# Chemical Composition of Date Palm (Phoenix dactylifera L.)

J.M.FAYADH AND S.S. AL-SHOWIMAN*
*Chemistry Department, College of Science,*
*King Saud University, P.O. Box. 2455, Riyadh-11451, Saudi Arabi.a*

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**Summary:** The date palm trees (Phoenix dactylifera L.) besides their known benefits to agriculture over centuries, has been one of the most important staple foods for the native population of Western Persia, Arabia and North Africa and has today a world- wide production which is estimated to be over 2,435000 metric tons. The dates were known for a long time to have established within the human nutrition specially in the oases of the Arabian Peninsula and the data study on the aspect of the nutritional value of dates showed its obvious contribution in the human health when consumed with other food constituents of the daily meals. Besides its economical values, the date palm tree have shown an outstanding ability to be cultivated in arid areas and an ideal plant to combat desert expansion.

The objective of this review is to give a comprehensive understanding about the chemical constituents of the plant of different varieties with biological activities when relevent alongwith the spectroscopic analysis and qualitative phytochemical screening of the important contents, i.e. fatty acids, sugars, minerals, vitamins, enzymes and other significant organic compounds.

## Introduction

The importance of *Phoenix dactylifera* L, the date palm tree, was appreciated by many nations over the centuries. This is because of the economic as well as the nutritional value of its fruit, one of the oldest cultivated tree crops. The nutritional value of the dates can be seen from the presence for example of amino acids in them. These amino acids like lycine, threonine, valine, methionine, leucine, isoleucine and phenylalanine must be included in diet for maintenance of proper nitrogen equilibrium in normal adult humans.

The first written reference to this fruit as food was 3600 years ago, found in the Abydos inscription of Khenzer [1]. Rules for leasing the tree orchards were laid down by Hammurabi in his "Code of Laws". Date seeds were found by J. de Margan in every stratum of his Egyptian excavation from Paleolithic onwards. From Western Persia across Arabia and North Africa, dates have long been a staple food for the native population. Today, worldwide production is over 2,435,000 metric ton.

Besides its economic values, the date palm tree has an outstanding ability to survive in hot, dry, desert regions. This makes it an ideal plant to combat desert expansion, a subject of so much interest these days [2].

An understanding of the chemical constituents of the plant will help to control, among other things, diseases and pests that inflict the tree during its growth. As an example, dates are known to be affected by a number of fungus diseases, including *Omphalia pigmentata* root rot, *diplodia* disease (*Diplodia phoenicum)* Sacc.; black scorch caused by *Thielaviopsis paradoxa* De Syn.; *graphiola* leaf spot (*Graphiola phoenicis*) Moug and fruit rots. Other diseases that affect the fruit are the Blacknose, Black scal and the Crosscuts, their causes being unknown. Besides, there are various fruit beetles and moth that affect dates [3].

The date palm is of the genus *Phoenix* and is of the family *Palmaceae* (palm tree family), of which there are more than 1100 species. These include the coconut palm tree for example. Chemically the family has been neglected, probably because of the difficulty of collecting fresh material and getting it authenticated. Most work has however been carried out on economically important plants such as *Phoenix dactylifera*, *Cocos nucifera* and other palms cultivated for their oils. Litchfiel [4], in surveying 10 genera, found some correlation of fat content, fatty acid composition and triglyceride composition at the subfamily level. Bennett *et. al* [5] isolated the steroidal estrogen, estrone

*To receive any correspondence

and cholesterol from the seeds and pollen of *Phoenix dactylifera*, the fruit of which contains the unusual p-coumaroyl, caffeoyl and feruloyl esters of shikimic acid [6,7].

There seems to be no comprehensive review on the chemical constituents of *Phoenix dactylifera* L, although few summaries have been published [1,3]. The present review devoted exclusively to the chemical constituents of the plant and to their biological activities when relevent.

*Isolation, Identification and Structure Determination.*

Chemical from the date palm can be isolated in a free state or bound to other chemicals. If bound, as in the case of some sugars, fatty acids or amino acids, then they have to be hydrolyzed in order to obtain the free components. Generally, solvent extraction, hydrolysis, followd by chromatography are the main techniques used in isolation and product identification. Fatty acids are usually freed by refluxing with methanolic KOH followed by acidification; methylation of the resulting acids makes them more volatile for CC identification [8]. Sugars are identified after acid hydrolysis of the isolated polysaccharides;methylation prior to hydrolysis is sometimes used in their identification [9]. Sugars can also be identified as their trimethylsilyl derivatives [10]. Amino acids are identified by chromatography after acid hydrolysis of the isolated proteins [11]. The protein content of date extracts can be determined after Kjeldahl digestion usig albumin as a reference protein. Stegemann *et. al* [12] found that the best protein separations and the most characteristic proteins with which to identify the cultivars were obtained after PoroPAGE or PAGIF, with both tube and thin layer techniques. Acid hydrolysis of leaf extracts has also been reported for the identification of flavonoid aglycones [13].

Column chromatography CC, gas liquid chromatography GLC, paper chromatography and thin layer chromatography, TLC are widely used techniques in the analysis of date palm products. *cis*-3,5,3',5'- Tetrahydroxy-4-methoxystilbene and *trans*-3,5,3',5'-tetrahydroxy-4-methoxystilbene from the stems of the plant were separated on silica column eluted with hexane-$Et_2O$ mixture [14]. Cholesterol, campesterol, stigmasterol, $\beta$-sitosterol and isofucosterol were identified as their trimethyl silyl derivatives by GLC using a glass column packed with 2% OV 17 [15]. This techniques was also used for the identification of sugars [10]. Descending and two-dimentional ascending paper chromatography were used for amino acids and sugars determination [11]. TLC was successfully used for the identification of $\beta$- amyrin and $\beta$-sitosterol [16]. Preparative silica gel G. plates (3 mm thickness) were also used for the separation of rutin and quercetin. High performance liquid chromatograph, HPLC, is another useful technique which has been described by Simpson [17] in his book on the subject. Sugar monomers in the fruit were determined by HPLC [18,19]. Separation of date sterols was carried out with a Zorbax ODS column and an acetonitrile water sodium acetate solvent system [15]. Separation of the plant sterols could only be achieved by reverse phase column packing [20] although the sterol mixture gave only one peak on the normal column packings. Minerals in the plant are usually determined by atomic absorption spectroscopy [21] or flame photometry [22].

Various spectroscopic techniques have also been used in the identification and structure determination of the plant products. For example, information about the nature of linkages in polysaccharides was obtained from its IR spectra;absorption band at 874 $cm^{-1}$ indicated $\beta$-linkages in *D*-manopyranose units [23]. IR, UV, $^1$H-NMR and GC-Mass spectroscopy were used in the structure determination of steroid diones as well as polyhydroxystilbenes [14,15].

*Biological Activities-General Remarks:*

Seeds of *Phoenix dactylifera* are known to be used in indigenous system of medicine [9]. The paste of the seeds, made by trituration with water is said to be applied for opacity of the cornea, and to the head to relieve headaches and hermicronia [23]. The antimicrobial activity of the alcohol extract of the seeds of one variety was tested against some microorganism. The test revealed the activity of the extract against *S. aureus, Pr. vulgaris* and *B. subtilis* with an MIC of 0.5 mg/ml in the case of *S. aureus* and *B. subtilis*. The extract also had a stimulant action on the motor activity of mice when compared with control animals [10]. The nutritive and therapeutic values of the pollen have also been reported; a glucoprotein was isolated and proved biologically to have gonadotrophic activity [16].

Mention is also made of the fact that stilbenes found in the stems of the date palm are antimicrobilogical agents responsible for the durability of heartwood of various tree species and they have been isolated from several higher plants [14]. Chlorogenic acid and isochlorogenic acid isolated from the date palm fruits are known to have an allelopathic effects on higher plants and many others, as well as many micoorganisms, by retarding or preventing the growth of such organisms. In the date palm, the production of these acids is considered to be a measure and a mean of protection against infection of diseases in the early stages of fruit maturation [24]. It is remarkable that all inhibitors, chemically identified from dry fruits, are phenolic acids or their depsides and polydepsides [25]. On the other hand, the presence of reducing sugars in the fruit of one date palm variety was blamed for its susceptibility to infestation [26].

The role of many chemicals in biosynthesis has also been reported. Ergosterol, found in the seeds of one variety is considered as a precurser for vitamin D which is the end product of the controlled irradiation of ergosterol [10]. Dactyliferic acid (3-*O*-caffeoylshikimic) acid was isolated from fresh green dates. The importance of this acid in the biosynthesis of aromatic compounds such as tyrosine, phenylalanine, the substituted cinnamic acids, flavonoids, cumarins and lignin have been discussed [7,27]. The isolation of p-hydroxybenzoic acid and 3,5-dihydroxy-4-methoxybenzoic acid, metabolites of the biogenetic route from shikimic acid, together with related stilbenes, is in accordanc with the hypothesis that one ring of stilbenes comes from shikimic acid, the other one (3,5-dihydroxy ring) being synthesised *via* the acetate malonate biogenetic route [14].

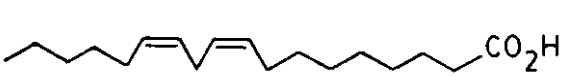
Finally, it is interesting to note that cystine was detected in the date fruits after their $\gamma$-irradiation with 25 K rad [28]. If the cystine in this process comes from cysteine, which is known to exist in the fruit [78], upon irradiation, then this may be viewed in term of protection against radiation.

*Lipids, Fatty Acids and Other Organic Acids:*
*A. Background:*

Lipids, natural derivatives of fatty acids, in plants are usually complex mixture of triesters of glycerol (tri-glycerides). They are described as fats when solid at ambient temperature and as oils when liquid. Lipids are found increasingly to be physiologically significant and chemically interesting. Renewed interest has come from the recognition of fatty acids such as linoleic (and possibly also $\alpha$-linolenic acid) as essential dietary requirements, from their link with prostaglandins, and from their involvement in structural membrane [29]. Most seed oils contain 5-10 different fatty acids and the distribution of these acids is not random but follows a marked selectivity in the acyl chains associated with each hydroxyl group. In vegetable fats for example, C-2 is acylated entirely by unsaturated $C_{18}$ acids, while saturated acids and long-chain unsaturated $C_{20}$, $C_{22}$ acids appear at C-1/3 and rately at C-2.

Naturally occurring fatty acids, whether saturated or unsaturated, are straight-chain compounds with an even number of carbon atoms. Although the range of chain length is great, the most common ones are $C_{16}$, $C_{18}$, $C_{20}$ and $C_{22}$. Mono-unsaturated acids usually contain a *cis* olefinic bond in a limited number of preferred positions in the carbon chain and the polyunsaturated acids have 2-6 cis double bonds in a methylene interrupted pattern. On hydrolysis with aqueous acid or alkali, acylglycerole yield glycerol and the fatty acids present in the glyceride. In the laboratory, ester or glyceride hydrolysis is most conveniently effected by aqueous ethanolic or methanolic alkali. Acidification of the hydrolysate liberates the fatty acids which can be extracted with ether. Non-acidic compounds such as hydrocarbons will also be present in the organic extract, but glycerol remain in the aqueous layer.

For fatty acids, an abbreviated structural representation is used in this review. A symbol such as 18:2 9C 12C will designate the $C_{18}$ acid (linoleic acid) (1) with two unsaturated centres whose position and configuration is indicated by the symbols 9C and 12C. In this system of representation, (c) refers to *cis* unsaturation, and (*t*) to *trans* unsaturation.




(1)

Linoleic acid (octadeca-cis-9, cis-12-dienoic acid) 18:2 9c 12c

Although most lipids are based on glycerol, acetylated derivatives of short-chain diols such as ethane-, propane- and butane-diols are also known. Most extracted samples of lipids contain some free sterol (cholesterol from animal sources, stigmasterol, $\beta$-sitosterol, and ergosterol from plant sources) along with their acetylated derivatives.

*Spectroscopic Analysis*

Various spectroscopic methods are being used for the identification and structure determination of fatty acids.

*UV spectroscopy*

Ultraviolet spectroscopy can be of little value for monoene and methylene interrupted polyene fatty acids since they absorb light at wavelengths too low for convenient studies, but it can be of immense value in the study of acids having conjugated unsaturation [30-32].

*IR and Raman spectroscopy*

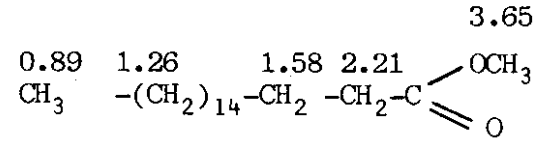
*Trans* Unsaturation in fatty acids can be detected by IR spectroscopy and the method can be applied for monoene as well as polyene acids (conjugated or non-conjugated). Raman spectroscopy is more valuable technique since it can be used to detect both *cis* and *trans* unsaturation.

In the IR spectra of oils and fats the peaks of interest are 1380, ($CH_3$), 1720 and 2915-2950 ($CH_2$), 1700-1715 ($CO_2H$) and 118- 1260 and 1740 $cm^{-1}$ ($CO_2R$). *Trans* Unsaturation is characterised by absorption at 968 $cm^{-1}$ [30-32, 34-37]. Raman spectra shows absorption bands at $1656\pm1$ for *cis* and at $1670\pm1$ for *trans* unsaturation [38,39].

*Nuclear magnetic resonance spectroscopy*

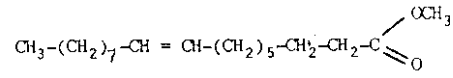
Low resolution $^1H$ n.m.r spectra of fatty acids are of limited value since many of the protons in these acids are chemically equivalent. The use of more powerful instruments and the application of the more sensitive $^{13}C$ spectra greatly enchanced the use of this technique in fatty acids analysis and in the determination of their structures.

The $^1H$-n.m.r. spectra of methyl stearate (2) for example shows signals at $\delta$ 0.89 ( $-CH_3$), 1.26 ($CH_2$ groups). 1.58 ($\beta$-$CH_2$), 2.21 ($\alpha$-$CH_2$) and 3.65 (ester methyl group).




(2)

Methyl oleate (3) will show in addition to the above signals a triplet for the two olefinic protons at $\delta$ 5-6 and a singlet for allylic protons at $\delta$ 1.99. *cis*- and *trans*-alkenes differ in the coupling constants for the vinyl protons (*cis* 10 Hz and *trans* 15 $H_2$) and in the chemical shift of the allylic protons (*cis*, $\delta$ 1.99; trans, $\delta$ 1.94).

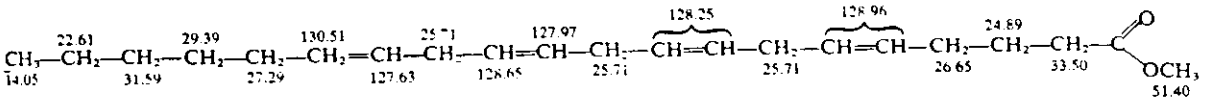



(3)

Smaller deshielding effects operate in an additive manner up to six atomic centres from the source of the deshielding influence and small differences in the chemical shifts between isomeric compounds, allow structural identification in many cases [38-40].

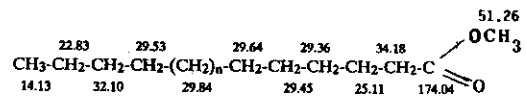
The $^{13}C$ n.m.r. spectra of fatty acids is more informative than the $^1H$ spectra. Unsaturated carbon atom unaffected by deshielding influence gives signals at 129.90 for *cis*-alkenes and 130.40 for *trans*-alkenes, which frequently appears as two signals under the influence of the $-CH_3$ or $CO_2CH_3$ groups.

The deshielding effect of one unsaturated centre on another has been studied and it is possible to allocate all the signals observed for a polyene ester. This is best illustrated by an example. The assignment of the 16 signals observed for methyl arachidonate (4) is as follows [41]:



(4)

A saturated methyl ester shows seven clearly separated signals along with a complex signal in the 29-30 p.p.m. range in which it is possible to distinguish five more signals. These arise from the deshielding influence of the $CO_2CH_3$ and $CH_3$ groups and have been allocated as follows:



*Mass Spectroscopy*

The mass spectrum of a saturated ester such as methyl stearate gives a molecular ion peak ($M^+$) and peaks at 74 $[CH_2=C(OH)OMe]^+$, M-31, 59 + 14n from $CH_3(CH_2)_n$. Although there is some selectivity, fission occurs between each pair of $CH_2$ groups.

Unsaturated esters such as methyl oleate, linoleate and linolenate give distinctive mass spectra but they are not readily distinguished from isomeric monoene, diene, and triene esters because of the general mobility of the double bonds under electron bombardment [42].

*B. Date Palm Products*

Lipids extracted from the date palm seeds are usually estimated and referred to as crude fat. Some varieties can have as high as 9.2% fat in their seeds [11]. The neutral fraction from a de-waxed hexane extract of the stems of the plant was separated by CC and found to contain mixtures of hydrocarbons ($C_{26}$-$C_{31}$), esters (alcohols: lupeol, $\beta$-sitosterol, stigmosterol, and campesterol; fatty acids: 10, 12: 1, 16, 18:1, and 18:2, triglycerides (16,18:2) [43].

Lipids from four seed varieties, namely, Khedhri, Sukkeri, Menifi and Nabt-Saif, were extracted using chloroform-methanol mixture (2:1 v/v). Alkali hydrolysis of the isolated lipids, followed by acidification and ether extraction, gave 10 saturated and 4 unsaturated fatty acids.

The isolated acids were methylated and then identified by GLC using a stainless steel column (2 mm x 4 m) packed with 10% w/w GBSB 2330 supported on 100 to 120 mesh Chromasorb w. Seven other compounds, thought to be acids were also detected [8].

Other seed varieties were also studied for their crude fat and fatty acids contents [10,11,45]. Acids produced in largest amount were: lauric (54%), oleic (51%), myristic (23%), palmitic (17%), linoleic (8%) and stearic (3%). This is in accordance with Hitchcock and Nichols [45] findings on commercial oil seeds composition. Some seed varieties seem to contain more unsaturated acids than saturated ones: this is true for the Negeeb as well as the Sifree cultivars for example which were found to be rich in linoleic and oleic acids [10].

Lipids in the dates flesh had more attention than those in the seeds. This is because of the nutritional as well as the commercial values of the fruit. The concentration of lipid (crude fat) in the flesh ranges from 0.1 to 2.5% depending on the stage of development and degree of dryness of the fruit [1,19,46]. Cultivars that were investigated are namely, Anbara, Khudari, Sifri, Shalbi, Nelt-Seif, Berni, Hilwa, Safawi, Agwa, Sakhi, Sukkaret, Yanbu, Holaya, Barhee, Sukkeri, Bukeira, Khalas, Ruzeiz and Khuneizi.

Free acids have also been isolated from the plant. Mair and co- workers [7] separated 3-o-caffeolshikimic acid from fresh green dates by extraction with methanol and purification by CC on silica acid. This acid, named by the authers as dactylifric acid is one of the main enzymic browning substances in dates.

p-Hydroxybenzoic acid and 3,5-dihydroxy-4-methoxy-benzoic acid were isolated from stems of the plant and their presence was discussed in terms of the biosynthesis of stilbenes in the plant [14]. Chlorogenic acid and isochlorogenic acid were detected in the fruit and the role of these two acids in the protection of the plant from diseases was also discussed [24].

Tabl-1: Component Acids (n-Saturated) of Some Seed's Oils.

| Common name in alphabetical order) | Systematic Name | Yield, cultivar and Reference |
|---|---|---|
| Arachidic (20)[a] | eicosanoic (20:0)[b] | 0.30-0.54; Khedri, Sekkeri, Menifi, Nabt-saif; 8. |
| Behenic (22) | docosanoic (22:0) | 0.24-3.4; Khedri, Sekkeri, Menifi, Nabt-saif, Khalas, Nabt-zamel, Nageeb, Sifree, Sugee; 8, 10. |
| Capric (10) | decanoic (10:0) | 0.03-2.3; Khedri, Sekkeri, Menifi, Nabt-saif, Khalas, Nabt-zamel, Negeeb, Sifree, Sugee; 8,10,43. |
| Caprylic (8) | octanoic (8:0) | 0.7; Khalas, Nabt-zamel, Nageeb, Sifree, Sugee, 10. |
| Lauric (12) | dodecanoic (12:0) | 12.88-54.4; Khedri, Sekkeri, Menifi, Nabt-saif, Khalas, Nabt-zamel, Negeeb, Sifree, Sugee; 8,10. |
| (21) | heneicosanoic (21:0) | 0.12-0.28; Khedri, Sekkeri, Menifi, Nab-saif; 9. |
| Carpric acid (Decanoic acid) | Seeds | 8,10 |
| Caprylic acid (Octanoic acid) | | |
| Chloride | Seeds | 61 |
| Chlorogenic acid | Fruit | |
| Cholesterol | Sarcocarp, Seeds | 5,10,15,89 |
| Copper | Fruit, Seeds | 10,22,61 |
| Cysteine | Fruit | 28,78 |
| Cystine | Fruit | 3,28 |
| Dactylifric acid (see caffeoyl-shikimic acid) | | |
| Decanoic acid | Seeds | 8,10 |
| Margaric (17) | heptadecanoic (17:0) | 0.05-0.06; Khedri, Sekkeri, Menifi, Nabt-saif; 9. |
| Myristic (14) | tetradecanoic (14:0) | 11.0-23.5, Khedhri, Sekkeri, Menifi, Nabt-saif, Khalas, Nabt-zamel, Negeeb, Sifree, Sugee; 8,10. |
| Palmitic (16) | hexadecanoic (16;0) | 2.9-17.6; Khedri, Sekkeri, Menifi, Nabt-saif, Khalas, Nabt-zamel, Negeeb, Sifree, Sugee, 8, 10, 43. |
| Stearic (18) | octadecanoic (18:0) | 2.89-3.83; Khedri, Sekkeri Menifi, Nabt-saif; 8. |
| (23) | tricosanoic (23:0) | 0.04; Khedri, Sekkeri, Menifi, Nabt-saif; 8 |

[a]Number in parenthesis indicates chain length.
[b] Numbers in parenthesis indicate symbol of acid.

Table-2: Component Acid (Unsaturated) of Some Seed's Oils.

| Common name in alphabetical order | Systematic Name | Yield, cultivar and Reference |
|---|---|---|
| Linoleic | octadeca-9, 12-dienoic (18:2 9c 12c)* | 6.19-8.08; Khedhri, Sekkeri, Menifi, Nabt-saif; 8. |
| Linolenic | octadeca-9,12 15-trienoic (18:3 9c 12c 15c) | 0.55-0.81; Khedhri, Sekkeri, Menifi, Nabt-saif; 8. |
| Oleic | octadeca-9 -enoic (18:1 9c) | 43.53-51.89; Khedri, Sekkeri, Menifi, Nabt-saif; 8. |
| Palmitoleic | hexadeca-9 -enoic(16:1 9c) | 0.05-0.08; Khedhri, Sekkeri, Menifi, Nabt-saif, Khalas, Nabt-zamel, Negeeb, Sifree, Sugee; 8. 10. |

* Numbers in parenthesis indicate symbol of acid. see text.

*Carbohydrates*

*A. Background*

Carbohydrates constitute a highly significant class of natural products. To the chemist they offer a complete series of diastereoisomers, readily obtainable in a state of high optical purity, and in the course of investigations of their chemistry they have afforded considerable information on mechanistic and stereochemical problems. Significant development have involved their use as chiral synthons and templates for the stereospecific synthesis of compounds such as prostaglandins, amino acids, heterocyclics, lipids, etc. For the biologist, the significance of carbohydrates lies in the dominant role they perform in living systems, and the intriguing complexity of their functions. The carbohydrate species involved in the majority of biological processes are macromolecules although free mono- and di- saccharides occur in many biological fluids, and most plants contain free glucose, fructose, and sucrose. Plants are responsible for the primary synthesis of carbohydrates via photosynthesis, in which atmospheric carbon dioxide is utilized in the presence of light as the energy source. Through this process, enormous amounts of cellulose and starch (a food storage product) are laid down, and this photosynthetic process alone maintains the balance between 'living' and non-living' carbon. Certain plants, notably sugar cane and beat, accumulate

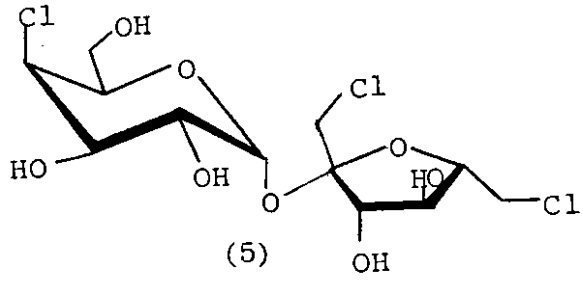
relatively high concentrations of the unique disacchride sucrose ($\alpha$- *D*-glucopyranosyl $\beta$-*D*-fructofuranoside), which is extracted and easily crystalized, and has long been a product of commerce and trade. It is now produced on a substantial scale and as a chemical is the cheapest pure organic substance available. *D*-Glucose has been known for several centuries because of its crystallization from granulated honey for example. It is also produced commercially by the hydrolysis of starch [52].

Chemical methods have been used extensively in the structure determination of carbohydrates but have now largely been supplanted by physical methods, in particular n.m.r. spectroscopy ($^1$H and $^{13}$C) [53], mass spectrometry [54], and X-ray crystallography [55].

Alditols, a reduced form of aldoses, occur in Nature, particularly in the plant Kingdom. Glycerol (1,2,3-trihydroxypropane) occurs as an essential component of lipids and is therefore widely distributed throughout Nature. *D*-Glucitol occurs extensively in many fruits, of the *Rosaceae, Pyrus, Sorbus, Photinia, Crataegus, Pyracantha,* and *Cotoneaster* species. *D*-Mannitol also occurs widely in plant, seaweeds etc., either in free or combined form. D-Glucitol also known as sorbitol, is nontoxic, slightly sweet, and mildly .hygroscopic, properties which make it useful as a humectant in cosmetic and pharmaceutical products.

Aldoses possessing a terminal carboxylic acid grouping, in addition to the reducing group, at the other end of the chain are known as alduronic acids. They occur widely in Nature, and *D*-glucuronic acid plays an important role in animal metabolism by aiding the excretion of phenols, steroids, and aromatic carboxylic acids. *D*-Galacturonic acid is a component of fruit pectin from which it is readily isolated after enzymic hydrolysis.

Monosaccharides in which one or more of the hydroxyl groups are replaced by some other functional group occur widely, but rarely aboundantly in Nature. Amino-sugars rarely occur free, or as simple derivatives, but almost always as components of polysaccharides, oligosaccharides, or as glycerides. A particularly abundant source of variety of amino-sugars is the *Streptomyces* family of moulds which elaborate a variety of antibiotics containing amino-sugars [56]. The antibiotic nuclecidin is one halogeno-derivative of a carbohydrate that has been isolated from natural sources. There has been a great deal of biological interest in halogenated sugars [57] because in other areas of natural products chemistry (e.g. steroids) the introduction of halogen has often led to increasing biological properties. It is interesting to note that replacement of various hydroxyl groups of sucrose by chlorine results in considerably anhanced sweetness [58]. The 1,4,6-trichloride (5) is 2000 times more sweet than sucrose itself.




(5)

Aldoses in which one or more hydroxyl groups are replaced by hydrogen occur widely in Nature, particularly those bearing a terminal deoxy-group such as 6-deoxy-*L*-mannose and 6-deoxy-6-galactose, which are found as components of many polysaccharides, glycoproteins, and plant glycosides. 2-Deoxy-*D*-ribose occurs throughout Nature in DNA, and many deoxy-and dideoxy-sugars occur as components of antibiotics [56].

The replacement of the constituent oxygen atoms of sugars by sulfur gives rise to thio-sugars. Thioglycosides, an example of which is sinigrin (a component of black mustard) and 5- methylthioadenosine (vitamin $L_2$) from yeast occur in Nature. In the thioglycosides the glycosidic oxygen is replaced by sulfur, many compounds of this type are known to occur naturally and are important flavour constituent known as the 'mustard-oil' glycosides [59].

*B. Date Palm Products*

The carbohydrate contents of the fruit (flesh andseed) have been extensively studied an widely reported. Sugars are usually estimated after acid hydrolysis of the isolated total carbohydrates [9,22].

The alkali soluble material isolated from the seeds of the plant contained, after partial acid

hydrolysis, the disaccharide 4-O-β-D-mannopyranosyl-D-mannose, 4-O-β-D-galactopyranosyl-D-mannose, and 6-O−β-D-manopyranosyl-D-mannose, as well as the trisaccharide O-β-D-manno pyranosyl (1 4) -O-β-O-mannosyl (1 4)-O-β-D-man -nose [9,23,60].

Total sugar have been determined in four seed varieties, namely, Khedhri, Sekkeri, Nabt-saif, and Menifi, after hydrolysis of the crushed samples with N-HCl followed by neutralization with sodium carbonate. Soluble sugar were determined in the neutral fraction by GLC and found to contain fructose, α-and β-glucose and sucrose [22]. The amount and type of sugars is found to be different for each variety.

Starch, reducing sugar, and non-reducing sugar of other seed varieties, namely, Taleese Adwi, Taghiat, Tasfert, Aspear, and Seloulou, were measured and found to be 20.6%, 2.4%, and 1.9% respectively. It was noticed that reducing sugars, starch, and total carbohydrates were significantly different among cutivars, whereas non-reducing sugars and total sugar did not show significant difference due to cultivars [61]. As mentioned earlier, pure polysaccharides were isolated from the seeds. These were hydrolysed and found to contain D-mannose and D-galactose in the ratio of 12:1. Xylose was also found. D-Mannopyranose units were found to have b-linkages as seen from their ir spectra [23]. Studies on seven different seed varieties revealed the presence of mannose, glucose, sucrose, lactose, and maltose after extraction of the powdered seeds with ethanol. The isolated sugars were trimethylsilylated and analysed by GLC [10]. No fructose could be detected in these varieties.

From pollens of the plant, glucose and rhamose were isolated [16].

Like lipids, carbohydrates in the flesh of the fruit had more attention by researchers than those in the seeds. This is obvious from the sweet nature of the fruit as well as its nutritional and commercial values. The carbohydrate content of the fruit varies from one cultivar to the other, but also depends on the stage of development and state of dryness of the fruit.

Many researchers in this field are accustomed to using the Arabic terms in referring to the stages of development of dates. "Kimri" refers to young, green-colored dates. The kimri stage may be divided into two phases: (1) The first phase is characterized by rapid increase in size and weight, rapid accumulation of reducing sugars, low but increasing rate of accumulation of total sugars (especially sucrose), high active acidity, and high moisture content. (2) The second phase is characterised by a reduced rate of gain in size and weight, greatly reduced rate of gain in reducing sugars, considerable reduction in the already low rate of gain in total sugars, slightly reduced active acidity, and a moisture content slightly higher than that of the first phase. The kimri stage continues until the dates begin to change from green to the characteristic colour of the "Khalal" stage.

Date in the Khalal stage may be yellow, pink, red, or scarlet, or yellow spotted with red, depending upon the cultivar. The rate of gain in size and weight continues to decrease, the weight may even decrease slightly, invert sugar accumulate slowly but sucrose accumulates at rapidly increasing rate, active acidity decrease, and moisture content decrease in both percentage and in quantity per fruit.

The "rutab" stage follows the khalal and encompasses the ripening period. The rutab stage begins when the fruit commences to soften and merges into the final "tamar" stage. Little or no sugar accumulates during the rutab stage. Dates continue to lose water, but not enough water to make them self-preserving.

Dates in the tamar stage have dried to a fairly firm consistency and the sugar-to-water relationship is such that the date are not subject to fermentation. Young dates contain as much as 85% water or more up to the time they have attained nearly full size. Invert sugar constitute from 40 to 97% of the total sugar in the very early stage of growth and remains high during the main period of growth. Invert sugar decreases rapidly in percentage as sucrose accumulate after the fruit has attained approximately full size. No other sugar, even in minute quantity, has been detected in date [3]. As date approaches full development, sucrose usually

constitutes about 80% of the sugar present. This is true for soft or as well as for semi dry and dry kinds.

Ripe dates contain 70% carbohydrates [1]. Reducing sugars were measured in five dry date cultivars, namely, Barkawi, Tamoda, Gondela, Gawa, and Mishrig, and found to range from 5-68%; the total sugars in these cultivars ranges from 63 to 72% [21].

Reducing sugar are dominant in the fruit of the Khalas cultivar. Based on their dry weight, glucose was found to be a major component (32%), followed by fructose (27%) and sucrose (16%). These sugars were also found in the seeds of this cultivar but in lower concentrations. Hydrolysis of the polysaccharides isolated from the flesh as well as the seeds with 1N-$H_2SO_4$ gives xylose, arabinose, glucose, and galactose as major components of these polysaccharides [11].

The figure for total sugar in one cultivar (Halwa), based on the dry weight of the fruit, was found to be 87%, with reducing sugar being 81%. Other cultivars, namely, Ajwa, Barni, Shabibi, Sukkarat, Maktumi, Sukkeri, Nabbat-Al-Seif, Mukai, Sukai, Khudhari, Hulwa Hail, Rakhim, Suwaini, Khalas, Hatami, Shashi, Raziz, Khunaizi, and Qatif, were also studied and found to contain sucrose (0.42%), glucose (49-56%), and fructose (38-57%) with total sugars raning from 53 to 82%. These measurements were taken at different stages of maturity of the fruit [19].

Other workers found toal sugar to range from 38 to 78%. The cultivars under study were: Barni, Jasb, Abyad, Humri, Safri, Agwa, Safawi, Hilwa, Shalbi,Khalas, Gur, Shaishi, Raziz, Helaili, Khudri, Nabbut Saif, Sufri, Sugee, Bakaria, Bint Al Sayed, Khusbah, Khasseib El-Razaiz, and Khumaizi. Sucrose was found to range from 0.3 to 19% with invert sugar being 29 to 75% [62].

Khudari, Sillaj, Rezaiz, Sufri, and Barni cultivars are reported to contain a total sugars ranging from 69 to 88% depending on the stage development of dates. Sucrose was found to range from 1 to 25% with reducing sugars ranging from 50 to 83% [64]. Freshdate (Zahdi cultivar), on the other hand contained 65% total sugars, with reducing sugars being 58%; non-reducing sugars were only 6% [65].

The effect of pollen type on the chemical composition of the fruits was also studied. Four cultivars, namely, Hallawi, Khadrawi, Sayer, Zaghlool, and Samani, were pollinated with four different pollen types (Siwi, Zaghlool, Ambat and Maghal). Results showed that total sugars (35-42%) varied with pollen type and depended on the female variety used [65]. These results are in agreement with reports that total sugar content of the fruit varied according to the source of pollen [67, 68, 69].

Date cultivars, Khudari, Sillaj, and Sifri were studied for total sugars content at the four stages of development of the fruit. Total sugar and reducing sugar increased, while non-reducing sugar comprised only of sucrose increased in the Khalal stage and then dropped sharply to low level in the tamar stage. The dominance of the reducing sugar and the low sucrose levels at the tamar stage, indicate that the cultivars belong to the group of soft dates [66].

Barhi, Hellawy, Samani, and Sayer cultivars were also studied for their sugar contents. Total sugar were highest in Hellawy fruits (30-31% of fresh weight), followed by Sayer (25-27%), Barhi (22- 27%), and Samani (21-23%). Non-reducing sugar were highest in Sayer fruits (13-14%), followed by Hellawy (9-10%), and Samani (2-3%). Reducing sugar were highest in Hellawy (21%) followed by Samani (18-91%), Sayer (11-14%), and Barhi (12%) [67]. Edible dates are reported to contain 72.9% total carbohydrates [3].

Safawi and Saukaria cultivars in the tamar stage were studied for their carbohydrates contents before and after irradiation with $\gamma$-rays for insect control. Based on dry weight, total carbohydrate were found to range from 82 to 84%; of those, reducing sugar were 49% and non-reducing sugar were 33%. Fructose ranged from 21 to 22%, glucose ranged from 21 to 23% and sucrose was found to be 41%. Polysaccharide hydrolysates contained xylose (1.8-1.9%), arabinose (1.7%), glucose (3.2-4.2%), and galactose (1.6-19%). Treatment with $\gamma$-rays produced no significant changes in the nutritional qualities of the fruit [28].

Total sugar, reducing sugar, and sucrose were measured in eighteen ripe fruit cultivars, namely, Anbara, Khudari, Sifri, Shlabi, Nebut Seif, Berni, Hilwa, Safawi, Agwa, Sakhi, Sukkaret Yanbu,

Holaya, Berhee, Sukkeri, Bukeira, Khalas, Ruzeiz, and Khuneizi. Total Sugars, based on the dry weight of the fruit, ranged from 72 to 83%. The amount of reducing sugars ranged from 36 to 83%, and sucrose ranged from zero to 40% [48]. These cultivars were classified according to their moisture contents and the results were in agreement with the findings of Cook and Furr [66] and those of Hussein [67] who reported that the texture and the degree of date firmness is related to the amount of invert sugar and sucrose present in them. High amount of reducing sugars in one fruit cultivars (Mishrig) was blamed for its susceptibility to infestation [26]. A detailed study on the carbohydrate content of the fruit was undertaken by MIzuno and Mikami [68]. They reported that the fruit consisted of 87% of fruit coat (flesh) and 13% seed. These contained respectively, on dry basis, water soluble total sugar 49.87, 7.55; reducing sugar 46.23, 3.21; pentosan, 3.88, 4.36%. The fruit coat gave on extraction with 80% ethanol, a purified sirup, (moisture (18.96%), consisting of 45.59% glucose, 26.97% fructose, and 3.77% sucrose, among which glucose was isolated as crystals. The sugars were almost completely (98%) fermented with Saccharomyces cerevisiae. Nine fractions of polysaccharides were separated from the fruit coat and were analysed by paper chromatography after hydrolysis. The seed contained 1.53% fructose, 1.68% glucose, 3.82% sucrose, 0.30% raffinose, and 0.22% stachyose, as revealed by quantitative paper chromatography. Polysaccharides in the seed were also analysed.

Chemical analysis of the fruits of the more important date cultivars showed that total sugars in the flesh ranged from 47 to 85% according to cultivar and stage of fruit development [47,66,69-75].

*Proteins and Amino Acids*

*A. Background*

Proteins are amongst the most complicated and the largest of molecules which occur naturally; in addition they remain some of the most labile and difficult to purify. Proteins occur in a considerable range of forms and exhibit a correspondingly wide range of physical properties. Early classifications of proteins were based on one of these physical criteria-their solubility in aqueous media. The solubility varies from the very soluble globulins and albumins to the virtually insoluble scleroproteins such as $\alpha$-keratin and sclerotin.

Another classification which has been employed is based upon the products of hydrolysis. Simple proteins are defined as those which yield only amino acid (or their degredation products) on hydrolysis. On the other hand, conjugated proteins produce not only amino acids but also other organic or inorganic molecules (prosthetic groups). The classification is then based on the chemical nature of the various prosthetic groups and typical categories which result are nucleoproteins, glycoproteins, lipoproteins, phosphoproteins, flavoproteins, and metalloproteins. Thus the nucleoproteins in ribosomes are combined with nucleic acids by multiple ionic linkages, glycoproteins are associated with lipids and cholesterol by various non-covalent forces, and metal ions are bound to metalloproteins by ionic or dative covalent bonds. The classification neverthless serves to illustrate the undoubted complexity of many proteins as they occur in living cell. However, as more and more has been learnt concerning the nature of proteins and their individual biological roles, classifications have generally changed to become based upon properties which relate to their great functional diversity and versatility. Whilst theprotein content of whole tissues varies widely, the protein within cells normally constitutes over half the cells weight. Several distinctive groups may be discerned: enzymes, which serve as catalysts for the biochemical reactions on the cell; the food storage protein; the structural proteins; transport proteins; contractile proteins; antibodies; toxins; hormones; and regulatory proteins. It is possible on a somewhat broaaer interpretation of their biological functions to classify these into three major categories:

1. Storage proteins

Albumin (egg white), casein (milk), Zein (corn), Gliadin (Wheat), Ferritin (spleen).

2. Structural or mechanical proteins

$\alpha$-Keratin and its derivatives (hair, hoof, horn); Collagen (bone and tendon); Fibroin (silk); Elastin (ligaments); Sclerotin (insectts);

Glycoproteins (cell wall); Myosin (muscle); Fibrinogen-Fibrin (blood).

3. Proteins which associate with other molecule or ions

Enzymes (e.g. Ribonuclease) Hormones and Regulatory proteins (.e.g. insulin) Immunoproteins (e.g. IgG Globulins) Transport Proteins (e.g. Haemoglobin) Photo and Chemo-receptors (e.g. Opsin)

Organisms use a basic set of 20 amino acids for protein synthesis, although threre are unusual amino acids which occasionally occur in protein structures. The genetically coded protein amino acids, in alphabetical order are:alanine (Ala)*, arginine (Arg), Aspartagine (Asn), aspartic acid (Asp), cystein (cys), glutamine (Gln), glutamic acid (Glu), glycine (Gly), histidine (His), isoleucine (Ile), leucins (Leu), lysing (lys), methionine (Met), phenylalanine (Phe), proline (Pro), Serine (Ser), threonine (Thr), tryptophan (Trp), tyrosine (Tyr), and Valine (Val). These are the only amino acids which can be coded for by triads of bases in messenger ribonucleic acid (mRNA). When other amino-acids are present in protein (E.g. cystine, hydroxyproline), they are formed by post-tranlational modifications (e.g. oxidation of two cystein residues, hydroxylation of proline) [75].

*B. Date Palm Products*

Ripe date is reported to contain 1.9% protein [1]. Considine puts the figure for protein content in dry date at 2.2% [3]. However, Mizuno reported that the fruit contains 4.3% protein [68]. Ejlali [77] studied four cultivars and found that one of them, Sayer, had the highest protein content.Auda [78] reported that the protein content of ripe dates of three cultivars, Khastawi, Khadrawi, and Zahid, was 2.3, 2.0, and 1.9% respectively.The analysis was based on Kjeldahl nitrogen determination. The same method was applied by Kamel and Kramer [79], who obtained values of 3% protein for the dried dates. Recently, Stegemann [12] measured the protein content of date extracts after Kjeldahl digestion using albumin as a reference protein. The calculated amount of protein in the cultivars, Reziz, Marzban, Mowahed, Khalas, Hatmy,Shishy, Shahl, Gir, and Muskade, ranged from 0.45 to 0.88 g protein/100 g fresh pulp, with Hatmy having the highest protein content and Muskade the lowest. Three cultivars, Khudari, and Sifri, were studied for their protein content at the four stages of fruit development; crude protein was found to range from 2.4% at the former stage to 4.7% at the Kimri stage. These figures were based in the dry weight of the fruit [18]. Crude protein was measured for five cultivars, Barkawi, Tamoda, Tawa, Gondela, and Mishrig, and found to range from 1.87 to 2.94% [21].

Twenty two cultivars, Barni, Jasb Abyad, Humri, Jasb, Sufri, Agwa, Safawi Hilwah, Shalbi, Kalas, Gu, Shaishi, Raziz, Helaili, Khudri, Nabtsaif, Sugeee, Bakaira, Bint Alsayed, Khusbah, Khaseib El-Razaiz, and Khunaizi, were analysed for their protein content at the tamar stage which was found to range from 0.511 to 1.791% [62]. Five other cultivars, Khudari, Sillaj, Rezaiz, Sufri, and Barni, were studies for their protein content at different stages of development and found to contain a minimum of 2.31% protein at the tamar stage and a maximum of 4.06% at the khalal stage; the figures differ for each cultivar and are based on the dry weight of the fruit [63]. Similar work was undertaken for twenty five cultivars and their protein content was measured at the khalal and the tamar stages. Crude protein, based on the dry weight of the fruit, was found to range from 2.07 to 4.36% at the khalal stage and 1.84 to 2.79% at the tamar stage [65]. Safawi and Saukaria cultivars were studied for their protein content before and after irradiation with $\gamma$-rays for insect control. Total protein, based on dry weight of the fruit, was found to be 1.8% for the Safawi and 1.6% for the Saukaria ccultivars before irradiation [28]. These figures were slightly less after twelve months of storage period at room temperature.

$\gamma$-Irradiation of ccompletely ripened date fruits up to 500 krads had no effecct on the protein ccontent of dates. However, storage decrease the protein content of both unirradiated and irradicated fruits [80].

From the pollen of the plant, a glyccoprotein was isolated and proved biologically to have a gonadotropicc activity [16].

*Symbols according to the instruction to authors in the Biochemical Journal, 1978.

Proteins in the seeds were also studied. This is because in countries where date palm in grown, seeds are used as animal feed. Seeds of four cultivars, Khederi, Sukkeri, Nabt-saif, and Manifi were analysed for their protein content [22]. The seeds of six cultivars, taleese, Adwi, Taghiat, Tasfert, Aspear, and Seloulou, were analysed for their protein ccontent. Based on their dry weight, they contained a maximum of 6.43% protein which varies according to the cultivar [61]. Seeds are also known to contain 6.23% crude protein [68]; higher figures 95.2 to 10.6 protein) were also reported [81].

Proteins from the flesh and seeds were hydrolysed and their amino acid composition was determined. In all, twenty one different amino acids were detected; they are: alanine, arginine, aspargine, aspartic acid, $\gamma$-aminobutyric acid, cysteine, cystine, glutamine, glutamic acid, glycine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine, and valine. For concentrations in various cultivars, see table 3 and 4. It is interesting to note that $\gamma-$ aminobutyric acid, detected in the Sfawi and Saukaria cultivars [28] in an important inhibitory neurotrasmitter [82].

*Other chemicals*

Other chemicals detectd or isolated from the date palm include enzymes, flavonoids, minerals, pectins, phenolic compounds sterols and vitamins.

*Enzymes*

Dates seeds at various stages of germination were assaysed biochemically and enzyme activities were found for endo-$\beta$-mannase, $\beta$-mannosidase, and thiol proteinase [83]. Electrophoretic analysis of leaf extracts revealed clear differences between male and female seedlings for peroxidase, the latter having two extra bands. The differences could be detected in seedlings at the two-leaf stage [84].

It has been reported that in all varieties except two, of date palm, the enzyme invertase is present in the cells and is responsible for the breakdown of complex sugars into the simple ones, glucose and fructose [1].

Table-3: Component Amino-acids Found in Date

| Amino-acid | Concentration | Cultivar and Reference |
|---|---|---|
| Alanine | 342[a] 147[b] | 3 |
| | 119[c] | Khalas, 11. |
| | 92,116,148[d] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 27,8,46[e] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 213,109[f] | Safawi, Saukaria, 28. |
| Arginine | 154[a], 66[b] 152[c] | 3 |
| | 80,62,74[d] | Khastawi, Khadrawi, Zahdi, 78. |
| | 5,2,4[e] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 261, 209[f] | Safawi, Saukaria, 28. |
| Aspartagine | 450, 230[f] | Safawi, Saukaria, 28. |
| Aspartic acid | 467[a], 201[b] | 3 |
| | 315[c] | Khalas, 11 |
| | 161,159,129[d] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 3,2,8[e] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 433, 375[f] | Safawi, Saukaria, 28. |
| $\gamma$-Amino butyric acid | 337,266[f] | Safawi, Saukaria, 28. |
| Cysteine | 58,40, 59[d] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 114, 11[f] | Safawi, Saukaria, 28. |
| Cystine | 122[a], 52[b] | 3 |
| | 0.73, 0.81[g] | Safawi, Saukaria, 28. |
| Glutamine | 65, 87[f] | Safawi, Saukaria, 28. |
| Glutamic acid | 631[a], 271[b] | 3 |
| | 398[c] | Khalas, 11 |
| | 226, 257, 257[d] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 40,52,101[e] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 616, 545[f] | Safawi, Saukaria, 28. |
| Glycine | 349[a], 150[b] | 3 |
| | 301[c] | Khalas, 11 |
| | 120,113, 117[d] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 5,4, 8[e] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 267, 241[f] | Safwi, Saukaria. |
| Histidine | 76[a], 33[b] | 3 |
| | 36, 0.1, 26[d] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 0.8, 0.2, 0.1[e] | Khastawi, Khadhrawi, Zahdi, 78. |
| Isoleucine | 154[a], 66[b] | 3 |
| | 61, 60, 47[d] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 0.5, 0.2, 0.7[e] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 465, 387[f] | Safawi, Saukaria, 28. |
| Leucine | 264[a], 114[b] | 3 |
| | 114, 110, 84[d] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 1.3, 0.5, 1.2[e] | Khastawi, Khadhrawi, Zahdi, 78. |
| Leucine and Isoleucine | 254[c] | Khalas, 11 |
| Lysine | 188[a], 81[b] | 3 |
| | 184[c] | Khalas, 11 |
| | 83, 66, 93[d] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 6,3,9[e] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 282, 245[f] | Safawi, Saukaria, 28. |
| Methionine | 51[a], 22[b] | 3 |
| | 15,22,12[d] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 0.5, 0.2, 0.2[e] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 155, 219[f] | Safawi, Saukaria, 28. |
| Phenylalanine | 173[a], 74[b] | 3 |
| | 62, 62, 53[d] | Khastawi,Khadrawi, Zahdi, 78. |

Table-3: continued.

| Amino-acid | Concentration | Cultivar and Reference |
|---|---|---|
| | 0.8, 1, 0.9[e] | Khastawi, Khadhrawi, Zahdi, 78. |
| Proline | 369[a], 159[b] | 3 |
| | 126, 108, 76[d] | Khastawi, Khadhrawi, Zahdi, 82. |
| | 12, 14, 30[e] | Khastawi, Khadhrawi, Zahdi, 82. |
| | 41, 72[f] | Safawi, Saukaria, 28. |
| Serine | 229[a], 98[b] | 3 |
| | 196[c] | Khalas, 11 |
| | 67, 69, 64[d] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 7, 6, 6[e] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 238, 213[f] | Safawi, Saukaria, 28. |
| Threonine | 178[a], 76[b] | 3 |
| | 98[c] | Khalas, 11 |
| | 62, 55, 46[d] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 1,2, 1[e] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 264, 230[f] | Safawo. Saukaria, 28. |
| Tyrosine | 48[a], 21[b] | 3 |
| | 173[c] | Khalas, 11 |
| | 36, 43, 27[d] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 1, 2, 4[e] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 181, 121[f] | Safawi, Saukaria, 28. |
| Valine | 216[a], 93[b] | 3 |
| | 88[c] | Khalas, 11 |
| | 85, 80, 72[d] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 1, 0.5, 1[e] | Khastawi, Khadhrawi, Zahdi, 78. |
| | 271, 255[f] | Safawi, Saukaria, 28. |

a Measured as Milligrams/gram of Nitrogen (Dried Date).

b Measured as Milligrams/100 grams of Food (Dried Dates).

c Measured as Mg/100 g of Dry Date.

d Measured as Milligrams of Total Amino acid per 100 g of Dry Date.

e Measured as Milligrams of Free Amino acid per 100 g of Dry Date.

f Measured as Microgram Free Amino acid per 100 gram of Dry Date.

g Measured as Milligram conjugated Amino acid per 100 gram Dry Date.

**Table-4: Component Amino acids Found in Seeds.**

| Amino acid | Milligrams/100 grms of dry Seeds (Khalas Cultivar)[11] |
|---|---|
| Alanine | 61 |
| Arginine | 35 |
| Aspartic acid | 174 |
| Glutamic acid | 172 |
| Glycine | 92 |
| Leucine and Isoleucine | 105 |
| Lysine | 32 |
| Serine | 58 |
| Threonine | 50 |
| Tyrosine | 58 |
| Valine | 31 |

*Flavonoids*

Rutin and quercentin were detected in the pollen extracts [16]. Flavonoid pigments have been isolated from leaves of the plant and found to contain luteolin 7-glucoside, luteolin 7-rutinoside, glycosylapigenin, and flavon C-glycosides [13,85].

*Minerals*

Minerals are sometimes measured and reported as "ash content". In the fruit, ash content ranges from 2.1. to 4.48% [48-50, 68, 86]. In seeds, the figure is reported to be = 1.2% [61,68]. The main constituents are:aluminum, calcium copper, chloride, cadmium, iron, lead, magnesium, manganese, potassium phosphorus, sodium, and zinc. [3,10,18,21,22,26,61]. The nutritional value of some of these elements has been discussed [10,65]. For the concentration of these elements in the flesh as well as the seeds, see table 5 and 6.

*Pectins*

Among the plant polysaccharides may be mentioned the pectins, which are used as jelling agents in the making of preserves and jellies from fruit. Pectic substances, that is protopectin, insoluble pectin, etc, are important to the date syrup industry, since their presence makes the filtration of the date slurry difficult.

The pectin content of eighteen date cultivars was measured and classified into three group. The first group includes the cultivars which contain more than 2% pectin, viz. Agwa (2.11%), Skhi (2.07%), and Sifri (2.05%). The second group includes 11 cultivars which contain 1 to 2% pectin. Of these, Nebut-seif showed the highest pectin content (1.97%), while Barhee contained only 1.05%. The remaining nine cultivars in this group were intermediate in their pectin content. The third group includes those cultivars in which the pectin content is less than 1%. These include Sukkaret Yanbu (0.78%) and Khuneizi (0.72%) [48].

The pectin content of twenty six cultivars was also analysed and found to range from 2.3 to 3.9% [62]. Zahidi and Red Shitwi cultivars contain 1.15 and 1.75% pectin respectively [64].

Table-5: Mineral content of Date Palm Fruit

| Mineral | Concentration | Cultivar and Reference |
|---|---|---|
| Calcium | 59[a] | 3. |
| | 14-76[b] | Ajwa, Barni, Shalabi; Hilawa, Sukkarat Al-Sharg, Maktumi, Sukkeri, Nabbut Al-Seif, Mukai, Sukai, Khudari, Hilwa Hail, Rakhimi, Suwaini, Khalas, Hatami,Shabibi, Shashi, Raziz, Khunaizi Qatif, Hamar Amik, Jasap, Sifri Beisha, Laha, Sillaj, Sifri. 18,65. |
| | 62-200[b] | Barkawi, Tamoda, Jawa, Gondela, Mishrig. 21. |
| Copper | 0.26-0.97[b] | Agwa, Barni, Shalabi, Hilwa, Sukkarat Al-Sharg, Maktumi, Sukkeri, Nabbut Al-Seif, Mukai, Sukai, Khudari, Hilwa Hail, Rakhimi, Suwaini, Khalas, Hatami, Shabibi, Shashi, Raziz, Khunaizi Qatif, Hamar Amik, Jasap, Sifri Beisha, Laha, Sillaj, Sifri, 18,65. |
| Iron | 3.0[a] | 3. |
| | | 1.05-2.7[b] |
| | | Ajwa, Barni, Shalabi, Hilwa, Sukkarat Al-Sharg, Maktumi, Sukkeri, Nabbut Al-Seif, Mukai, Sukai, Khudari, Hilwa Hail, Rakhimi, Suwaini, Khalas, Hatami, Shabibi,Shashi,Raziz, Khunaizi Qatif, Hamar Amik, Jasap, Sifri Beisha, Laha, Sillaj, Sifri. 18,65. |
| | 16.0-75.0[b] | Barkawi, Tamoda, Jawa, Gondela, Mishrig. 21. |
| Magnesium | 37-127[b] | Ajwa, Barni, Shalabi, Hilwa,SukkaratAl-Sharg, Maktumi, Sukkeri, Nabbut Al-Seif,Mukai, Sukai, Khudari, Hilwa Hail, Rakshimi, Suwaini, Khalas, Hatami, Shabibi, Shashi, Raziz, Khunaizi Qatif, Hamar Amik, Jasap, Sifri Beisha, Laha, Sillaj, Sifri. 18,65. |
| | 57.0-264.0[b] | Barkawi, Tamoda, Jawa, Condela, Mishrig. 21. |
| Manganese | Traces | Ajwa, Barni, Shalabi, Hilwa, Sukkarat Al-Sharg, Maktumi, Sukkeri, Nabbut Al-Seif, Mukai, Sukai, Khudari, Hilwa Hail, Rakhimi, Suwaini, Khalas, Hatami, Shabibi, Shashi, Raziz, Khunaizi Qatif, Hamar Amik, Jasap, Sifri Beisha, Laha, Sillaj, Sifri. 18,65. |
| Potassium | 648[a] | 3 |
| | 566-1821[b] | Ajwa, Barni, Shalabi, Hilwa, Sukkarat Al-Sharg, Maktumi, Sukkeri, Nabbut Al-Seif, Mukai, Sukai,Khudari, Hilwa Hail, Rakhimi, Suwaini, Khalas, Hatami, Shabibi, Shashi, Raziz, Khunaizi Qatif, Hamar Amik, Jasap, Sifri Beisha, Laha, Sillaj, Sifri. 18,65 |
| | 32.50-275.0[b] | Barkawi, Tamoda, Jawa, Gondela, Mishrig. 21. |
| Phosphorus | 63 | 3 |
| | 36-111[b] | Ajwa, Barni, Shalabi, Hilwa, Sukkarat Al-Sharg, Maktumi, Sukkeri, Nabbut Al-Seif, Mukai, Sukai, Khudari, Hilwa Hail, Rakhimi, Swaini, Khalas, Hatami, Shabibi, Shashi, Raziz, Khunaizi Qatif, Hamar Amik, Jasap, Sifri Beisha, Laha, Sillaj, Sifri. 18,65. |
| | 65.0-109.0[b] | Barkawi, Tamoda, Jawa, Gondela, Mishrig. 21. |
| Sodium | 1[a] | 3 |
| | 16-42[b] | Ajwas, Barni, Shalabi, Hilwa, Sukkarat Al-Sharg, Maktumi, Sukkeri, Nabbut Al-Seif, Mukai, Sukai, Khudari, Hilwa Hail, Rakhimi, Suwaini, Khalas, Hatami, Shabibi, Shashi, Raziz, Khunaizi Qatif, Hamar Amik, Jasap, Sifri Beisha, Laha, Sillaj, Sifri, 18,65. |
| Zinc | 0.19-1.3[b] | Ajwa, Barni, Shalabi, Hilwa, Sukkarat Al-Sharg, Maktumi, Sukkeri, Nabbut Al-Seif, Mukai, Sukai, Khudari, Hilwa Hail, Rakhimi, Suwaini, Khalas, Hatami, Shabibi, Shashi, Raziz, Khunaizi Qatif, Hamar Amik, Jasap, Sifri, Beisha, Laha, Sillaj, Sifri, 18, 65. |

a Measured as Milligrams per 100 Edible Grams.

b Measured as $\mu$g/100 gry weight.

Table-6: Mineral content of Date Palm Seeds.

| Element | Concentration | Cultivar and Reference |
|---|---|---|
| Aluminum | 3.13-12.75[a] | Khalas, Nabt-Saif, Nabt-Zamel, Negeeb, Sukkari, Sifree, Sugee, 10. |
| Calcium | 18.0-436.0[a] | Khalas, Nabt-Saif, Nabt-Zamel, Negeeb, Sukkari, Sifree, Sugee, 10. |
| | 5.88-8.09[b] | Khedhri, Sekkeri, Nabt-Saif, Menifi, 22. |
| | 0.038[c] | Taleese, Adwi, Taghiat, Tasfert, Aspear, Seloulou. 61. |
| Copper | 0.63-2[a] | Khalas, Nabt-Saif, Nabt-Zamel, Negeab, Sukkari, Sifree,Sugee, 10. |
| | 0.013-0.019[b] | Khedhri, Sekkeri, Nabt-Saif, Menifi, 22. |
| | 8.1[d] | Taleese, Adwi, Taghiat, Tasfert, Aspear, Seloulou.61. |
| Chloride | 0.161[c] | Taleese, Adwi, Taghiat, Tasfert, Aspear, Seloulou. 61. |
| Cadmium | 0-9.0[a] | Khalas, Nabt-Saif, Nabt-Zamel, Negeeb, Sukkari, Sifree, Sugee, 10. |
| Iron | 4.9-16.6[a] | Khalas, Nabt-Saif, Nabt-Zamel, Negeeb, Sukkari, Sifree, Sugee, 10. |
| | 0.25-0.31[b] | Khedhri, Sekkeri, Nabt-Saif, Menifi. 22. |
| | 30.4[c] | Taleese, Adwi, Taghiat, Tasfert, Aspear, Seloulou. 61. |
| Lead | 0.1-4.0[a] | Khalas, Nabt-Saif, Nabt-Zamel, Negeeb, Sukkari, Sifree,Sugee 10. |
| Magnesium | 4.11-7.08[b] | Khedhri, Sekkeri, Nabt-Saif, Menifi.22. |
| Manganese | 0.021-0.027[b] | Khedri, Sekkeri, Nabt-Saif, Menifi 22. |
| | 15.7[d] | Taleese, Adwi, Taghiat, Tasfert, Aspear, Seloulou. 61. |
| Potassium | 28.0-138.0[a] | Khalas, Nabt-Saif, Nabt-Zamel, Negeeb, Sukkari, Sifree, Sugee.10. |
| | 78.37-93.20[b] | Khedhri, Sekkari, Nabt-Saif, Menifi.22. |
| | 0.244[c] | Taleese, Adwi, Taghiat, Tasfert, Aspear, Soloulou. 61. |
| Phosphorus | 27.17-34.69[b] | Khedhri, Sekkeri, Nabt-Saif,Menifi. 22. |
| | 0.112[c] | Taleese, Adwi, Taghiat, Tasfert, Aspear, Seloulou. 61. |
| Sodium | 15.3-38.2[a] | Khalas, Nabt-Saif, Nabt-Zamel, Negeeb, Sukkeri, Sifree, Sugee. 10. |
| | 5.62-12.85[b] | Khedhri, Sekkeri, Nabt-Saif, Menifi. 22. |
| | 0.0082[c] | Taleese, Adwi, Taghiat, Tasfert, Aspear, Seloulou. 61. |
| Zinc | 0.663-10.0[a] | Khalas, Nabt-Saif, Nabt-Zamel, Negeeb, Sukkeri, Sifree, Sugee. 10. |
| | 0.30-0.36[b] | Khedhri, Sekkeri, Nabt-Saif, Menifi, 22. |
| | 28.84[d] | Taleese, Adwi, Taghiat, Tasfer[b] Aspear, Seloulou. 61. |

a Measured as $\mu$g/g of dry powdered seeds.
b Measured as $\mu$ MMole/g oven dried weight.
c Measured as grams per 100 grams dry seeds.
d Measured as PPM.

*Phenolic compounds*

Among the phenolic compounds that have been detected or isolated from the plant are chlorogenic acid and isochlorogenic acid [24] from the fruit; trans-3,5,3',5'-tetrahydroxy-4-methoxystilbene, cis-3,5,3',5'-tetrahydroxy-4-methoxystilbene, trans-3,5,4'-trihydroxystilbene, p-hydroxybenzoic acid, and 3,5-dihydroxy-4-methoxybenzoic acid from the stem of the plant [14].

*Sterols*

The term steroid is genrally applied to compounds containing a hydrogenated cyclopentanophenanthrene carbon skeleton. Most of these

compounds are alcohols, and sometimes the name sterol is used for the whole class.

A crystalline sterol mixture was isolated from the sarcocarp of the plant. Analysis of the mixture by gas chromatography showed the presence of cholesterol, stigmasterol, campesterol, $\beta$-sitosterol, and isofucosterol. HPLC separation of the sterol mixture showed the presence of the same components [15]. $\beta$-sitosterol was also isolated from the pollent of the plant; oesterone was detected by TLC [16].

From the seeds of the plant, the unsaponificed matter of different cultivars was analysed by gas chromatography and showed the presence of estrone, one of the steroidal hormones, in all the varieties tested except the Negeeb cultivar. This variety was also free from cholesterol, brassicasterol, and campesterol. Cholesterol was detected in the Sukkeri and Sugee cultivars. Ergosterol was only found in the Neggeb cultivar. b-sitosterol was found in all the varieties tduied, which cinluded Khalas, Nabt-saif, Nabt-zamel, Negeeb, Sukkeri, Sifree, and Sugee. Brassicasterol was found in all varieties except Neggeb [10]. Bennett et al [5], isolated the steroidal estrogen, estrone, and cholesterol from the seeds and pollen of the plant. The presence of estrone in date palm seeds and pollen was demonstrated by thin-layer chromatography, isolation, I.R. spectrum, and reduction to estradiol. Cholesterol was obtained from date palm pollen and identified by thin-layer chromatography, isolation, I.R. spectrum, and conversion to cholesterol acetate [87,88,89,82].

From the stem of the plant, the following compounds were identified: $\beta$-sitosterol, stigmasterol, campesterol, stigmast-4-en-3-one, stigmast-4-22-dien-3-one, campest-4-en-3-one, 5$\alpha$-stigmastan-3,6-dione, 5$\alpha$-stigmast-22-en-3,6-dione, stigmast-4-3,6-dione, stigmasta-4,22-dien-3,6-dione, campest-4-en-3,6-dione, hydroxystigmast-4-en-3-one, hydroxystigmasta-4-,22- dien-3-one and 6 $\beta$-hydroxycampest-4-en-3-one [43].

Table-7: Vitamin Content of Date.

| Vitamin | Concentration | Cultivar and Reference |
|---|---|---|
| Ascorbic acid | 1.3-2.2[a] | Khudari, Sillaj, Sifri.18 |
| (Vitamin C) | 1.1-4.0[b] | Ajwa, Barni, Shalabi, Hilwa, Sukkarat Al- Sharaq, Maktumi, Sukkeri, Nabbut Al-seif, Mukai, Sukai, Khudari, Hilwa Hail, Rkhimi, Suwaini, Khalas, Hatimi, Shabibi, Shashi, Raziz, Khunaizi Qatif, Hamar Amik, Jasap, Sifri Beisha, Laha. 19. |
| | 0.17-0.24[c] | Barkawi, Tamoda, Jawa, Gondela, Mishirg. 21. |
| Vitamin A | 0-75[a] | Khudari, Sillaj, Sifri, 18. |
| | 0-132[b] | Ajwa, Barni, Shalabi, Hilwa, Sukkarat Al-Sharaq, Maktumi, Sukkeri, Nabbut Al-seif, Mukai, Sukai, Khudari, Hilwa Hail, Rakhim, Suwaini, Khalas, Hatimi, Shabibi, Shashi, Raziz, Khunaizi Qatif, Hamar Amik, Jasap, Sifri Beisha, Laha. 19. |
| | 50[d] | 3 |
| Nicotinic acid | 2.2[b] | 3 |
| (Niacin) | 0.35-0.667[c] | Barkawi, Tamoda, Jawa, Gondela, Mishrig.21. |
| Riboflavin | 0.1[b] | 3 |
| (Vitamin $B_2$) | | |
| Thiamine | 0.09[b] | 3 |
| (Vitamin $B_1$) | 0.160-0.524[c] | Barkawi, Tamoda, Jawa, Gondela, Mishrig. 21. |

a. Measured as I.U/100 g fresh date.

b. Measured as $\mu$g/100 g fresh date.

c Measured as $\mu$g/100 g dry date.

d. Measured as I.U.per 100 g edible grams.

*Vitamins*

Vitamins, such as ascorbic acid (vitamin C), $\beta$-carotene (provitamin-A), nicotinic acid (niacin), riboflavin (vitamin $B_2$), and thiamine (vitamin $B_1$) are known to be present in the fruit of the plant. Their concentrations in different cultivars are given in Table 7. Finally, chemicals such as saponins [16], tannins [19,64,89],, and terpenes ($\beta$-amyrin) [16] are also known to exist in the plant.

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Table-8: Chemical Constituents of Date Palm in Alphabetical Order.

| Chemical | Location in Plant | Reference |
|---|---|---|
| Alanine | Fruit, Seeds | 3, 11, 28, 78 |
| Aluminium | Seeds | 10 |
| $\gamma$-Aminobutyric acid | Fruit | 28 |
| $\beta$-Amyrin | Pollen | 16 |
| Arachidic acid (Eicosanoic acid) | Seeds | 8 |
| Arginine | Fruit, Seeds, | 3, 11, 28 |
| Ascorbic acid (Vitamin C) | Fruit | 18, 19, 21 |
| Aspargine | Fruit | 28,78 |
| Aspartic acid | Fruit, Seeds | 3, 11, 28, 78, 91 |
| Behenic acid (Docosanoic acid) | Seeds | 8,10 |
| Benzoic acid, 3,5-dihydroxy-4-methoxy | Stem | 14 |
| Benzoic acid, 4-hydroxy | Stem | 14 |
| Brassicasterol | Seeds | 10 |
| Cadmium | Seeds | 10 |
| Calcium | Fruit, Seeds | 3,10,18,21,22,61,65 |
| Caffeoylshikimic acid (Dactylifric acid) | Fruit | 7 |
| Campest-4-en-3-one | Stem | 43 |
| Campest-4-en-3, 6-dione | Stem | 43 |
| Campestan-4-en-3-one | Stem | 43 |
| Dodecanoic acid (See Lauric acid) | | |
| Docosanoic acid (See Behenic acid) | | |
| Eicosanoic acid (See Arachidic acid) | | |
| Ergosterol | Seeds | 10 |
| Estrogen | Pollen, Seeds | 5 |
| Estrone | Pollen, Seeds | 5,10,88,89,92 |
| Fructose | Fruit, Seeds | 11,22 |

Table-8: continued.

| Chemical | Location in Plant | Reference |
|---|---|---|
| D-Galactose | Seeds | 9,23 |
| Glucose | Fruit, Seeds | 10,16,18,22,28 |
| Glutamic acid | Fruit | 3,11,28,78,91 |
| Glutamine | Fruit | 28 |
| Glycine | Fruit | 3,11,28,78 |
| Glycosylapigenin | Leaves | 85 |
| Heneicosanoic acid | Seeds | 8 |
| Heptadecanoic acid (see Margaric acid) | | |
| Hexadecanoic acid (see Palmitic acid) | | |
| Cis-9-Hexadecenoi acid (see Palmitoleic acid) | | |
| Histidine | Fruit | 3,78 |
| Hydroxystigmast-4-en-3-one | Stem | 43 |
| Hydroxystigmasta-4,22-dien-3-one | Stem | 43 |
| 6$\beta$-Hydroxy-campest-4-ene-3-one | Stem | 43 |
| Iron | Fruit, Seeds, | 3,10,18,21,22,26,61,65 |
| Isochlorogenic acid | Fruit | 24 |
| Isofucosterol | Sarcocarp | 15 |
| Isoleucine | Fruit | 3,11,28,78,91 |
| Lactose | Seeds | 10 |
| Lauric acid (Dodecanoic acid) | Seeds | 8,10 |
| Lead | Seeds | 10 |
| Leucine | Fruit | 3,1,78,91 |
| Linoleic acid (cis, cis-9,12-octadeca-dienoic acid) | Seeds | 8 |
| Linolenic acid (cis, cis, cis-9,12,15-octadectrienoic acid). | Seeds | 8,10 |
| Lupeol | Stem | 43 |
| Lupyl acetate | Stem | 43 |
| Luteoline-7-glycoside | Leaves | 13,85 |
| Luteoline-7-rutinoside | Leaves | 13,85 |
| Lysine | Fruit | 3,11,28,78,91 |
| Magnesium | Fruit, seeds | 10,18,21,22,26,65 |
| Maltose | Seeds | 10 |
| Manganese | Fruit, seeds | 18,61,65 |
| D-Mannose | Seeds | 9,10,23 |
| Margaric acid (Heptad-ecanoic acid) | Seeds | 8 |
| Methionine | Fruit | 3,28,78 |
| Myristic acid (Tetrade-canoic acid) | Seeds | 8,10 |
| Nicotinic acid (Niacin) | Fruit | 3,21 |
| cis, cis-9,12-Octade-cadienoic acid (see Linoleic acid) | | |
| Octadecanoic acid (see Stearic acid) | | |
| cis, cis cis-9,12,15- | | |

Table-8: continued.

| Chemical | Location in Plant | Reference |
|---|---|---|
| octadecatrienoic acid (see Linolenic acid) | | |
| Octanoic acid (see Caprylic acid) | | |
| Oleic acid (cis-9-octadecenoi acid) | Seeds | 8,10 |
| Oesterone | Pollen | 16 |
| Palmitic acid (Hexadecanoic acid) | Seeds | 8,10 |
| Palmitoleic acid (cis-9-Hexadecenoic acid) | Seeds | 8 |
| Phenylalanine | Fruit | 3,80 |
| Phosphorus | Fruit, Seeds | 3,18,21,22,61,65 |
| Potassium | Fruit, Seeds, | 3,10,18,21,22,61,65 |
| Proline | Fruit | 3,28,78 |
| Quercetin | Pollen | 16 |
| Rhamnose | Seeds | 16 |
| Riboflavin (Vitamin $B_2$) | Fruit | 3 |
| Rutin | Pollen | 16 |
| Serine | Fruit | 3,11,28,78 |
| $\beta$-Sitosterol | Pollen, Stem, Sarcocarp | 10,15,16,43 |
| Stearic acid (Octadecanoic acid) | Seeds | 8 |
| Stigmast-4-ene-3-one | Stem | 43 |
| 5$\alpha$-Stigmast-22-ene-3,6-dione | Stem | 43 |
| Stigmast-4-ene-3,6-dione | Stem | 43 |
| Stigmasta-4,22-diene-3-one | Stem | 43 |
| Stigmasta-4,22-dien-3,6-dione | Stem | 43 |
| 5$\alpha$-Stigmastan-3,6-dione | Stem | 43 |
| Stigmasterol | Sarcocarp, Stem | 15,43 |
| Stilbene, trans-3,5,3'5'-tetra-hydroxy-4-methoxy | Stem | 14 |
| Stilbene, cis-3,5,3'5'-tetra-hydroxy-4-methoxy | Stem | 14 |
| Stilbene, 3,5,4'-trihydroxy | Stem | 14 |
| Sucrose | Fruit | 10,18,22,28 |
| Tetradecanoic acid (see Myristic acid) | | |
| Thiamine (Vitamin $B_1$) | Fruit | 3,21 |
| Threonine | Fruit | 3,11,28,78 |
| Tricosanoic acid | Seeds | 8 |
| Tryptophan | Fruit | 11 |
| Tyrosine | Fruit | 3,11,28,78 |
| Valline | Fruit | 3,11,28,78 |
| Vitamin A | Fruit | 3,18,19 |

Table-8: continued.

| Chemical | Location in Plant | Reference |
|---|---|---|
| Vitamin $B_1$ (see Thiamine) | | |
| Vitamin $B_2$ (see Riboflavin) | | |
| Vitamin C (see Ascorbic acid) | | |
| Xylose | Seeds | 23 |
| Zinc | Fruit, Seeds | 10,18,22,26,61,65 |

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