

1. Understanding the raw material

More than 2000 different date varieties have been identified worldwide, varying in their physical and compositional characteristics. Date palm (*Phoenix dactylifera* L.) belongs to the family Arecaceae (syn. Palmaceae). Dates are ellipsoid-shaped fruits that vary in color from deep red to yellowish depending on species and ripening stage. A seed, also known as a kernel or pit, is found in the middle of the date fruit, which is covered by a thin layer of endocarp and surrounded by pulp (mesocarp) and a thin layer of flesh (Epicarp).

Dates' ripening occurs at five stages of maturation, including Hababouk, Kimri, Khalal, Rutab, and Tamar stages (Figure 1) that take about 6-8 months. During the ripening and maturation phases, external and internal changes in the fruit, sugar content, texture, and chemical composition, occur. Dates are mostly consumed as fresh fruits at Tamar stage; however, they can also be consumed at Khalal and Rutab stages.

- (1) **Hababouk:** The first stage that appears after pollination and continues for 4–5 weeks. The fruit has round shape, whitish-cream color with green stripes.
- (2) **Kimri (turn their characteristic color):** This stage appears in the first 17 weeks after pollination. The fruit is young, elongated, greenish in color, hard in texture and with about 85% moisture. Fruit weight increases significantly and the tannin concentration is high. Although the fruit is inedible for direct consumption at this stage, it can be used for making chutney (sauce) or pickles.
- (3) **Khalal (lose water):** During the next 6 weeks, date fruit gains maximum size and weight, color gradually becomes a typical yellow, purplish-pink, or red depending on the cultivar, with hard texture. At this stage, sugar increases slowly and becomes mainly sucrose. This is the stage at which dates are mainly consumed raw as fresh fruit or they can be used for jam, butter, or date-in-syrup.
- (4) **Rutab (accumulate sugar):** In the next 4 weeks, the dates lose water with half of the fruit becoming soft, sweeter and darker in color (light brown), and less astringent. Sucrose converts to reducing sugars and protein, fat and ash percentages decrease. This

stage is the start of ripening. Dates at Rutab stage from many cultivars are eaten fresh or processed into jam, butter, date bars, and date paste.

(5) **Tamr or Tamar (ripen completely)**: During this final stage, that typically lasts 2 weeks; the fruit gains maximum total solids, highest sweetness, lowest astringency, dark brown color, soft texture, and a typical wrinkled shape. There is a high concentration of reducing sugars, especially glucose and fructose, with no or very low sucrose. The percentages of protein, fat and ash are less compared to Rutab stage. Owing to low moisture and high sugar content, dates of this stage have good storage stability (about one year at room temperature if they are packed tightly). For dry cultivars, Tamr dates become light colored with a dry hard skin, whereas for soft cultivars the flesh remains intact and soft and intact with a dark color.

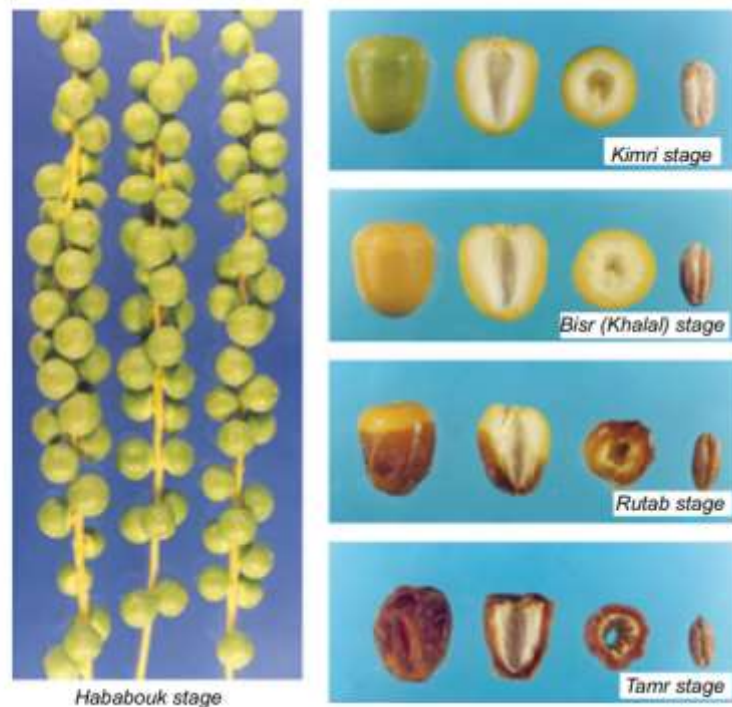


Figure 1. Different growth and maturity stages of date fruit.

2. Date composition

The composition of date fruits changes with species, the ripening stage, harvesting, and post-harvest conditions, etc. Several studies have reported the physical and chemical composition of various date fruits at different stages of maturation. The moisture, protein, fat, ash and carbohydrates of various fresh and dried dates are shown in **Table 1**.

Table1. Proximate analysis for date fruit varieties (g/100 g).

| Varieties | Moisture | Carbohydrates | Crude Protein | Fat | Ash |
|--------------------|--------------|---------------|---------------|--------------|-------------|
| Barhe | 16.4 ± 0.1 | 78.1 ± 0.13 | 2.73 ± 0.04 | 0.29 ± 0.005 | 1.96 ± 0.02 |
| Bumaan | 17.7 ± 0.2 | 71.5 ± 0.16 | 2.36 ± 0.02 | 0.38 ± 0.002 | 1.77 ± 0.01 |
| Khalas | 20.5 ± 0.3 | 72.7 ± 0.3 | 3.12 ± 0.05 | 0.31 ± 0.003 | 1.72 ± 0.01 |
| Ajwah | 14.56 ± 0.59 | 74.23 ± 0.65 | 3.15 ± 0.05 | 0.42 ± 0.015 | 2.5 ± 0.53 |
| Rezazy | 11.97 ± 0.86 | 77.56 ± 0.86 | 2.47 ± 0.57 | 0.49 ± 0.01 | 2.47 ± 0.57 |
| Helwah hail | 23.83 ± 0.49 | 66.39 ± 0.01 | 2.95 ± 0.05 | 0.56 ± 0.06 | 1.87 ± 0.65 |
| Assiane | 10.6 ± 0.95 | 68 | 2.5 ± 0.07 | 0.3 ± 0.15 | 2.74 ± 0.5 |
| Deglet nour | 21.2 ± 0.85 | 65 | 2.43 ± 0.1 | 0.1 ± 0.06 | 2.33 ± 0.81 |
| Mejhoul | 12.88 ± 0.93 | 60 | 2.7 ± 0.2 | 0.2 ± 0.11 | 3.04 ± 0.97 |
| Mabseeli | 14.58 ± 0.26 | 79.61 ± 0.56 | 1.15 ± 0.08 | 3.25 ± 0.18 | 1.41 ± 0.04 |
| Um-sellah | 9.73 ± 0.07 | 84.45 ± 0.40 | 1.79 ± 0.17 | 2.04 ± 0.15 | 1.99 ± 0.01 |
| Shahal | 17.52 ± 0.12 | 77.34 ± 0.51 | 1.10 ± 0.07 | 2.20 ± 0.17 | 1.84 ± 0.15 |
| Fard | 21.7 | 70.4 | 2.6 | N/A | 2.36 |

Carbohydrates and fibers

Carbohydrates in the date fruits such as soluble sugars (glucose, fructose, and sucrose) and dietary fiber (cellulose, hemicelluloses, pectin, and fructans) are the most important components. The high content of carbohydrates in the date makes it a valuable nutrition and energy source. Previous studies have shown that the predominant sugars in dates are fructose and glucose, with small sucrose fractions varying for different varieties.

Amino acids

Amino acids are organic compounds that play a critical role in the human body, known as protein building blocks, found in date fruit. Amino acids are classified into two types: essential amino acids and non-essential amino acids. Essential amino acids are those that cannot be produced in the body to fulfill the body's requirement, but the human body can produce non-essential amino acids. The predominant essential amino acids in fresh and dried dates include lysine and leucine, whereas the non-essential amino acids are proline, glutamic, aspartic, and glycine.

Vitamins and macrominerals

Dates are also a good source of water soluble vitamins, including B1, B2, B9, A, and C in moderate quantities, as well as a significant amount of macrominerals such as K, Mg, Ca, and P.

Secondary metabolites

Phytochemicals are non-nutritive bioactive chemical compounds, generated by secondary plant metabolism. Some phytochemicals have been shown to reduce the risk of cardiovascular disease, reduce inflammation and enhance insulin sensitivity, protect against neurodegenerative diseases, and lower cancer risk. These compounds are present in date fruit in the form of phenols, sterols, carotenoids, anthocyanins, procyanidins, and flavonoids. Significant carotenoids in dates are lutein, β -carotene, and neoxanthin, depending on the date varieties. Dates contain phenolic acids such as protocatechuic acid, syringic acid, vanillic acid, and gallic acid.

3. Dates products

Dates are consumed directly as fresh fruit or processed into a wide variety of products, including dry dates, date bars, syrup, juice concentrate, jam, butter, candy...etc. Low-quality dates, collected after the sorting operation are used as feedstock in the date processing industry to produce the aforementioned products. Date paste is prepared by pitted dates in the tamer stage which are first soaked in hot water or steamed and then turn into a paste by grinding. Immature and low-quality dates may be used to produce concentrated date juice as the fruit is a good source of glucose and fructose. Date syrup, which is more concentrated than date juice, is one of the most popular products in the date processing industry. As the dates contain a significant amount of nutrients suitable for microbial growth, they are considered as a potential substrate for fermentation processes. One of the most critical fermentation products of date fruit is vinegar. Dates of low quality can be used as a substrate for the processing of bakery yeast, mostly as a cheap carbon source for the yeast

4. Date processing options

Harvested date fruits are treated for increased durability, better marketing, lower transfer costs, and better preservation. Common treatments involve fumigation, cleaning or washing, drying, sorting and grading, and packaging.

✚ **Fumigation:** A critical step to eliminate pests (insects and larvae) to meet international food safety standards and extend shelf life. Fumigation is a pest and infestation control method typically using a chemical fumigant including methyl bromide gas, carbon disulfide, hydrocyanic acid, phostoxine, and ethylene oxide, or applying other insect disinfestations methods such as heat treatments or freezing.

✚ **Washing**

Cleaning aims to remove dust, dirt, and other foreign materials from dates using various methods such as simple hand-operated water spraying in baskets, to the more mechanized dry or wet cleaning systems for more extensive operation.

✚ **Sorting**

Sorting is carried out in two stages of initial sorting to remove rotten dates and foreign materials, followed by final sorting into the grades required by the market. In the sorting process, dates are categorized based on their quality into four grades, 1st, 2nd, 3rd, and culls. Culls are the lowest grade dates used for animal feed; 3rd grades may be used for date products, while first and second grade are consumed as fresh fruit.

✚ **Drying**

Reduces moisture content to a specific level to prevent fermentation and spoilage.

✚ **Packaging**

The final step in bringing date fruits to market is packing, with proper packaging utilizing insect proof container under nitrogen or vacuum protecting the dates from moisture, maintaining shelf life, and avoiding insect infestation during storage and transport.

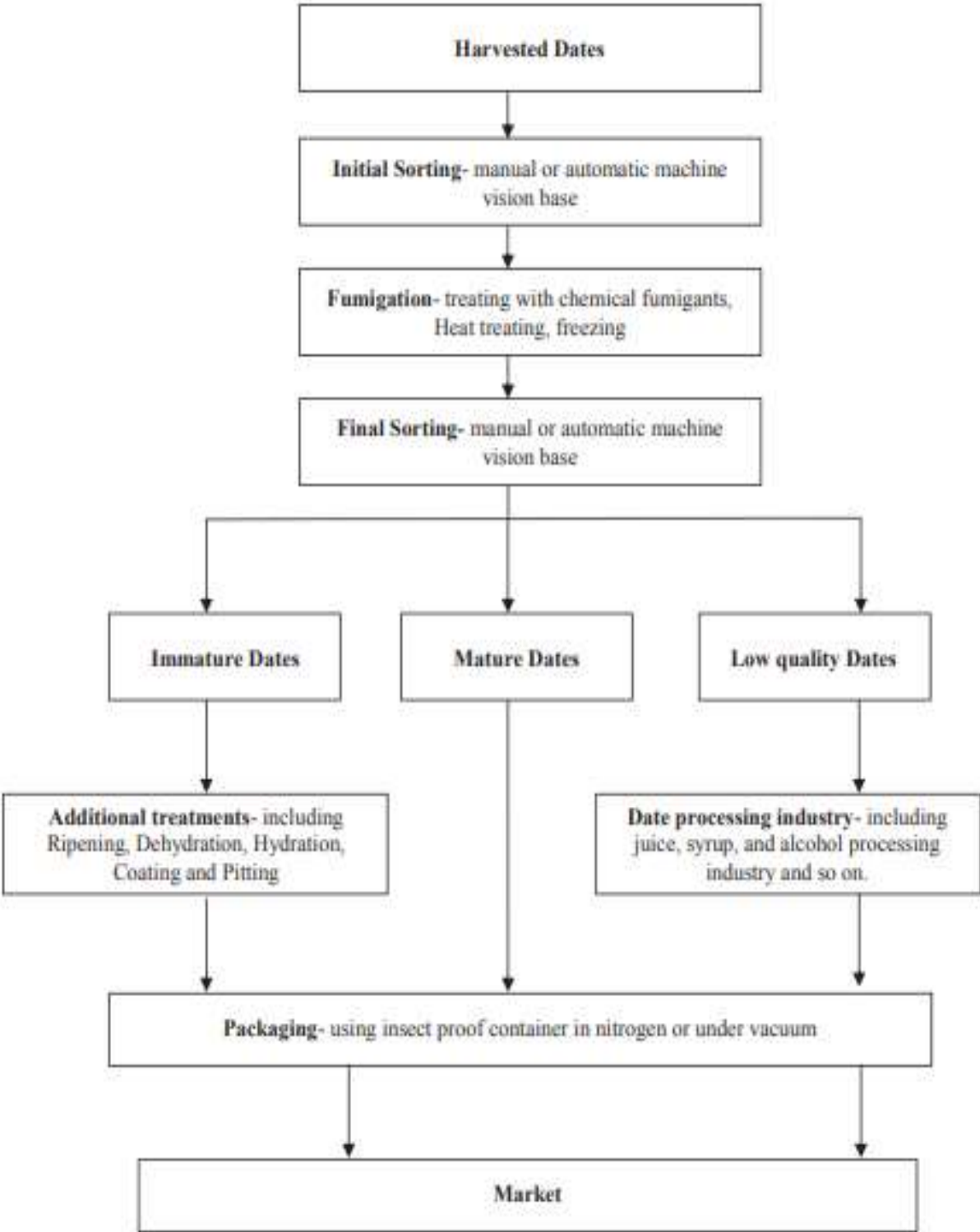


Figure 2. Date fruits marketing process.

In some cases, additional treatments are provided to improve the quality of date fruits, prolong their shelf life and increase their marketability.

Table 2. Post-harvest treatments for dates.

| Treatment | Purpose | Common Methods |
|-----------------------------|-------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|
| Ripening | To ripen immature date fruit. | Artificial heat, controlled freezing, chemical treatments (acetic acid, ethanol), or bagging with polyethylene. |
| Dehydration (Drying) | To reach optimal moisture (23–25%) to prevent spoilage and extend shelf life. | Ambient air-drying, controlled air circulation, or dehydro-freezing. |
| Hydration | To soften the texture of hard-type date cultivars. | Low-pressure steam or sprinkling with water followed by sun exposure under a mat. |
| Coating | To reduce stickiness and improve appearance (gloss). | Surface coating with wax, vegetable oil, various syrups (glucose, corn, date), or glycerol. |
| Pitting | To increase marketability. | Mechanical date pitters or manual removal. |

5. Date processing waste and related challenges

Large amounts of waste are generated during the date fruit processing. It has been estimated that more than 30% of date fruit harvested in Algeria is lost during the post-harvesting phases, including compaction, separation, storage, transport, and marketing. The residues discarded from date processing industries could be categorized into three types. The first is the fruit discarded during the sorting process because of being immature or rotten with inadequate texture, spoiled, or infested by insects. The second type is the seeds resulting from the depitting of dates, and the third being the waste produced by the processing industries, such as juice extraction and date syrup production.

Date waste is high in moisture and contains a significant amount of biodegradable organic compounds, which lead directly to environmental pollution during the disposal,

resulting mainly in the generation of leachate and odor emissions. Inappropriate disposal of such waste to the environment not only results in inevitable ecological risks but also increases the risk of diseases by facilitating the growth of bacteria, pests, and mice. However, from another perspective, the waste of the date processing industry, is an ideal source of nutrients, such as sugars, fiber, proteins, minerals, and vitamins, which make it a potential feedstock for many bioprocesses.

Date seed comprises 11%–18% of the weight of the date fruit. Vast quantities of date seeds are obtained from the date processing industry, of which a small fraction is used as animal feed or sometimes as a food ingredient, while the major fraction is discarded as waste. Date seeds have been shown to be a carbon-rich substance containing lignin, cellulose, hemicelluloses, and proteins, as well as a high fatty acid content such as oleic acid. Several studies have shown that the date seed is a potential feedstock for bio-oil. Seed oil is also a feedstock for many bioprocesses, such as the production of biodiesel.

6. Postharvest quality evaluation

The quality profile of dates in the marketplace involves evaluating four aspects: (a) color, shape, size, taste, texture, pit/flesh ratio, and uniformity in color and size of the fruit; (b) moisture, sugar, and fiber content; (c) defects of the fruits, which may include discoloration, broken skin, sunburn, blemishes, shrivel deformity, etc.; and (d) insect infestation, foreign matter, pesticide residues, mold, and decay. Such evaluation forms the basis of “chemical,” “physical,” and “sensory” quality attributes.

6.1. Chemical quality attributes

Date varieties can vary significantly in their chemical composition, especially the amounts of reducing, non-reducing sugars, and the amount and composition of dietary fiber. The variations in composition have a significant effect on their structural, sensory and textural properties.

6.2. Physical quality attributes

Texture is the most important physical quality attribute of dates, which is determined by instrumental analysis. The texture profile analysis includes measuring hardness, cohesiveness, adhesiveness, springiness, resilience, and chewiness. Hardness, chewiness, and resilience usually increase exponentially with the decrease of moisture content, whereas adhesiveness, cohesiveness, and springiness increase exponentially with the decrease of moisture content.

6.3. Sensory quality attributes

With respect to consumers, important quality criteria of a produce are appearance (including color, size, and shape, condition and absence of defects, mouth feel or texture, flavor and nutritional value. A well-defined, standardized scoring system for evaluating the total quality of a date (Tamar) based on consumer preferences was developed and tested for validity, as shown in **Table 3**.

Table 3. Quality definitions of attributes based on consumer preferences.

| Attribute | Quality definition |
|-------------------------------|----------------------------------------------------------------------------------------|
| Color | Good quality dates tend to be light brown in color |
| Appearance | Most preferable dates tend to be uniform in shape and long |
| Sweetness | Preferred dates tend to be moderately sweet |
| Fruit size | A good quality date fruit tends to be moderately large |
| Chewiness | A date of good quality ranges from slightly to moderately chewy |
| Flesh thickness | The flesh thickness of a good quality date fruit ranges from moderately thick to thick |
| Solubility | A good quality date tends to be moderately soluble to very soluble when consumed |
| Elasticity | Dates of good preference tend to range between slightly elastic and moderately elastic |
| Texture and mouth feel | A good quality date tends to have a smooth texture and mouth feel |
| Mouth shear | A slight force is needed to shear or tear a good quality date fruit |
| Pit size | The pit of a good quality date tends to be medium in size, i.e., neither big nor small |