP-L enzyme (26 000 U/mL) was purchased from Novo Nordisk (Princeton, NJ, USA). *Spirulina platensis* was obtained from the Department of Botany and Microbiology, College of Science, King Saud University, Riyadh, Saudi Arabia. The spirulina was dried under shade, ground to powder, and stored for 7 days or less at −18°C before being used. All other chemicals were of analytical grade and were obtained from Sigma-Aldrich (St. Louis, MO, USA).

**Preparation of date puree**

To prepare the date puree, the fruits were washed using tap water to remove dust and impurities, pitted, and the flesh was cut into small pieces. The fruit pieces were blanched for 10 min at 100°C using a pressure cooker, cooled to 45°C, and then treated with 200, 400, and 600 ppm of Pectinex Ultra SP-L enzyme. The enzymatic reaction was carried out at 40–45°C for 2 h and, thereafter, the reaction was inactivated by heating at 85°C for 10 min. The mixture was homogenized using a Moulinex blender (Blender Mixer, type: 741), filtered with cheese cloth and stored in plastic bags at −18°C for 7 days or less before being used.

**Preparation of date-spirulina nectar blends**

The date nectar blends were prepared using date puree (17% total solids, pH 3.5) and spirulina powder was added in portions of 0%, 2.5%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, and 20% relative to the date puree. To each blend, water and a 25% sugar solution were added to reach the final concentration (17% total solids), and citric acid was used to adjust the pH to 3.5. The mixtures were homogenized, filled in bottles, and sterilized for 15 min at 121°C before being cooled and then stored at 4°C until analysis.
Physicochemical determination

Date puree, spirulina, and developed nectar blends were analyzed to determine their physicochemical properties. Moisture and total solid contents were determined by drying samples in an oven at 105°C until a constant weight was achieved. Meanwhile, ash contents were determined using a muffle furnace at 500°C and fat contents were measured using the Soxhlet method at a rate of 5 or 6 drops per second by condensation for about 4–5 h. The protein content was determined by the Kjeldahl method, ascorbic acid content was determined using the 2,6-Dichloroindophenol titration method given by the AOAC, method number 967.21. pH values were measured using a pH meter, and titratable acidity values were determined by titration using AOAC\textsuperscript{[13]} methods. The contents of total carbohydrates, starch, and reducing sugars were determined by the Shaffer and Hartman method, as described in the AOAC\textsuperscript{[14]} method. The total pectin content and fractional pectin components were determined following the method described by Robertson.\textsuperscript{[14]} Total carotenoid content was determined as described by Harvey and Catherine.\textsuperscript{[15]} The total anthocyanin content was measured according to the method described by Skalaki and Sistrunk.\textsuperscript{[16]} Finally, the total dietary fiber content in the dates was determined using enzymatic-gravimetric method number 991.43.\textsuperscript{[17]}

Determination of total energy

The total energy values of the products were calculated according to Sharoba et al.\textsuperscript{[18]} using the following equation:

\[
\text{Total energy (kcal/100 g)} = [(\% \text{ available carbohydrates} \times 4) + (\% \text{ protein} \times 4) + (\% \text{ fat} \times 9)]
\]

Amino acid analysis

Amino acid analysis was carried out using an amino acid analyzer with the procedure of acid/alkaline hydrolysis, separation by cation exchange column, post-column derivatization with ninhydrin, and detection using a UV/Vis detector at 570 nm as described in AOAC standard methods.\textsuperscript{[18]}

Fatty acid composition profile

The fatty acid profile was analyzed using a gas chromatographic model (GC-17A) according to the AOAC standard method.\textsuperscript{[14]}

Mineral content

Mineral content was determined according to the AOAC standard method\textsuperscript{[14]} using a Perkin-Elmer 2380 atomic absorption spectroscopy apparatus.

Vitamin Assay

Vitamin C was determined in all samples using the dichlorophenol indophenol dye reduction method\textsuperscript{[14]}. The contents of vitamin A, thiamine, riboflavin, niacin, pyridoxine, vitamin B12, folic acid, inositol, vitamin E, vitamin K, pantothenate, and biotin were determined using the HPLC system according to AOAC standard methods.\textsuperscript{[14]}

Phytog pigment Assay

The contents of some phytog pigments (total carotenoids, beta carotene phycocyanin, chlorophyll, zeaxanthin, and xanthophyll) were determined using an HPLC system as described in the standard methods.\textsuperscript{[14]}. 

**Determination of chlorophyll and carotenoids**

The samples were homogenized using a mortar and pestle in a water bath containing squash ice. Sixteen milliliters of acetone–hexane (4:6) solvent was added to 1.0 g of homogenized sample and mixed in a test tube. Automatically, two phases were separated, and an aliquot was taken from the upper solution to measure the optical density (OD) at 663 nm, 645 nm, 505 nm, and 453 nm in a spectrophotometer. Chlorophyll, lycopene, and β-carotene contents were calculated according to the following equations [19].

\[
\text{Chlorophyll a (mg/100 mL of extract)} = (0.999 \times \text{OD 663}) - (0.0989 \times \text{OD 645})
\]

\[
\text{Chlorophyll b (mg/100 mL of extract)} = (-0.328 \times \text{OD 663}) + (1.77 \times \text{OD 645})
\]

\[
\text{β-Carotene (mg/100 mL of extract)} = (0.216 \times \text{OD 663} - 1.22 \times \text{OD 645} - 0.304 \times \text{OD 505} + 0.452 \times \text{OD 453})
\]

Chlorophyll a, b, and β-carotene were expressed as mg/100 mL.

**Microbiological examination**

The total viable bacterial count was done and mesophilic spore-forming bacteria, yeasts, molds, and coliform groups were enumerated. Similarly, the presence of *Salmonella* spp. and *Staphylococcus aureus* was detected, according to the American Public Health Association (APHA) [20]; the results for which were expressed as CFU/g.

**Analysis of rodent hairs, insect fragments, heavy metals, and bulk density in spirulina samples**

Rodent hairs and insect fragments in spirulina were determined as previously described by Thind [21]. The determination of arsenic, cadmium, and lead in spirulina samples was performed according to the methods described by Haeng-Shin et al. [23], by inductively coupled plasma–emission spectrometry (Model JY 38 S; Horiba, Jobin Yvon Cedex, France). Duplicate samples were run in triplicate for the analysis of each heavy metal. For bulk density analysis, 2 g of spirulina powder was carefully poured into a 10 mL graduated cylinder, while holding the cylinder and tapping 10 times on a rubber mat from a height of 15 cm. The ratio of the mass of the powder to the volume occupied in the cylinder was considered to be the bulk density.

**Sensory evaluation**

Sensory evaluation was carried out by 12 trained panelists (7 males and 5 females aged 25–45 years) in a room with pale light and a room temperature of 25 °C. The samples were carefully selected based on having high reproducibility (>90%) in 10 different tests. The panelists were asked to evaluate the color, taste, odor, texture, mouth feel, and overall acceptability of the products using a 100-point scale [13]. On this scale, (90–100) = excellent, (70–80) = very good, (50–60) = good, (30–40) = fair, and (10–20) = poor. The panelists used mineral water to rinse their mouths between the testing of each sample.

**Statistical analysis**

Data on the chemical composition of ingredients and formulas were expressed as the mean of three replicates ± standard error (SE). Data for the sensory evaluation of all nectar formulas were subjected to analysis of variance followed by the multiple LSD test using SPSS v21 software [22].

**RESULTS AND DISCUSSION**

**Physical properties, microbial load, and contaminants of date puree and spirulina powder**

The results of the physical properties and contaminants of spirulina, and the microbial loads of date puree and spirulina, are shown in Table 1. The spirulina samples were dried to a fine, consistent,
uniform powder with a blue-green color and a seaweed-like taste and odor. The bulk density of the powder was 0.83 Kg/L. The presence of contaminants in the powder was checked to ensure that the powder used was safe for human consumption. The results showed that the spirulina used in this study was free from pesticide residues, rodent hair, and insect fragments. In addition, the levels of heavy metals, namely arsenic, cadmium, lead, and mercury, were very low (< 1.0 ~ < 0.05 ppm) and were comparable with the international standard limits and the results of previous reports. The microbiological quality of the date puree (Khalas and Sukkari cultivars) and spirulina powder are shown in Table 1. The total number of viable bacteria is widely used as an indicator of the microbiological quality of food products. The results indicated that the spirulina and date puree were either free from or contained fewer counts of the total viable mesophilic bacteria, yeast, and molds. This suggests that these ingredients are of good quality and acceptable for use in nectars and drinks. Interestingly, coliforms, Salmonella, and Staphylococcus were not detected in the puree and spirulina powder, indicating the high hygienic quality and safety of these ingredients. Similarly, previous results had indicated that the low total viable counts and the absence of pathogenic bacteria in spirulina were attributed to its preparation procedure, which led to the production of a safe product. In addition, spirulina is considered as GRAS (generally recognized as safe) by the Food and Drug Administration (FDA).

Chemical properties of date puree and spirulina powder

The chemical compositions of the date puree and spirulina powder are shown in Table 2. The moisture content was highest in the Khalas puree, followed by the Sukkari puree and then spirulina. The low moisture content in spirulina was due to the dry form in which the spirulina was in when compared to that of the date puree. The total solid content of spirulina was higher than that of the date purees. Further, among the purees, the Sukkari date puree contained higher total solid contents than the Khalas puree. Furthermore, ash, fat, and protein contents were higher in the spirulina powder than in the date puree of both cultivars. Interestingly, spirulina contained substantially higher amounts of protein (62.84 g/100 g DW) than the Khalas date puree (1.97 g/100 g FW) and Sukkari date puree (1.45 g/100 FW), indicating the suitability of spirulina as a rich source of protein for food fortification.
Previous studies on dates have indicated that date fruit is a rich source of nutrients such as ash, fiber, and sugars, and is also low in protein and fat \([26,27]\). In contrast, spirulina is known to contain high amounts of protein and suitable amounts of high-quality oil \([29]\). Sugar contents indicated that the Sukkari puree contained higher amounts of total sugars and sucrose than the Khalas puree, whereas the latter contained higher amounts of glucose and fructose than the former. Spirulina contains appreciable amounts of inositol and starch. In addition, it contains higher amounts of fibers when compared to the date purees of both cultivars. Similarly, reports have indicated that spirulina contains appreciable amounts of carbohydrates, fibers, and sugars \([28,29]\). Therefore, the incorporation of spirulina into date nectar is expected to improve the nutritional quality of the product.

**Vitamin and mineral contents of date puree and spirulina powder**

The results of the vitamin and mineral contents of date puree and spirulina are depicted in Figure 1. Generally, the vitamin content was higher in the date puree of both cultivars than in spirulina, except vitamin B3, which had high concentrations in spirulina (Figure 1a). Among the date purees, the levels of vitamins B1, B2, B3, B7, and C were higher in the Khalas cultivar puree than in the Sukkari cultivar puree; whereas, vitamin B9 was higher in the Sukkari puree than in the Khalas cultivar. The differences in vitamin contents between date types could be due to variations in genetic makeup, growing conditions, maturity stage, and postharvest processing conditions. It is well known that dates are a richer source of vitamins than other dried fruits, and that fresh dates contain higher levels of vitamins than dry dates. This could be due to the fact that the drying process has a negative impact on vitamins \([27,30,31]\). The vitamins B5, B6, B12, E, and K were only detected in spirulina and were not detected in the date puree. Spirulina is also known to contain appreciable amounts of vitamins \([29]\). Interestingly, combining these ingredients into a product, such as drinks or nectar, could increase the multivitamin content of the product and, hence, improve its nutritional and health properties. The mineral contents of date puree and spirulina indicate that these ingredients contain substantial quantities of essential minerals (Figure 1b). With the exception of Mg, which is high in date puree, spirulina contained considerably higher quantities of all assessed macro- and micro-minerals when compared to the date puree of both cultivars. The high concentration of minerals in spirulina powder is of high importance, as fortification of date nectar with spirulina will greatly enhance the nutritional quality of the product. Previous studies have shown that spirulina is a rich source of minerals and contains high amounts of both macro- and micro-minerals \([32,33]\). In addition to minerals and vitamins, spirulina is rich in essential fatty acids (Figure 1c) and phytopigments (Figure 1d). Palmitic acid (40.60%) was found to be the major fatty acid in spirulina, followed by gamma linolenic

| Components          | Khalas date puree | Sukkari date puree | Spirulina |
|---------------------|-------------------|--------------------|-----------|
| Moisture (%)        | 33.5 ± 0.27a      | 29.95 ± 0.55b      | 4.93 ± 0.89 c |
| Total solids (%)    | 66.45 ± 0.28b     | 70.05 ± 0.28a      | 95.07     |
| Titratable acidity (%) | 0.34 ± 0.01a    | 0.25 ± 0.02a       | 6.82 ± 0.11a |
| pH value            | 6.92 ± 0.05a      | 6.42 ± 0.10a       | 7.47 ± 0.57a |
| Ash content (%)     | 2.24 ± 0.11b      | 2.35 ± 0.06b       | 6.93 ± 0.41a |
| Fat (%)             | 2.11 ± 0.07b      | 1.96 ± 0.05b       | 62.84 ± 1.12a |
| Protein (%)         | 1.97 ± 0.04b      | 1.45 ± 0.14c       | 1.24      |
| Total sugars (%)    | 43.46 ± 0.22b     | 55.72 ± 0.24a      | -         |
| Sucrose (%)         | 1.24 ± 0.04b      | 45.22 ± 0.14a      | -         |
| Glucose (%)         | 21.37 ± 0.13a     | 5.68 ± 0.008b      | -         |
| Fructose (%)        | 20.85 ± 0.08a     | 4.82 ± 0.18b       | -         |
| Starch              | -                 | 3.56 ± 0.18        | 1.24      |
| Inositol            | -                 | 58.14              | 1.24      |
| Total pectin (%)    | 2.36 ± 0.05a      | 1.52 ± 0.12b       | -         |
| Fiber (%)           | 4.27 ± 0.03a      | 3.85 ± 0.14b       | 8.12 ± 0.43 |

*: Not analyzed, ND: Not detected
acid (24.49%) and linoleic acid (17.95%); whereas, the fatty acid of least concentration was myristic acid (0.46%). The total saturated fatty acid content of spirulina was 44.12%, while the unsaturated fatty acid content was 55.79%, indicating that spirulina has significant nutritional and health properties. Interestingly, spirulina is considered an important food source that contains high concentrations of essential fatty acids that help to regulate the entire hormone system within the human body. Spirulina is called a superfood because its nutrient profile is better than that of any other food, including plants, grains, and herbs. In addition, spirulina contains substantial amounts of phytochemicals such as phycocynin, chlorophyll, and carotenoids. These nutrients and phytonutrients make spirulina a complete nutritional alternative to isolated food supplements. Thus, the incorporation of spirulina into foods could significantly improve the functional properties of the final products.

**Sensory evaluation of date puree prepared using different concentrations of enzyme**

During nectar processing, enzyme treatment is a crucial step in increasing the nectar yield, as well as in the recovery of bioactive compounds and functional properties of the product. In this study, different concentrations of Pectinex Ultra SP-L enzyme from *Aspergillus niger*, which contains pectin transeliminase, polygalacturonase, pectinesterase, and hemicellulases, were used to degrade pectin substances in date fruits and produce date nectar. Sensory analysis was conducted to select the most ideal concentration that gave a highly acceptable product and the results for which are presented in Table 3. Generally, treatment of the date puree of both cultivars significantly improved sensory attributes (texture, color, taste, odor, and overall acceptability) of the product, as the lowest values of all attributes were found in the untreated puree. Similarly, a report on the impact of Pectinex enzymes on the quality of the sensory attributes of Tabasco pepper showed that enzymatic treatment alters the sensory attributes in different ways; however, it generally enhanced most of the sensory attributes of Tabasco sauce and peach juice. The scores of all attributes increased concomitantly with the concentration of the enzyme, which reached their maximum in the 400 ppm treatment before decreasing again as the level of enzyme increased to 600 ppm. The increase in sensory attributes
following the treatment of the puree with moderate concentrations of Pectinex enzymes is probably due to the fact that these enzymes release more specific compounds that enhance the sensory properties of the puree matrix, thereby increasing the sensory attributes of the product. However, at high enzyme concentrations, these compounds might be further degraded to compounds of a smaller size with less sensory attributes. In both date types, the treatment of the puree with 400 ppm of enzyme yielded nectar with higher scores in all sensory attributes, indicating that this is a suitable concentration that can yield acceptable amounts of nectar. Consequently, the purees of both date cultivars (Khalas and Sukkari) were treated with 400 ppm enzyme for nectar production.

**Sensory evaluation of different date nectar and spirulina blends**

To develop fortified date nectar, mixtures of date nectar with different concentrations (0%, 2.5%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, and 20%) of spirulina were prepared and analyzed for sensory attributes (texture, color, taste, odor, and overall acceptability). The results showed that the incorporation of spirulina into the date nectars of both cultivars significantly affected the sensory attributes of the product (Table 4 and 5). Increasing the concentration of spirulina gradually increased the sensory attributes to the highest scores at a 10% substitution rate; these scores then reduced to their lowest values with higher substitution rates of spirulina (20%). Generally, the addition of a low concentration of spirulina (2.5% – 10.0%) to date nectar showed higher scores in all sensory attributes when compared to the higher concentrations (12.5% – 20.0%). The increase in sensory attributes at low concentrations of spirulina could be attributed to the low range of nutrients added by spirulina that enhance the sensory attributes of the developed products. However, the reduction of sensory attributes at higher concentrations of spirulina is likely due to the higher substitution rate at which the acceptable characteristics of date nectar have been greatly altered. In addition, a higher addition of spirulina increased the greenish color of the nectar and, hence, negatively affected consumer acceptability of the product. Overall, the substitution of date nectar with 10% spirulina gave the highest scores, and was recommended by consumers as the best and most acceptable nectar. Consequently, this blend was used for the formulation of functional nectar from date nectar and spirulina. Similarly, the incorporation of spirulina in food formulations affected the sensory attributes of the developed products in different ways depending on the concentration of spirulina in the product. With the fortification of yogurt with different concentrations (0.1%, 0.3%, and 0.5%) of fresh and dried spirulina, it was demonstrated that panelists preferred yogurt fortified with 0.3% spirulina to those fortified with 0.1% or 0.5% spirulina. In addition, a study on the effect of supplementation with different amounts of spirulina (0.5%, 0.75%, 1%, 2%, and 3%) on the sensory attributes of yogurt

Table 3. Sensory evaluation of the enzyme addition to the date purees of the Khalas and Sukkari date varieties.

| Date puree           | Texture(Mouth feel) (25) | Color (25) | Taste (25) | Odor (25) | Overall acceptability (100) |
|----------------------|-------------------------|------------|------------|-----------|-----------------------------|
| **Khalas**           |                         |            |            |           |                             |
| Date puree           | 18.03 ± 0.22 c          | 17.00 ± 0.76 b | 18.08 ± 0.40 c | 17.50 ± 0.56 c | 79.08 ± 6.08 c               |
| Date puree + 200 ppm | 21.33 ± 0.87 b          | 21.75 ± 1.16 a | 20.33 ± 0.72 b | 19.33 ± 0.51 b | 85.66 ± 3.32 b               |
| Date puree + 400 ppm | 23.08 ± 1.07 a          | 22.66 ± 0.50 b | 23.83 ± 0.21 a | 22.08 ± 0.19 b | 93.66 ± 1.89 a               |
| Date puree + 600 ppm | 22.47 ± 0.86 ab         | 22.41 ± 0.23 a | 23.16 ± 0.30 a | 22.08 ± 0.19 a | 90.33 ± 2.53 a               |
| LSD                  | 1.14                    | 1.16       | 1.20       | 1.31      | 6.13                        |
| **Sukkari**          |                         |            |            |           |                             |
| Date puree           | 20.08 ± 0.63 b          | 19.08 ± 0.51 c | 19.41 ± 0.75 c | 18.03 ± 1.45 b | 80.58 ± 2.86 b               |
| Date puree + 200 ppm | 21.58 ± 0.47 b          | 20.50 ± 0.60 b | 20.00 ± 1.08 bc | 19.00 ± 0.96 b | 85.08 ± 7.67 b               |
| Date puree + 400 ppm | 24.23 ± 0.23 a          | 23.41 ± 0.38 a | 22.66 ± 0.48 a | 21.08 ± 1.35 a | 95.25 ± 3.08 a               |
| Date puree + 600 ppm | 23.25 ± 0.20 a          | 22.75 ± 0.25 a | 21.08 ± 0.72 b | 20.75 ± 0.85 a | 91.25 ± 3.57 a               |
| LSD                  | 1.28                    | 1.12       | 1.20       | 1.04      | 5.52                        |

Values represent 12 panelists (Mean ± S.E.). a, b, c indicate that there is no significant difference (p ≥ 0.05) between any two averages of different nectar with the same superscripts, within the same acceptability attribute.
Table 4. Sensory properties of different formulas of date nectar with spirulina.

| Date nectar | Texture(Mouth feel) (25) | Color (25) | Taste (25) | Odor (25) | Overall acceptability (100) |
|-------------|-------------------------|------------|------------|-----------|---------------------------|
| Khulas      |                         |            |            |           |                           |
| Date nectar | 22.16 ± 0.34 b          | 21.58 ± 0.47 b | 22.08 ± 0.31 b | 21.25 ± 0.45 b | 90.08 ± 0.94 b           |
| D 97.5 + S 2.5% | 22.50 ± 0.26 ab | 22.25 ± 0.25 ab | 22.66 ± 0.28 ab | 21.75 ± 0.25 ab | 93.00 ± 0.64 ab          |
| D 95 + S 5%  | 23.75 ± 0.33 ab         | 22.75 ± 0.52 ab | 23.25 ± 0.47 ab | 22.25 ± 0.80 ab | 93.25 ± 0.99 ab          |
| D 92.5 + S 7.5% | 23.33 ± 0.14 ab     | 22.66 ± 0.28 ab | 22.91 ± 0.29 ab | 22.50 ± 0.29 ab | 94.58 ± 0.45 ab          |
| D 90 + 5% 10% | 24.33 ± 0.14 a          | 23.50 ± 0.36 a | 23.91 ± 0.29 a  | 23.41 ± 0.38 a | 96.33 ± 0.48 a           |
| D 87.5 + S 12.5% | 20.08 ± 0.84 c | 20.83 ± 0.73 b   | 20.50 ± 0.40 b   | 20.33 ± 0.80 b  | 84.25 ± 2.77 c           |
| D 85 + S 15%  | 20.08 ± 0.91 c         | 19.66 ± 0.51 c | 20.00 ± 0.49 c  | 19.50 ± 0.60 c | 82.75 ± 1.90 cd          |
| D 82.5 + S 17.5% | 20.33 ± 1.18 c     | 18.83 ± 1.18 c  | 18.16 ± 1.12 c  | 19.41 ± 0.71 c | 81.50 ± 2.00 cd          |
| D 80 + S 20%  | 19.58 ± 1.01 c         | 18.16 ± 1.01 c  | 17.91 ± 1.09 d  | 17.25 ± 0.99 d | 78.75 ± 2.16 d           |
| LSD         | 1.96                    | 1.89        | 1.72        | 1.69       | 4.43                      |
| Sukkari     |                         |            |            |           |                           |
| Date nectar | 21.75 ± 0.35 b          | 21.58 ± 0.43 b | 20.50 ± 0.68 b | 20.41 ± 0.26 b | 88.50 ± 1.43 b           |
| D 97.5 + S 2.5% | 21.91 ± 0.34 ab | 22.08 ± 0.19 ab | 20.66 ± 0.45 ab | 20.50 ± 0.44 ab | 90.33 ± 2.53 a           |
| D 95 + S 5%  | 22.00 ± 0.28 ab         | 22.41 ± 0.23 ab | 21.00 ± 0.89 ab | 20.38 ± 0.31 ab | 91.00 ± 1.75 a           |
| D 92.5 + S 7.5% | 22.41 ± 0.38 ab     | 22.66 ± 0.50 ab | 21.75 ± 0.48 ab | 21.00 ± 0.46 ab | 92.25 ± 1.78 a           |
| D 90 + S 10%  | 23.83 ± 0.21 b          | 23.16 ± 0.30 b  | 22.23 ± 0.54 b  | 21.75 ± 0.60 b | 93.66 ± 1.89 a           |
| D 87.5 + S 12.5% | 21.25 ± 0.63 b | 20.33 ± 0.72 bc | 20.00 ± 1.01 bc | 19.50 ± 1.02 b | 83.54 ± 3.32 b           |
| D 85 + S 15%  | 21.16 ± 0.35 ab         | 19.33 ± 0.52 c  | 19.83 ± 0.72 bc | 19.25 ± 0.68 b | 82.34 ± 2.56 b           |
| D 82.5 + S 17.5% | 20.91 ± 0.42 b     | 18.16 ± 0.60 c  | 18.58 ± 1.29 c  | 18.66 ± 0.62 b | 80.66 ± 3.56 b           |
| D 80 + S 20%  | 20.33 ± 1.18 b         | 18.08 ± 0.40 c  | 18.16 ± 1.06 c  | 18.33 ± 0.94 b | 78.25 ± 4.30 b           |
| LSD         | 1.96                    | 1.36        | 1.72        | 1.88       | 5.66                      |

where D: Date nectar S: Spirulina. Values represent 12 panelists (Mean ± S.E.) (D): Dates (S): Spirulina a, b, c indicate that there is no significant difference (p ≥ 0.05) between any two averages of different nectar blends with the same superscripts, within the same acceptability attribute.

Table 5. Chemical composition of formulated date drinks prepared with the replacement of spirulina (g/100 g sample, on a wet basis).

| Components            | Khulas               | Nectar               | Sukkari              | Nectar + 10% spirulina |
|-----------------------|----------------------|----------------------|----------------------|-----------------------|
| Moisture %            | 80.49 ± 0.18 a       | 80.82 ± 0.3 a        | 70.53 ± 0.44 b       | 71.17 ± 0.05 b        |
| Total solids %        | 19.51 ± 0.17 b       | 19.18 ± 0.26 b       | 29.47 ± 0.32 a       | 28.83 ± 0.3 a         |
| Total soluble solids %| 18.54 ± 0.11 b       | 18.56 ± 0.24 b       | 27.11 ± 0.1 a        | 26.83 ± 0.24 a        |
| pH values             | 5.91 ± 0.06 a        | 5.92 ± 0.07 a        | 5.94 ± 0.06 a        | 5.94 ± 0.02 a         |
| Titratable acidity %  | 0.29 ± 0.02 b        | 0.31 ± 0.01 b        | 0.34 ± 0.01 a        | 0.34 ± 0.01 a         |
| Ash %                 | 0.74 ± 0.01 b        | 0.69 ± 0.01 b        | 1.46 ± 0.04 a        | 1.59 ± 0.06 a         |
| Protein %             | 0.44 ± 0.01 b        | 0.51 ± 0.06 b        | 5.52 ± 0.1 a         | 5.65 ± 0.12 a         |
| Fat %                 | 0.53 ± 0.04 b        | 0.59 ± 0.01 b        | 1.01 ± 0.006 a       | 1.09 ± 0.02 a         |
| Total sugars %        | 17.51 ± 0.04 b       | 17.08 ± 0.06 b       | 21.14 ± 0.02 a       | 20.18 ± 0.01 a        |
| Carotenoids (mg/L)    | 4.68 ± 0.01 b        | 4.92 ± 0.01 b        | 52.13 ± 0.01 a       | 52.07 ± 0.1 a         |
| Chlorophyll (mg/L)    | -                    | -                    | 121.14 ± 0.57 a      | 121.17 ± 0.64 a       |

reported that the treatment with the addition of 1% spirulina to yogurt outperformed the other concentrations in enhancing the sensory quality of the product. [38] Interestingly, in the current study, a considerably higher concentration (10%) of spirulina was used, without adverse effects on the sensory attributes of the date nectar, when compared to the aforementioned studies. This indicates the high nutritional quality of the nectar developed in the current study.

**Chemical composition of the developed date drink (nectar) with 10% spirulina**

Moisture, crude protein, fat, ash, sugar, and natural pigments are known to be of great importance when determining the properties of food. A date nectar preparation fortified with spirulina (as a source of protein) was prepared as a healthy and highly nutritional drink for all individuals such as athletes, infants, children, pregnant women, and lactating women, who have high requirements for
protein-rich diets. The nutritional composition of date nectar fortified with 10% spirulina is shown in Table 4. The moisture content of both nectar types (Khalas and Sukkari) were greatly reduced in nectars with 10% spirulina powder; whereas, the total solids and total soluble solids were greatly increased in fortified nectars when compared to the control. This is likely due to the addition of spirulina powder which increased the solids, and consequently reduced the moisture content of the nectars. Similarly, an increase in total solids and a decrease in moisture following the addition of spirulina have been observed in yogurt [10]. In addition, the increase in total solids was also found in yogurt fortified with spirulina when compared to plain yogurt [38] as well as in ice cream fortified with spirulina [9]. The pH was insignificantly higher in fortified nectars than in the controls; whereas, the acidity values were greatly increased following the addition of 10% spirulina to the date nectar of both cultivars. The ash, protein, and fat in date nectar fortified with 10% spirulina extract were much higher than those of unfortified samples. In addition, higher total sugar and carotenoid contents were found in date nectars supplemented with 10% spirulina when compared to the control nectars of both cultivars. Moreover, high chlorophyll content was determined in nectars fortified with 10% spirulina. In agreement with these findings, Barkallah et al. [39] reported that the incorporation of Spirulina platensis in yogurt enhanced the levels of fat, protein, ash, carotenoids, chlorophyll, and sugars in the fortified yogurt when compared to plain yogurt. Moreover, Lucas et al. [39] reported that the incorporation of spirulina into snacks increased the levels of fat, protein, carbohydrates, carotenoids, pigments, and minerals of the fortified product in comparison to the control. Interestingly, the incorporation of 10% spirulina in the date nectars significantly increased the levels of total solids, protein, ash, fat, sugars, carotenoids, and chlorophyll, thereby improving the nutritional and health properties of the developed product. Finally, it is clear that the prepared beverage mixes cover the daily requirements of sugar, calories, and carotenoids, according to the Food and Agriculture Organization [40]. Therefore, they are suitable for athletes, and also for children, especially children with subclinical diseases such as a lack of calories, dehydration, diarrhea, natural laxity, night blindness, and scurvy. Similarly, Santos et al. [12] reported that the incorporation of spirulina in powdered food products improved its nutritional quality and resulted in products that are suitable as energy and protein sources for elderly populations. From the foregoing, it is clear that fortification with spirulina has led to an increase in the nutritional value of drinks prepared from dates, which increases the demand for them as functional foods in all life stages.

**Amino acid composition of the developed drink**

Amino acids are key elements in proteins that act as precursors for many co-enzymes, hormones, and nucleic acids; they have several functional and structural roles in the body. Therefore, foods with a complete set of essential amino acids are very important and are required to overcome several nutritional and health problems. An adequate supply of dietary protein is essential for maintaining cellular integrity and function, as well as for good health and reproduction. The amino acid compositions of spirulina and the date nectars with 10% spirulina are shown in Figure 2. It can be seen that the fortified drinks contain substantially high levels of essential amino acids, with the highest being observed in Sukkari nectar fortified with 10% spirulina (Figure 2a). The total essential amino acids in spirulina, Sukkari nectar with 10% spirulina, and Khalas nectar with 10% spirulina, were 38.46%, 48.69%, and 46.02%, respectively. This indicates that the incorporation of spirulina significantly enhanced the essential amino acid levels of date nectar in both cultivars. Generally, the increase in the essential amino acid concentration of date nectars following the addition of 10% spirulina could be attributed to the fact that spirulina protein has a higher quantity and quality compared to the date protein. The non-essential amino acids of date nectars with 10% spirulina are depicted in Figure 2b. Furthermore, spirulina contains high levels of total non-essential amino acids (61.54%). This is followed by Khalas nectar with 10% spirulina (53.98%) and then Sukkari nectar with 10% spirulina (51.32%). The enhancement of the amino acid composition of date nectar following the addition of spirulina is likely due to the high protein level and high quality of the amino acid profile of spirulina.
When comparing the essential amino acid pattern of the developed nectars with that of hen egg protein as a standard, it was found that the essential amino acid content in the blends had a good proportion of the corresponding quantities in the egg protein. It should be noted that the total essential amino acid levels in the prepared drinks are also very suitable for building the body according to the daily needs of amino acids. This can be explained by the fact that although eggs contain a much higher percentage of protein, the percentage of protein content in the developed nectar drinks was within the range of the Recommended Dietary Allowance (RDA) for protein and amino acids for children aged 1–3 years according to the FAO/WHO.

**CONCLUSION**

This study was conducted to develop functional drinks using date nectar and spirulina, and the results indicated success in developing such drinks. The use of the enzymes pectinase and cellulose, had a very clear effect in obtaining a clear liquid from the date puree, and the best concentration was found to be 400 ppm with a 1:1 ratio of the two enzymes. The most ideal percentage of added spirulina was 10%, based on the sensory evaluation. The developed drinks contain sufficient mineral elements and amino acids necessary for the normal growth of children; this is in addition to the contents of their other components such as fat, carbohydrates, and sugars. The total energy content resulting from every 100 mL of these mixtures can provide the body with the energy required for activity and movement. The developed products were found to be very safe for consumption and healthy, and compared to their commercial counterparts offered on the market, they can be considered as cheap products with high nutritional qualities.
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Data Availability Statement

The authors declare that they have no competing interests.

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References

[1] Qadir, A.; Shakeel, F.; Ali, A.; Faiyazuddin, M. Phytotherapeutic Potential and Pharmaceutical Impact of Phoenix Dactylifera (Date Palm): Current Research and Future Prospects. J. Food Sci. Technol. 2020, 57(4), 1191–1204. DOI: 10.1007/s13197-019-04096-8.
[2] Baliga, M. S.; Baliga, B. R. V.; Kandathil, S. M.; Bhat, H. P.; Vayalil, P. K. A Review of the Chemistry and Pharmacology of the Date Fruits (Phoenix Dactylifera L.). Food Res. Int. 2011, 44(7), 1812–1822. DOI: 10.1016/j.foodres.2010.07.004.
[3] Echegaray, N.; Pateiro, M.; Gullon, B.; Aamarowicz, R.; Mishairabgwi, J. M.; Lorenzo, J. M. Phoenix Dactylifera Products in Human Health – A Review. Trends Food Sci. Technol. 2020, 105, 238–250. DOI: 10.1016/j.tifs.2020.09.017.
[4] Hussain, M. I.; Farooq, M.; Syed, Q. A. Nutritional and Biological Characteristics of the Date Palm Fruit (Phoenix Dactylifera L.)– A Review. Food BioSci. 2020, 34, 100509. DOI: 10.1016/j.fbio.2019.100509.
[5] Aleid, S. M.; Al-Khayri, J. M.; Al-Bahrainy, A. M. Date Palm Status and Perspective in Saudi Arabia. In Date Palm Genetic Resources and Utilization, Volume 2: Asia and Europe; Al-Khayri, J. M., Jain, S. M., Johnson, D. V., Eds.; Springer Dordrecht Heidelberg: New York, USA, 2015; pp 49–96. DOI: 10.1007/978-94-017-9707-8_3.
[6] Vijayanand, P.; Kulkarni, S. G. Processing of Dates into Value-Added Products. In Dates Production, Processing, Food, and Medicinal Values; Manickavasagan, A., Mohamed Essa, M., Sukumar, E., Eds.; CRC Press, Taylor & Francis Group, Broken Sound Parkway NW: USA, 2012; pp 255–264.
[7] Simpore, J.; Kabore, F.; Zongo, F.; Dansou, D.; Bere, A.; Pignatelli, S.; Biondi, D.; Ruberto, G.; Musumeci, S. Nutrition Rehabilitation of Undernourished Children Utilizing Spirulina and Misola. Nutr. J. 2006, 5, 1–7. DOI: 10.1186/1475-2891-5-3.
[8] Agustini, T. W.; Ma’ruf, W. F.; Widayat, S.; Hadiyanto, M.; Benjakul, S. Application of Spirulina Platensis on Ice Cream and Soft Cheese with respect to Their Nutritional and Sensory Perspectives. J. Teknol. (Sciences & Engineering). 2016, 78, 245–251. DOI: 10.11113/jt.v78.2816.
[9] Bchir, B.; Felfoul, I.; Bouaziz, M. A.; Gharred, T.; Yaich, H.; Noumi, E.; Snoussi, M.; Bejaoui, H.; Kenzali, Y.; Blecker, C.; et al. Investigation of Physicochemical, Nutritional, Textural, and Sensory Properties of Yoghurt Fortified with Fresh and Dried Spirulina (Arthrospira Platensis). Int. Food Res. J. 2019, 26, 1565–1576.
[10] Sidari, R.; Tofalo, R.; Comprehensive, A.; Comprehensive, A. Overview on Microalgal-Fortified/Based Food and Beverages. Food Rev. Int. 2019, 35(8), 778–805. DOI: 10.1080/87559129.2019.1608557.
[37] Beheshtipour, H.; Mortazavian, A. M.; Mohammadi, R.; Sohrabvandi, S.; Khosravi-Darani, K. Supplementation of Spirulina Platensis and Chlorella Vulgaris Algae into Probiotic Fermented Milks. Compr. Rev. Food Sci. Food Saf. 2013, 12(2), 144–154. DOI: 10.1111/1541-4337.12004.

[38] Agustini, T. W.; Soetrisnanto, D.; Ma’ruf, W. F. Study on Chemical, Physical, Microbiological and Sensory of Yoghurt Enriched by Spirulina Platensis. Int. Food Res. J. 2017, 24, 367–371.

[39] Lucas, B. F.; de Morais, M. G.; Santos, T. D.; Costa, J. A. V. Spirulina for Snack Enrichment: Nutritional, Physical and Sensory Evaluations. LWT-Food Sci. Technol. 2018, 90, 270–276. DOI: 10.1016/j.lwt.2017.12.032.

[40] FAO. Statistical Databases; http://faostat.fao.org, accessed June 2, 2007.

[41] Barkallah, M.; Dammak, M.; Louati, I.; Hentati, F.; Hadrich, B.; Mechichi, T.; Ayadi, M. A.; Fendri, I.; Attia, H.; Abdelkafi, S. Effect of Spirulina Platensis Fortification on Physicochemical, Textural, Antioxidant and Sensory Properties of Yogurt during Fermentation and Storage. LWT-Food Sci. Technol. 2017, 84, 323–330. DOI: 10.1016/j.lwt.2017.05.071.

[42] FAO/WHO. Protein Quality Evaluation. FAO Food and Nutrition Paper 51. Rome: FAO. 1991.