Processing, evaluation and water relations of date paste

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Abstract Date fruits (Phoenix dactylifera) are a major fruit crop in many developing countries. Less than 10% of the produce is processed and substantial quantities are lost due to pest infestation and lack of efficiency in marketing operations. Processing of dates to produce date paste and its use in confectionery, bakery, and other food items could open new outlets for dates.

Date paste prepared from Ruzeiz dates has a lower water activity value (0.41) and its water sorption isotherm is of sigmoid shape. Date paste contains high levels (78%) of invert sugar, is a good source of minerals and trace elements, and its high level of dietary fibre (7%) is of particular interest.

Both steaming and soaking can be used to process date paste. The optimum steaming time is 3–5 min and for soaking 5–10 min. A moisture content of 23% (0.65 a.s.) for date paste could be considered as the lower safe limit for microbial spoilage. Hysteresis is apparent in date paste isotherms and over the entire relative humidity range.

Keywords: dates, Phoenix dactylifera, processing, date paste, chemical composition, water activity, water sorption isotherms, hysteresis effect.

Introduction

Dates are considered a major fruit crop in the countries of the Middle East where 75 to 80% of the world production is grown.

Processing of date fruits into date paste is a way to preserve the fruit and to reduce transportation and storage costs. Processing into date paste also results in an availability of the fruit paste during the whole year. It is also easier to protect the date paste from darkening in colour, microbial spoilage, and insect infestation by proper formulation and packaging.

Although a number of references can be cited from the literature on fruit paste processing, most of these data refer to the processing of apricot, guava, mango, fig, and apple pastes (Karla and Revathi 1981, Anon 1981, Ziemke 1977).

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No survey has been conducted to determine the uses of and attitudes towards date paste. Many scientific papers have pointed out the importance of date paste as an intermediate product in the food industry (Hussein 1975, Baraveld 1971).

Water activity (a_w) could be considered the most useful criterion that can characterize the state of water in foods. Reduction of a_w provides a very important means of stabilizing food products.

The moisture sorption isotherm has many practical as well as theoretical applications in food. Besides predicting the microbial or physicochemical stability of foods, a knowledge of water sorption isotherms is also very important for engineering purposes related to concentration, dehydration and packaging (Gal 1983, Iglesias and Chirife 1982).

For most foods the water content will be higher when the a_w is achieved by desorption of water from a moist food than when the route is by adsorption into a dry food. This difference is termed hysteresis (Kapsalis 1981). Wolf et al. (1972) indicated that quality changes upon storage of cooked, freeze-dried foods could be detected by the corresponding changes in sorption hysteresis.

If date paste is to play an important role in confectionery, bakery, and other food industries, a basic knowledge of its nutritive value, processing standardization and techniques, and water sorption is required.

Materials and methods

Date fruits of the Ruzeiz variety were cleaned, pitted (destoned by hand), packed into 500-g plastic bags, and kept frozen (at −20°C) prior to further treatment and analysis.

**Date paste preparation.** In an attempt to standardize a procedure for date paste preparation, two methods were used: steaming and soaking; and the effect of each method on the paste preparation was studied.

**Effect of steaming on date paste preparation**

The effect of steaming on the concentration of the total soluble solids (Brix value) of the date paste was determined. Pitted date fruits from the freezer were allowed to thaw overnight at 25°C, weighed into 500-g portions, placed in a stainless steel screen inside a pressure cooker, and subjected to steam for 3, 5, 10, and 15 min at 1 atmosphere pressure. The samples were allowed to drain for 10 min and ground at a moderate speed in a Kraft meat grinder, model A2-3. The Brix values were then measured on the prepared paste.

**Effect of soaking on date paste preparation**

Five hundred grams of pitted and thawed date fruits were soaked in sufficient water at the two temperatures (25 and 95°C) for different periods of time (see Table 4). Draining time and paste preparation were the same as in the steaming treatment. The effect of soaking time and temperature were evaluated by measuring the Brix values of the treated date paste samples.
Effect of adding citric acid

Five-hundred-gram portions of pitted and thawed date fruits were used to study the effect of adding three levels of citric acid: 0.2, 0.5, and 0.8% (by weight) on the pH of the prepared date paste. The required amount of citric acid was added to the date sample in solution. Draining time and paste preparation were identical with the preparations for the steaming treatment.

Effect of moisture content on the water activity and sorption isotherms of date paste

To study the effect of initial moisture content on the water activity and sorption isotherms of date paste, dates were soaked for different times; i.e. 0 (DP1), 5 (DP2) and 10 (DP3) min in tap water. The dates were prepared as detailed in the steaming treatment.

Preparation of the adsorption system. To prepare for the adsorption system, date paste DP2 was mixed with glycerol as the humectant, because of its vapour pressure lowering effect, at the ratio of 50:50 for DP4 and 70:30 for DP5 (w/w).

Preparation of the desorption system. To prepare for the desorption system, date paste DP2 was humidified with water in the ratio of 50:50 for DP6 and 70:30 for DP7 date paste/water (w/w). Mould growth was prevented by the addition of 0.3% (w/w) sorbic acid to the date paste before humidification.

Chemical analysis

Moisture, crude fat, crude protein, (N × 6.25), pectin, and ash were determined by the standard methods of AOAC (1984). The sugar monomer were determined by high-pressure liquid chromatography (HPLC) as described by Kruger and Matsuo (1982).

Cell wall constituents. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin were determined as described by Robertson and Van Soest (1981). Cellulose was determined using the method of Morton (1944). Hemicellulose content was calculated by subtracting the acid detergent fibre from the mean of neutral detergent fibre values, whereas dietary fibre content was calculated by adding the mean of NDF values to the mean of pectin values (Ross et al. 1985).

The colour of the date paste samples was measured by following the extraction procedure described by Maier and Schiller (1960). Date paste mineral composition, i.e. zinc, iron, copper, magnesium, calcium, manganese, and potassium, was determined using an atomic absorption spectrophotometer (Perkin–Elmer Model Sigma 30) as described by the methods 7.093–7.103, AOAC, 1984.

The energy value was estimated using the Atwater factor (Joint FAO/WHO 1973). Water activity was determined using standard salt solutions as described by D,Alton (1966). Date paste water vapour sorption isotherms were determined by the static desiccator method (Young 1967). In order to study the hysteresis effect in the date paste, the sorption isotherms (adsorption and desorption systems) were determined. With regard to the sorption behaviour of the date paste, gain or loss in weight in grams per gram solids
Table 1. Chemical composition of date paste* (on dry weight basis)

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Content†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>12·8%</td>
</tr>
<tr>
<td>Protein</td>
<td>2·66%</td>
</tr>
<tr>
<td>Fat</td>
<td>0·42%</td>
</tr>
<tr>
<td>Ash</td>
<td>2·96%</td>
</tr>
<tr>
<td>Total sugars</td>
<td>78·2%</td>
</tr>
<tr>
<td>Sucrose</td>
<td>00·00%</td>
</tr>
<tr>
<td>Fructose</td>
<td>37·2%</td>
</tr>
<tr>
<td>Glucose</td>
<td>41·0%</td>
</tr>
<tr>
<td>pH</td>
<td>5·96</td>
</tr>
<tr>
<td>Colour (absorbancy)</td>
<td>0·143 OD</td>
</tr>
<tr>
<td>K</td>
<td>1091 mg/100 g</td>
</tr>
<tr>
<td>Ca</td>
<td>71 mg/100 g</td>
</tr>
<tr>
<td>Mg</td>
<td>62 mg/100 g</td>
</tr>
<tr>
<td>Mn</td>
<td>0·43 mg/100 g</td>
</tr>
<tr>
<td>Cu</td>
<td>0·52 mg/100 g</td>
</tr>
<tr>
<td>Zn</td>
<td>1·52 mg/100 g</td>
</tr>
<tr>
<td>Fe</td>
<td>5·80 mg/100 g</td>
</tr>
<tr>
<td>Energy</td>
<td>315·00 kcal/100 g</td>
</tr>
</tbody>
</table>

*Date paste was prepared by grinding dates directly
†Mean of three determinations

was plotted versus time in hours for different date pastes. The isotherms can only be considered as indicative due to the temperature variation from 20–30°C in the holding desiccators.

Statistical analysis

Data were analysed using the SAS computing system. The analysis of variance procedure was used and the LSD values were calculated for all means (SAS 1982).

Results and discussion

The nutritive value of date paste

Sugars are the major components (78·24%) in date paste (Table 1) present as invert sugar (fructose and glucose).

Potassium is by far the most abundant mineral element in date paste (1·09%). The high level of potassium in dates and its important role in optimum protein utilization (Barness et al. 1961) is of special concern from a nutritional point of view.

Considering the human daily requirements of minerals and trace elements (Robinson 1972), the data in Table 1 show that date paste could be considered a good source of
Evaluation and water relations of date paste

Table 2. Mean values of cell wall constituents* of date paste compared with the mean values of other fresh fruits

<table>
<thead>
<tr>
<th></th>
<th>Dates‡‡</th>
<th>Apple†</th>
<th>Strawberries†</th>
<th>Peaches†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>20·1</td>
<td>85·4</td>
<td>89·6</td>
<td>88·8</td>
</tr>
<tr>
<td>Neutral detergent fibre (NDF)</td>
<td>5·73</td>
<td>1·15</td>
<td>0·94</td>
<td>0·95</td>
</tr>
<tr>
<td>Acid detergent fibre (ADF)</td>
<td>3·82</td>
<td>0·75</td>
<td>0·71</td>
<td>0·88</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>1·90</td>
<td>0·39</td>
<td>0·21</td>
<td>0·32</td>
</tr>
<tr>
<td>Lignin</td>
<td>2·12</td>
<td>0·05</td>
<td>0·23</td>
<td>0·08</td>
</tr>
<tr>
<td>Cellulose</td>
<td>1·34</td>
<td>0·71</td>
<td>0·50</td>
<td>0·56</td>
</tr>
<tr>
<td>Pectin</td>
<td>1·29</td>
<td>0·49</td>
<td>0·36</td>
<td>0·55</td>
</tr>
<tr>
<td>Dietary fibre (DF)</td>
<td>7·02</td>
<td>1·64</td>
<td>1·30</td>
<td>1·50</td>
</tr>
</tbody>
</table>

*On wet weight basis
†From Toma and Curtis (1986)
‡Mean of three determinations
‡‡Dates were soaked for 5 min in tap water, then ground and the paste was used in the determination of moisture and cell-wall constituents

potassium, magnesium, copper, and iron, and a fair source of calcium, zinc, and manganese. Yousif et al. (1982) reported that dates are a poor source of sodium. The high level of potassium and the low level of sodium in date paste can be important to persons on a low-sodium diet.

Data in Table 1 indicate that date paste contains a small but significant amount of protein (2·66%). This protein, however, was reported to be of a good dietary quality relative to standard egg protein (Auda et al. 1976).

The fibre content of foods and human diets has been a point of popular and scientific interest over the past few years. Data in Table 2 indicate that date paste contains relatively high amounts of all the cell wall constituents compared with the other fresh fruits such as apples, peaches, and strawberries (Toma and Curtis 1986). A close similarity can be observed between dietary fibre, cellulose, hemicellulose and acid detergent fibre (ADF) values found by this study and those reported for the American Deglet Noor dates (Coggins et al. 1968).

Processing of date paste

Table 3 shows that steaming time affects significantly (P < 0·05) the total soluble solid values (Brix values) for date paste. Initially there is a considerable decrease in the Brix values, indicating the high water absorptivity of date paste. However, water absorptivity was markedly decreased by increasing the steaming time. The same trend in the water absorptivity of the date paste can also be seen in the soaking treatment (Table 4). No significant difference (P < 0·05) could be detected between the Brix value of the date paste soaked for 20 min and that soaked for 30 min, indicating the low water absorptivity of
date paste with increasing soaking time. The considerable increase in water absorptivity of
the date paste as a function of steaming or soaking for a short time might be due to the
presence of capillaries of large dimensions in the regions A and B of the water sorption
isotherm of date paste (Troller and Christian 1978). These would aid the adsorption of
higher amounts of water by the date paste initially.

The effect of adding citric acid on the pH of date paste is shown in Table 5. Preliminary
organoleptic evaluation of the acidified date paste showed that the addition of more than
0.2% citric acid was not desirable, due to the acidic taste. A pH value of 5.4 or more was
not detectable. Consequently the addition of 0.2% citric acid was used in further studies.

Water sorption of date paste

It is clear from the data presented in Table 6 that the Ruzeiz dates (DP1) used in this study
have a low aw value (0.41), which accounts for their high stability against microbial
Table 5. Effect of adding citric acid on the pH value of date paste

<table>
<thead>
<tr>
<th>Citric acid added (%)</th>
<th>pH of the date paste*†</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>5.96 ± 0.040</td>
</tr>
<tr>
<td>0.20</td>
<td>5.40 ± 0.006</td>
</tr>
<tr>
<td>0.50</td>
<td>4.48 ± 0.010</td>
</tr>
<tr>
<td>0.80</td>
<td>4.26 ± 0.006</td>
</tr>
</tbody>
</table>

*Mean ± standard deviation
†Least significant difference (0.05) = 0.066

Table 6. Effect of initial moisture content on the water activity of date paste

<table>
<thead>
<tr>
<th>Initial moisture content (%)</th>
<th>FWB*</th>
<th>DWB*</th>
<th>Water activity†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date paste</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DP1</td>
<td>12.62</td>
<td>14.14</td>
<td>0.41e</td>
</tr>
<tr>
<td>DP2</td>
<td>18.79</td>
<td>23.14</td>
<td>0.66d</td>
</tr>
<tr>
<td>DP3</td>
<td>22.44</td>
<td>28.89</td>
<td>0.69c</td>
</tr>
<tr>
<td>DP4</td>
<td>11.23</td>
<td>12.65</td>
<td>0.36f</td>
</tr>
<tr>
<td>DP5</td>
<td>6.70</td>
<td>7.18</td>
<td>0.32g</td>
</tr>
<tr>
<td>DP6</td>
<td>60.61</td>
<td>154.00</td>
<td>0.91b</td>
</tr>
<tr>
<td>DP7</td>
<td>69.52</td>
<td>228.00</td>
<td>0.96a</td>
</tr>
</tbody>
</table>

DP nos refer to the following methods of preparation:
DP1: grinding dates directly
DP2: soaking dates in water for 5 min
DP3: soaking dates in water for 10 min
DP4: mixing DP2 with 50% glycerol
DP5: mixing DP2 with 70% glycerol
DP6: mixing DP2 with 50% water
DP7: mixing DP2 with 70% water
*Fresh-weight basis and dry-weight basis
†Values followed by same letters are not significantly different (P = 0.05)

spoilage. These results are in agreement with the findings of Labuza et al. (1972), who reported that fruits could be preserved by dehydration to $a_w$ of 0.65. Soaking of dates for 5 and 10 min caused a profound increase in both $a_w$ and moisture content of the two date pastes produced (DP2 and DP3), compared with the control date paste (DP1). The moisture content is 23.14% for DP2 and 28.89% for DP3. According to Labuza et al. (1972), who defined intermediate moisture foods (IMF) as foods with an $a_w$ of 0.60–0.85 and a moisture content greater than 20 g H₂O/100 g solids, DP2 and DP3 date pastes could be considered as intermediate moisture foods. However, these two date pastes still
have a safe $a_w$ limit with regard to microbial spoilage (Labuza et al. 1972). A significant reduction in the $a_w$ values was achieved by mixing date paste with glycerol (Table 6).

The familiar sigmoid-shaped curve representing the sorption isotherm of the fresh date paste (DP2) is presented in Figure 1A. This water sorption isotherm is characterized by a multilayer sorbing system, which may be attributed to the presence of high concentration of soluble, low molecular weight components such as simple sugars in the date paste (Troller and Christian, 1978). It is well known that many types of fruits are preserved by dehydration to $a_w$ of 0.65 (Labuza et al. 1972). Taking this $a_w$ (0.65), which is equal to 65% ERH, as a safe limit, Figure 1A shows that 65% ERH is reached at a moisture of 23%. Therefore, below this percentage there need be no fear of microbial spoilage. These results are in agreement with those reported by Yousif et al. (1986), who found that the moisture content of date paste at which microbial spoilage could be avoided was 22%. Similar results for a safe moisture content of Libyan (24%) and American (22%) dates, from the viewpoint of microbial spoilage, were also reported by Barreveld (1962) and Rygg (1948). As shown in Figure 1A, it is easy to calculate the relative humidity levels or $a_w$ values at which date pastes with a certain moisture content can best be stored, so that there is neither gain nor loss in moisture content and they remain in equilibrium with the surrounding air once the in-store humidity is controlled. Figure 1B shows that increasing the $a_w$ by 0.28 units (from 0.41 for DP1 to 0.69 for DP3), which is equivalent to 14.75 g H$_2$O/100 g solids (from 14.14% for DP1 to 28.89% for DP3), did not cause any noticeable change in the shape of the water sorption isotherm. This indicates that dates with a
moisture content ranging between 14 and 29% should have the same water sorption isotherm shape. On the other hand, lowering the \(a_w\) (from 0.66 for DP2 to 0.32 for DP5) and moisture content (from 23.14 for DP2 to 6.7% for DP5) by the addition of glycerol caused a considerable shift in the isotherms to the left (Figure 1C). This shift, however, resulted in a shortened monomolecular region for dry date pastes (DP4 and DP5), suggesting that a lower storage humidity is needed for these dry date pastes relative to the fresh date paste (DP2).

Hysteresis effect in date paste

Figure 2 shows that the hysteresis effect is apparent in date paste and it carries on over the entire relative humidity range. Two hysteresis patterns could also be distinguished from the above curves. The first pattern represents the date pastes DP1, DP2 and DP3, and it is characterized by a fairly constant separation between adsorption and desorption lines until an ERH of about 58% is reached, where hysteresis is reduced. However, the hysteresis effect starts to increase again and reaches its maximum at about 80% ERH. The second hysteresis patterns are apparent in Figure 2D, which represents the date paste sample containing 50% glycerol (DP4) as the adsorption system and is characterized by a considerable change in the distribution of the hysteresis loop along the isotherm. However, the existence of these two hysteresis patterns in date paste confirms the important role that the compositional factor can play in defining the shape of hysteresis in food (Wolf et al. 1972). The above results are at variance with the hysteresis behaviour of figs and sultanas (high-sugar dried fruits) reported by Pixton and Warburton (1973, 1976). It must
be recognized that the hysteresis loop is valid only for a particular product or variety, at one particular temperature, although in general the influence of temperature is small, at least in the range of 25 to 35°C (Pixton and Warburton 1976). In these experiments there was a considerable temperature variation from 20° to 30°C.

**Sorption behaviour of date paste**

The sorption behaviour of date paste is illustrated in Figure 3. It is clear from these curves that the water sorption rate (adsorption or desorption system) of date paste was not uniform over the entire period of the experiment, which extended to 16 days. Equilibrium was reached very slowly at high equilibrium relative humidity (ERH) and very rapidly at low ERH values. Significant variations can be detected in the sorption behaviour of the studied date paste (DP1, DP2, DP5 and DP6), especially at higher ERH values. These variations, however, may be attributed to the differences in the size of capillaries present in the date paste as a function of $a_w$ (Watt 1983) and/or to the structural alteration in the date paste resulting in the exposure of new sites with high affinity for water (Duckworth 1983).

**Conclusions**

Date paste from Ruzeiz dates, a Saudi Arabian variety, are rich in sugars, dietary fibre, minerals, and trace elements. Incorporation of date paste into other food items could contribute significantly to their nutritive value.
Both steaming and soaking can be used to process date paste. The optimum steaming time is 3–5 min and for soaking 5–10 min at 25°C.

The water sorption isotherm of date paste is of sigmoid shape. It is apparent from the sorption isotherm obtained that a date paste moisture content of 23% (0.65 a_w) could be considered the lower safe limit for microbial spoilage.

The findings of the water sorption isotherms, hysteresis, and water sorption behaviour of date paste, which can be considered as only indicative, are of special interest and could be used to overcome the hardening problem of date paste and to predict the proper storage requirements and packaging.

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References


