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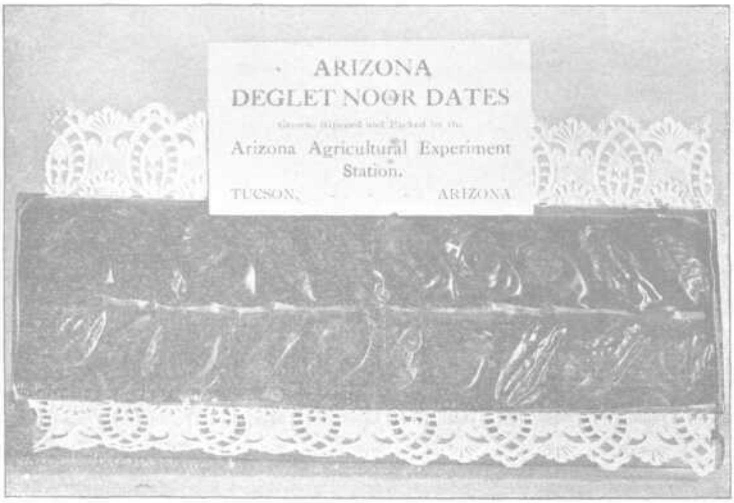

Chemistry and Ripening of the Date

By A. E. Vinson

Ripening Dates by Incubation

By G. F. Freeman

Tucson, Arizona, May 1, 1911

UNIVERSITY OF ARIZONA
AGRICULTURAL EXPERIMENT STATION

The Experiment Station offices and the botanical and chemical laboratories are located in the University buildings at Tucson. The range reserves (cooperative, U. S. D. A.) are suitably situated adjacent to and southeast of Tucson The work in horticulture and animal husbandry is conducted mainly on the Experiment Station Farm, three miles northwest of Phoenix, Arizona. The date-palm orchards are three miles south of Tempe (cooperative, U. S. D. A), and one mile southwest of Yuma, Arizona, respectively. The experimental dry-farms are near Snowflake and McNeal.

Visitors are cordially invited, and correspondence receives careful attention.

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Address, THE EXPERIMENT STATION,

Tucson, Arizona.

PREFACE

This publication is a record of scientific studies relating to the composition and ripening of dates; and of economic results in ripening and marketing them. Eleven years ago, when attention to this subject was renewed, it was supposed that the imported date palms at Tempe would soon develop large and remunerative crops. But it soon became evident that there were some cultural difficulties and various enemies to be overcome, before this desirable condition could be realized. Among the causes of delay to a successful outcome were the ground squirrels and the rats which injure or destroy the trees; the Old World scale insects which multiply enormously here upon them; the untimely storms which cause the fruit to rot and sour; and the peculiarities of American taste which must be known and satisfied in marketing the product. The active enemies of the palm have been brought under control for the most part; but the excessive waste of fruit due to insects, birds and untimely wet weather has remained a most serious drawback, as high as ninety percent of the crop having been lost during unfavorable seasons. It is therefore fortunate, at this time, that we are ready to submit methods whereby this loss may be almost wholly saved.

The methods of artificial date ripening developed here fall into two classes—those depending upon stimulation by chemicals at ordinary temperatures; and the incubation process, with variations, employing only heat and moisture. The chemical methods, in particular, and the scientific foundations of the subject in general have been worked out by Dr. Vinson. One of the most promising of the many substances employed by him in ripening experiments is nitrous ether, by the use of which Deglet Noor dates may be ripened inexpensively, and without extensive inversion of cane sugar.

The incubation method, first employed by Dr. Vinson, but laid aside by him for chemical processes, was, later, independently developed, amplified, and economically tested by Mr. Freeman, who studied the scientific rationale of the process and who ripened and marketed the first successful crop of Deglet Noor dates from the Tempe Cooperative Orchard by its means.

Working along the lines suggested above, commercial agencies will in time devise and adopt the processes best suited to the economic ripening and marketing of the date crop. The advantages of artificial ripening of dates, with any method, are:

1. The fruit can be harvested cheaply, by the bunch, before the berries begin to drop or are attacked by insects, moulds, or bacteria.

2. Danger of loss by untimely rains is minimized.

3. The ravages of worms in the ripened crop are avoided

4. Greater cleanliness of the product is possible than with naturally ripened dates.

5. Late varieties, among them the Deglet Noor, which do not ripen satisfactorily here, may be successfully brought through.

6. Early varieties may probably be grown and ripened at higher altitudes than formerly.

7. Dates while yet hard may be shipped without injury to a distance, then ripened artificially, and marketed in fresh and prime condition.

Consequent upon its work with the date palm since 1900, and especially in view of the economic results of the past season, the Arizona Station definitely recommends the planting of Deglet Noor palms in the Salton Basin, along the Lower Colorado, and in Southern Arizona up to an altitude of 1,200 feet. Other excellent varieties, some of which may ripen at higher altitudes, will of course be discovered; but the Deglet Noor, which is the standard of excellence in the Sahara, is already extensively grown in that region and offshoots are comparatively easy to obtain.

R. H. FORBES.

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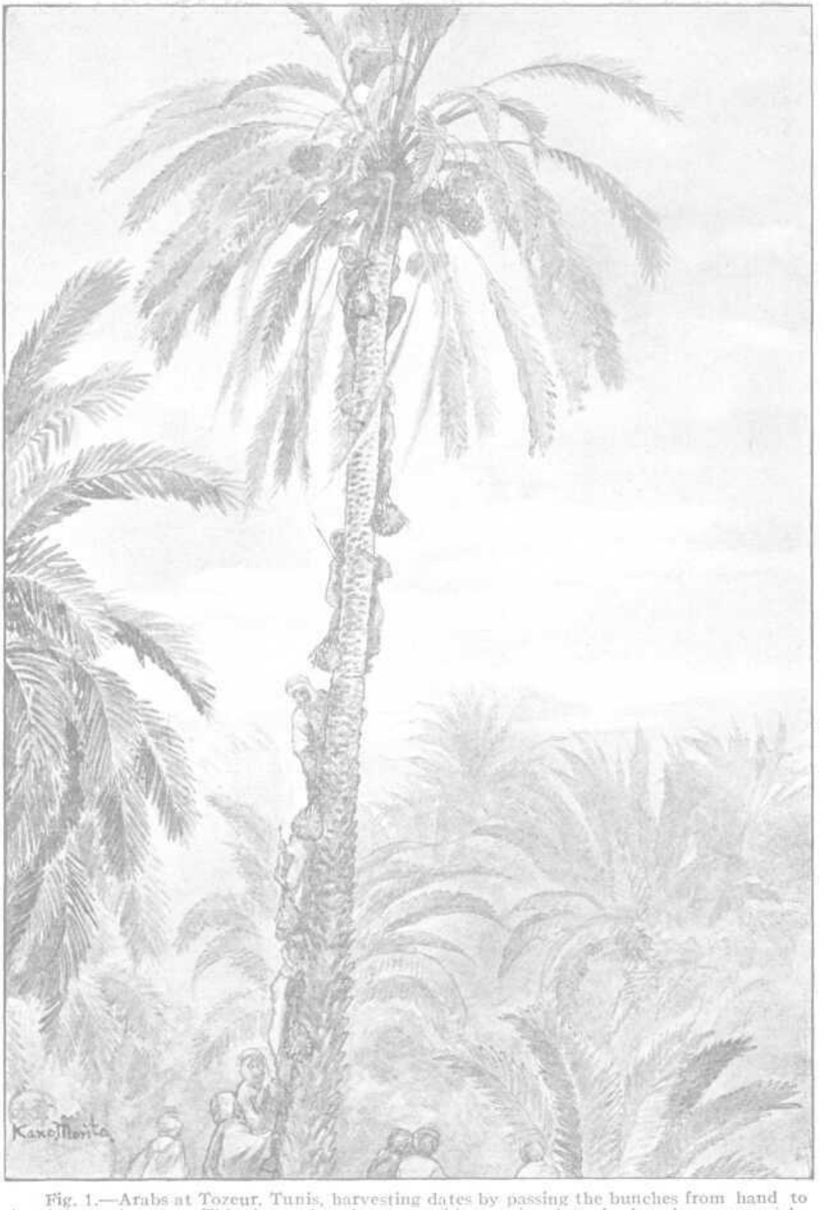

Fig. 1.—Arabs at Tozeur, Tunis, harvesting dates by passing the bunches from hand to hand down the tree. This shows the advantage of harvesting dates by bunches over picking the individual berries as they ripen.

CHEMISTRY AND RIPENING OF THE DATE

By A. E. Vinson

HISTORICAL

Observations on the growth and ripening of fruits have held, since the middle of the last century, an important place in the development of the biochemistry of plants. The early literature of the subject has been reviewed sufficiently elsewhere.[1] The chemical life history of many ordinary fruits and the transformations which some of their constituents undergo during after-ripening and storage, have been worked out in great detail by Bigelow and Gore. The ripening of the banana has been studied by Bailey[2] and Ricciarde[3] and of many other tropical fruits by Prinsen Gerligs[4] in Java. French and Rodenberg[5] have traced the development of the pea during the final period of its growth, and Leclerc de Sablon[6] that of cucurbits. The black walnut, also, has been studied lately by M'Clenahan.[7]

Although the chemical changes taking place in the date during growth and ripening had never been traced, the investigations reported in this writing were undertaken primarily to furnish a scientific foundation for a rational method of artificial ripening. This problem was suggested to the Arizona Experiment Station by the failure of Deglet Noor dates to mature and ripen naturally under our climatic conditions. Preliminary work was begun by Mr. Henry B. Slade, but was cut short by his untimely death in June, 1905. His report to the Director of the Station a few days before his death shows that he had made analyses of a large number of Mexican seedling dates and of imported varieties from the Tempe Date Orchard. By these analyses he demonstrated the existence of two distinct chemical types of dates—the invert sugar and the cane sugar types. He observed the action of several enzymes in dates and believed ripening to be an enzymic process which could be accelerated by chemical stimulation, notably with manganese chloride. His work was greatly retarded by the lack of a convenient method for the

1 Bigelow and Gore. Bur. of Chem. U. S. D. A. Bul. 94.
2 J. Biol. Chem. I. 355. 1906.
3 Compt. rend. 95. 393.
4 Intern. Sugar J. 10. 372.
5 Arch. Pharm. 243. 675. 1905.
6 Compt. rend. 140. 321. 1905.
7 J. Am. Chem. Soc., 31. 1093. 1909.

determination of levulose and dextrose in mixed sugars, but this difficulty was removed by the timely publication of Browne's[1] formula for the estimation of dextrose and levulose in the presence of cane sugar.

The investigation of the rationale of date ripening and its economic application has been continued by the writer through several seasons. Although Deglet Noor dates equal to those maturing naturally in the Sahara have not been produced, a fairly satisfactory product has been prepared after a certain degree of maturity is reached, both by chemical stimulation and by the application of heat. In conjunction with improved cultural methods, ultimate success may be obtained in producing Deglet Noor dates of highest quality. Other more reactive varieties, however, have already yielded to treatment, and the artificially ripened products offer important advantages over the natural ones. Many scientific observations of considerable interest and value have been made. As a direct result of this work the following papers have been published by the writer in which various phases of the subject are presented in greater detail than can be appropriately brought within the scope of this bulletin.[2]

PUBLISHED PAPERS

The Function of Invertase in the Formation of Cane and Invert Sugar Dates. Botanical Gazette, **43**: 393. 1907.

Some Observations on the Date. Plant World, **10**: 215. 1907.

The Endo and Ektoinvertase of the Date. Journal of the American Chemical Society, **30**: 1005. 1908.

The Chemical Stimulation of Artificial Ripening in Fruits. Science, **30**: 604. 1909.

The Chemical Organization of a Typical Fruit. Plant World, **13**. 1910.

Fixing and Staining Tannin in Plant Tissues by Nitrous Ethers. Botanical Gazette, **49**: 222. 1910.

The Stimulation of Premature Ripening by Chemical Means. Journal of American Chemical Society, **32**: 208. 1910.

Summaries of progress in the Sixteenth to Twenty-first Annual Reports of the Arizona Agricultural Experiment Station.

Also, a paper entitled, "Development and Nutrition of the Embryo, Seed and Carpel in the Date,(*Phoenix Dactylifera*, L.)" was published by Dr. Francis E. Lloyd, Cytologist of the Station, in the Twenty-first Annual Report of the Missouri Botanical Garden, pp. 103–164. This article deals exhaustively with the occurrence

1 J. Am Chem Soc, 28: 439. 1906.
2 A limited number of reprints of these papers is available to interested readers and may be had on application to the Arizona Agricultural Experiment Station, Tucson, Arizona.

and significance of the tannin of the date during its various stages of development.

SUMMARY OF PUBLISHED RESULTS

In these publications it has been shown that:

1. Two distinct chemical varieties of dates exist—the invert sugar and the cane sugar types. These are determined by the presence or relative absence of the enzyme, invertase.

2. All, or at least nearly all, of the sugar in the invert type has passed through the form of cane sugar, and at some stage of their development all dates contain a high percentage of cane sugar.

3. The greatest influx of sugar into dates takes place shortly before ripening. Dates, therefore, cannot be artificially ripened into an economic product before a certain minimum accumulation of sugars takes place.

4. The invertase of the unripe date is in the intracellular or endo form and probably forms an insoluble compound with the protoplasm. When ripening begins, the invertase, at least in the invert sugar dates, passes into the extracellular or ekto form, and is then readily soluble in water or glycerin.

5. The presence of soluble tannin in the green date does not prevent the invertase from dissolving in glycerin, nor does invertase precipitated by tannin or by lead subacetate lose its property of inverting cane sugar.

6. Most of the tannin of the date is deposited as insoluble grains in a zone of tannin cells near the cuticle. There is no segregation of tannin but deposition takes place in those cells where it is generated. Deposition may be accomplished at any time by subjecting the fruits to the vapor of nitrous ether.

7. Premature ripening may be induced artificially in some varieties by the action of various chemicals, or by killing the protoplasm by heat. Ripening appears to he the direct result of the release of previously insoluble intracellular enzymes.

CHEMICAL COMPOSITION

The date is preeminently a saccharine fruit, usually from 75 to 80 percent of its dry weight being made up of dextrose, levulose and cane sugar. Pectin bodies are often present in considerable amounts and cause the juice to jelly on long boiling. Such jelly, prepared by the native Mexicans, is known as *colache*. Glycerin extracts of ripening dates also jelly spontaneously due to the action of an enzyme, pectase, on the pectin present. Protein is present in very small amounts, but little being known of its character. Soluble tannin is present in the green fruits in small amounts, usually from about one half to one percent, but this becomes insoluble and forms hard tannin grains as the fruits ripen. The tannin in the juice of the green date, unlike that in persimmon juice, is precipitated by nitrous ethers. Both are precipitated by formaldehyde. Inulin has been reported present in traces.

The seed of the date is composed very largely of hemicellulose, which is readily converted into dextrose by heating with acids. There is present in the embryo an enzyme, cytase, which effects this same transformation when the seed germinates. For this reason it has been a favorite material for the study of cytase autolysis.

Varieties differ in chemical composition as well as in physical form. Variations in color, for example, are chemical differences. Deglet Noor and M'Kentchi Degla are also distinguished from other varieties by containing some substance which causes their juice to turn pink on exposure to the air. This color is more pronounced if the juice is boiled, but does not develop even in boiled juices if oxygen is excluded. While these two varieties, among many examined, were the only ones to show this peculiarity, and while they further resemble each other in not yielding extracts that invert cane sugar, they possess many very notable dissimilarities. Deglet Noor develops a bright red coloring matter in the skin and eventually softens, while M'Kentichi Degla, which has a yellow skin, eventually dries up and loses astringency but never softens. It is known as a dry date. It seems entirely possible that other varietal differences, such as early and late maturing qualities, will also be found ultimately to depend on chemical composition.

Analyses of dates to determine the usual nutritive groups offer so little of value from the biochemical standpoint that none have been made in this study. Determinations of the proportion of the three sugars present at any given time have afforded much valuable information with regard to the chemical processes going on, but cannot serve as a basis for judging the relative value of varieties. Thus the amount of cane sugar found depends upon the length of time the sample has been picked, its degree of ripeness, and above all else upon the speed with which it has been handled in the preparation of the sample for analysis. Samples must be heated nearly to boiling as rapidly as possible to prevent inversion of cane sugar. The rate of this inversion is well illustrated by the following experiments: Unripe seedling dates were ground through a meat chopper and the juice running off was quickly filtered. The pulp was transferred to a powerful press as rapidly as possible and portions of the juice obtained at various pressures were analyzed. After complete inversion with hydrochloric acid the various portions polarized alike, showing that all had originally the same composition.

TABLE I.—POLARIZATION AND COMPOSITION OF DATE JUICES OBTAINED AT DIFFERENT PRESSURES

<table>
<tr><th rowspan="2">Pressures in atmospheres</th><th colspan="4">SAMPLE 1</th><th colspan="4">SAMPLE 2</th></tr>
<tr><th>Direct polarization</th><th>Inverted</th><th>Cane sugar</th><th>Nitrogen in 25 cc juice</th><th>Direct polarization</th><th>Inverted</th><th>Cane sugar</th><th>Nitrogen in 25 cc juice</th></tr>
<tr><td></td><td></td><td></td><td>percent</td><td>grams</td><td></td><td></td><td>percent</td><td>grams</td></tr>
<tr><td>0 ...</td><td>+8.7</td><td>−4.8</td><td>10.4</td><td>.0234</td><td>+15.0</td><td>−7.3</td><td>17.2</td><td>.0262</td></tr>
<tr><td>0 to 50...</td><td>−2.5</td><td>−4.8</td><td>1.8</td><td>.0266</td><td>−2.8</td><td>−7.5</td><td>3.6</td><td>.0393</td></tr>
<tr><td>50 to 100...</td><td>−3.3</td><td>−4.9</td><td>1.2</td><td>.0334</td><td rowspan="2">−5.0</td><td rowspan="2">−7.4</td><td rowspan="2">1.9</td><td rowspan="2">.0397</td></tr>
<tr><td>100 to 350 ...</td><td>−3.4</td><td>−4.9</td><td>1.1</td><td>.0262</td></tr>
</table>

The almost total inversion of cane sugar in the juice is due to contact with the macerated pulp during the short time required for pressing. Mieran[1] has found similar difficulty in the analysis of the banana.

The following table has been selected from a number of analyses of date varieties made in the early part of this investigation. Some of them were made on fresh material, others on material several weeks after ripening. The average weight of the date gives a fair idea of size. The percentage of seed is of special interest from the standpoint of the consumer. The dry matter in commercial dates depends on the length of time they have been cured and not on the variety. The amount of dry matter present at the time of ripening, however, is a property of the variety and has considerable economic interest as will be shown later. Marc is that part of the fruit which does not dissolve in water. It is composed of the skin, insoluble tannin grains, cell walls, and the fibrous material about the seed. A low percentage of marc is one of the qualities that makes a pleasing luscious date. The acid of the date is so low that in most cases it has little or no effect in giving character to the flavor. Cane sugar in general has no permanent importance since it disappears rapidly after ripening, excepting in a few varieties with large percentages which remain uninverted. Glucose and fructose (levulose and dextrose) when present in molecular proportions constitute invert sugar. In most cases they are probably present in this proportion and originate in the fruit from the hydrolysis of cane sugar by contact with invertase. Variation from these proportions may be due to many causes. In some instances, however, it may be apparent only, since data from two different samples enter into the formula for their calculation,

[1] Chem. Ztg., 56, 1003, 1021, 1283.

TABLE II.—COMPOSITION OF TYPICAL VARIETIES OF DATES

Variety	Condition of sample	Ave. wt of dates, grams	Percent seeds	Percent dry matter	Percent marc	Percent acid as H_2SO_4	Percent canesugar	Percent fructose	Percent glucose
Deglet Noor	Ripened on tree, Tempe	7.26	9.52	74.03	7.85	.14	41.51	8.20	8.31
Deglet Noor	Ripened on tree, Tempe	7.32	7.83	69.98	6.24	.28	38.84	9.90	10.08
Deglet Noor	Ripened after frost	8.19	8.41	73.20	7.72	20	44.71	7.74	7.47
Deglet Noor	Ripened on tree, California	9.59	7.66	77.88	7.81	.18	40.55	10.40	10.53
M'Kentichi Degla	Nearly ripe	6.98	17.90	54.24	8.38	.17	31.38	4 53	4.21
M'Kentichi Degla	Partly shriveled	5 74	16.80	77.50	7 32	.16	48.72	..	.....
M'Kentichi Degla	Cured	5.69	16.32	83.26	11.61	.24	48.63	8.81	7.43
Halloua	Cured	4.31	17.40	83.69	11.97	.35	26.98	15 73	10.77
Halloua	Cured	7.42	15.00	78.16	8.68	.11	20 53	20 35	17.76
Amari	Cured	3.56	22 34	86.82	11.32	.16	.37	33.93	33.42
Amhat	Cured	4.15	16.34	80 01	10.98	.26	.84	32.69	31.85
Amreeyeh	Cured	7 46	.....	72 74	8.48	.10	4 05	27 41	25 31
A'Oochet	Half ripe	9.42	11.55	60 34	7.43	.12	14.50	16.22	14.75
A'Oochet	Ripe, fresh	8.16	14.73	66 07	7.96	.15	2.55	27.10	25.98
Birket el Haggi	Nearly ripe	17.88	10.78	49.95	5.50	.16	7.67	15.59	14.89
Birket el Haggi	Ripe, fresh	12.45	11.13	53.62	5 67	.18	11.61	14.16	13.66
Hamraia	Half ripe	8.94	9.34	68.85	8.82	.20	8.79	20.85	17.21
Hayania	Dark red	8.50	18.51	47.95	6.74	.11	6.26	12.45	9.75
Hayani	Ripe, fresh	5.37	16.07	72.54	8.91	.17	1.11	26.34	24.23
Oga de Bedreschen	Ripe, fresh	15.00	10.04	60.69	6.43	.16	2.67	24.69	24.69
Rhars	Nearly ripe	10.54	9.22	61.96	5.40	.13	12.07	18 46	16 25
Rhars	Ripe, fresh	8.99	10.95	65.55	5.56	14	1.96	27.25	27.08
Rhars	Cured	6.37	13.01	70.12	4.65	.32	.47	31.33	29.70
Rhars	Packed, half ripe	.....	....	77.20	7.74	.14	3.58	30.31	29.81
Safraia	Unripe	12.09	12.47	61.93	8.83	.28	9.47	18.55	13.39
Safraia	Nearly ripe	10.99	12.02	73.75	9.30	.33	9.14	20.34	20.10
Safraia	Cured	5.53	17.32	75.71	10.09	46	3.90	25.08	19.61
Tennessim	Cured	5.36	13.21	69.25	8.83	22	72	29.31	27.17
Timdjouert	Cured	4.63	18.08	85.84	9.39	.85	1.12	34.32	32.84
Tentebusht	Cured	9.99	9.60	71.00	6.99	.14	4.05	28.10	25.57
Row 15, No. 7	Ripe, fresh	.....	.....	63.69	7.90	.10	1.06	27.11	25.81
Tadala	Cured	9.31	13.33	64.95	4.09	.19	.47	27.81	28 50

and the inversion taking place in these samples after weighing out and before the invertase is rendered inactive, may not be uniform in both cases. Excess of glucose may be due to hydrolysis of small quantities of sugar other than cane sugar, as maltose. Excess of levulose may result from the hydrolysis of inulin or from the preferential metabolism of dextrose. However, it is clear that at least the most part of the sugar of the date has been in the form of cane sugar at some time, because levulose and dextrose are present in approximately molecular proportions and certain varieties retain the greater part of their sugar permanently as cane sugar.

INVERT AND CANE SUGAR DATES

Dates were once believed to contain invert sugar only and Selny further strengthened this belief by the analysis of a number of dates from Mesopotamia in which the sugar was almost wholly invert. At about the same time Lindet examined dates originating in North Africa and found thirty-eight percent of cane sugar with only twenty-three percent of invert sugar. He cautioned against generalizing from few analyses when they concern plants and fruits,since climate, season, degree of maturity, soil and other external factors influence composition. Lindet erred in this explanation of the varying relations between cane and invert sugars in dates from different sources, because dates from North Africa and dates similar to those from Mesopotamia, growing side by side in the Tempe orchard, still show the same differences observed by Lindet and Selny.

Slade first pointed out the existence of two distinct chemical types of dates—the cane and invert sugar types—and showed that most dates belong to the invert type. The physiological reason for this was found by the writer to depend on the absence of any notable quantities of extracellular invertase in mature fruits of the cane sugar type. The relative inverting power of glycerin extracts of several varieties was determined as follows: Equal volumes of glycerin extract of each of the varieties tested were added to like volumes of the same cane sugar solution and the action traced by means of the polariscope, with results shown in the following table:

TABLE III.—INVERTING POWER OF DATE EXTRACTS

Date	Hour	Deglet Noor	Rhars	Birket el Hagg'	Row 12, No. 7
		Polarization	Polarization	Polarization	Polarization
Nov. 6	2 P. M.	+5.14	+4.51	+4.47	+4.49
Nov. 6	5 P. M.	+5.05	+4.32	+4.33	+4.26
Nov. 7	9 A. M.	+5.17	+3.36	+2.92	+3 05
Nov. 7	4 P. M.	+5.19	+3.01	+2.61	+2.72
Nov. 8	9 A. M.	+5.18	+0.81	+1 13	+1.04
Nov. 9	9 A. M.	+5.16	−1.69	−0.65	−1.41
Nov. 10	9 A. M.	+5.15	−1.77	−1 99	−1.58
Nov. 12	9 A. M.	+5.15	−1.92	−1.79	−1.76

The failure of Deglet Noor extract to invert cane sugar was not due to any antiferment since invert-sugar date extracts inverted Deglet Noor extract as readily as artificial mixtures having the same composition. Neither was the inverting power of invert-sugar date extract diminished by the addition of Deglet Noor extract.

The invertase of the invert sugar varieties appears to be distributed very evenly throughout the fruit. Determinations of the relative inverting power of the basal, middle and apical portions, as well as of the outer and inner portions,and the tannin zone,of Hamraia dates, showed no appreciable difference. The Safraia date, however, retains a small amount of residual cane sugar although samples over one year old showed very strong inverting action. In one year the cane sugar had decreased from nearly 4 percent to 2.96 percent. The slowness of this inversion is probably due to the dryness of the date. Deglet Noors one year old contained 42 percent cane sugar and M'Kentichi Deglas 59 percent.

CHEMICAL LIFE HISTORY

The development of a bunch of dates after pollination, takes place in three principal stages. During the first few weeks growth is confined almost entirely to the long main stem which reaches nearly its full size before marked development of the fruit begins. The fruit next increases in size until a maximum is reached, when it resembles in composition any other non-starchy fruit and contains about 20 percent of dry matter. During this time the seed has also reached apparent maturity. The fruit now enters a third stage of development marked by the accumulation of sugar without further noticeable increase in size. When fifty or more percent of dry matter is present, depending on the variety, ripening begins. Table IV shows the changes taking place in the composition of typical representatives of both cane sugar and invert-sugar varieties during growth, ripening and storage.

The analyses in Table IV are given on the fresh basis only, since reduction to the dry basis can give but a partial idea of what is actually taking place. Variation in water content is as important a part of these changes as variation in cane or invert sugar. A date having twenty percent of dry matter may change in a short time to one of sixty percent in three ways: By the addition of dry matter without loss of water and consequently with gain in weight; by loss of water and decrease in weight; or by increase in dry matter and loss of water without change in weight. With the date there is a more or less

TABLE IV.— DEVELOPMENT OF TYPICAL CANE AND INVERT SUGAR DATES

Cane Sugar Date; Deglet Noor, Tempe, Arizona

Date	Condition of sample	Condition of bunch	Av. wt. grams	Av. wt. seeds	Percent seeds	Percent dry matter	Percent cane sugar	Percent fructose	Percent glucose
Sept. 18, 1906	Pea size	Belated	1.15	0.145	1.25	17.66	1.99	2.62	3.34
Sept. 18, 1906	Green, about half grown	Belated	5.02	0.572	11.39	17.41	0.62	3.82	3.27
Sept. 18, 1906	Slightly yellow	Belated	6.96	0.905	13.01	20.15	5.14	2.90	3.20
Oct. 5, 1906	Green, half grown	Belated	6.66	0.705	10.58	17.22	1.48	2.84	4.17
Oct. 5, 1906	Green, yellow tinge	Belated	8.22	0.968	11.77	18.22	3.78	2.06	3.76
Oct. 5, 1906	Red	Some slightly ripe	9.98	1.079	10.82	35.34	15.62	3.92	4.39
Sept. 7, 1906	Slightly turned green to red	Many green dates	6.57	0.992	15.10	23.59	5.05	3.09	3.97
Sept. 7, 1906	Change more marked	Same bunch	6.40	0.794	12.41	30.24	13.86	2.89	3.46
Oct. 17, 1906	Bright red	None ripe	7.19	0.911	12.66	29.71	13.10	1.83	2.96
Oct. 2, 1905	Reddish yellow	Some soft on end	8.84	0.636	7.20	25.56	12.57	2.93	2.94
Oct. 31, 1905	Red, stored 5 days	A few had ripened	8.91	0.705	7.92	47.20	31.61	3.36	3.49
Oct. 26, 1905	Red, considerable yellow	Same bunch	8.45	0.638	7.55	36.89	21.62	2.55	2.79
Oct. 26, 1905	Slightly spotted	Same bunch	8.92	0.671	7.33	53.45	34.20	5.26	5.40
Oct. 26, 1905	About one-third soft	Same bunch	8.31	0.604	7.27	56.29	31.74	7.42	8.09
Nov. 27, 1905	Slightly ripened	Some soft at stem	8.53	0.679	7.96	59.69	36.79	5.65	5.57
Nov. 27, 1905	Apparently fully ripe	Same bunch	9.06	0.632	6.98	62.65	33.07	9.60	9.86
Nov. 31, 1905	Same apparently inferior	Same bunch	6.97	0.637	9.14	62.02	27.18	12.54	12.11
Nov. 13, 1905	Ripe on tree		7.32	0.572	7.83	69.98	38.84	9.90	10.08
Nov. 21, 1906	Ripe on tree		7.26	0.691	9.52	74.03	41.51	8.20	8.31
Dec. 4, 1906	Ripe on tree after frost		8.19	0.643	8.41	73.20	44.71	7.74	7.47

Invert Sugar Date; Seedling, University Campus

Date	Condition of sample	Condition of bunch	Av. wt. grams	Av. wt. seeds	Percent seeds	Percent dry matter	Percent cane sugar	Percent fructose	Percent glucose
Sept. 7, 1906	Very green	Like sample	10.26	1.215	11.83	15.87	0.00	2.11	4.47
Oct. 3, 1906	Yellow	Like sample	10.67	1.120	10.47	31.72	7.95	8.01	9.90
Oct. 10, 1906	Yellow, after cold week	Not maturing well	11.26	1.084	9.63	31.48	4.59	9.01	6.60
Oct. 24, 1906	Yellow, ripe in spots	Ripening slowly	12.37	0.903	7.31	51.33	15.02	12.95	11.50
Oct. 4, 1905	Partly ripe, softened slightly	A few ripe	12.18	. .	.	45.07	11.56	13.89	13.46
Oct. 16, 1905	Partly brown	Ripening rapidly	11.58	0.767	7.58	51.37	10.01	16.81	15.90
Oct. 16, 1905	Ripe, not overripe	Ripening rapidly	8.77	0.907	10.19	52.36	6.18	21.92	20.08
Oct. 24, 1906	Ripe, still light brown	Ripening slowly	12.07	0.907	7.51	56.14	6.76	16.67	15.70
Nov. 6, 1906	Ripe, stored 14 days		10.07	0.927	9.21	55.29	0.28	23.87	24.91

parallel increase in percentage of dry matter and in weight (or size) till approximately twenty percent of dry matter is present. Growth, so far as size is concerned, has then apparently reached its limit, but accumulation of dry matter in the form of sugar now takes place more rapidly, and in a relatively short time the dry matter has risen from twenty or twenty-five percent to fifty or sixty percent. During this time the dates show no decided increase in weight. The only rational interpretation then is that water has been replaced, to a considerable extent at least, by sugar. Curing again increases the dry matter to seventy or even eighty-five percent but this change is due exclusively to loss of water.

Since this rapid accumulation of sugar takes place during the last stage of development before ripening, it is evident that the fruit should be left on the tree as late as is possible without danger of loss by souring. Fruit picked when too immature can not be ripened into a marketable product by any artificial means, because of its lack of substance. Such fruits shrivel away till only a thin layer of insipid flesh is left about a full-sized and apparently mature seed. A certain degree of maturity is thus essential to any method of artificial ripening.

The high percentage of cane sugar in the seedling invert sugar date, as shown in the above table, seems to indicate that all dates belong to the cane sugar type at some period of their life history. This is confirmed by the content of cane sugar in the following varieties of unripe or recently ripe dates which have been found to contain little or no cane sugar soon after ripening.

TABLE V.—CANE SUGAR IN DATES OF THE INVERT SUGAR TYPE

Variety	Condition	Percent
A'ouchet	Partly ripe	14.50
Tentebusht	Partly ripe	9.71
Not named	Nearly ripe	6.99
Purdy seedling	Ripe, fresh	7.03
Birket el Haggi	Nearly ripe	7.67
Rhars	Unripe	12.07
Safraia	Unripe	9.47
Seedling	Ripe, fresh	6.18
Hamraia	Partly ripe	8.78

Similarly, many other fruits, such as cherries and peas, have been shown to contain a small amount of cane sugar just before ripening, but never in amount comparable with that of the date. Much of the sweetness and superior quality of a fresh date is due to this cane sugar which vanishes so rapidly in the invert sugar types.

SPECIFIC GRAVITY AS AN INDEX OF MATURITY

It is often desirable to approximate the degree of maturity of a given variety without actually determining the percent of dry matter in it. The size and color of the fruit offer little of value to guide one in this respect. When very young all varieties are green, but after reaching maturity in size they become yellow or red and remain so until ripe. A fair approximation, however, can be made quickly at any time by taking the specific gravity of the whole fruit. Coarse-seeded varieties may be judged more accurately by the specific gravity of the half fruit after the seed has been removed. The air space about the seed varies somewhat from one individual to another but this error is eliminated in using the half fruit. Occasionally an individual will be found whose dry matter is much higher than its specific gravity seems to indicate and the anomaly holds both with and without seed. This is probably due to differences in compactness of the tissues, aside from differences in chemical composition. For example, a Deglet Noor fruit with seed sp. gr. 1.054, dry matter 42.5 percent, gave without seed sp. gr. 1.099, dry matter 37.8 percent, which is much higher than the general average of dry matter for those gravities. With Deglet Noor, at least, the correspondence between specific gravity and percentage of dry matter is about as uniform with as without the seed and much more easily ascertained.

TABLE VI.—RELATION BETWEEN SPECIFIC GRAVITY AND PERCENT OF DRY MATTER IN DEGLET NOOR DATES

WITH SEEDS				WITHOUT SEEDS			
Specific gravity	Percent dry matter	Specific gravity	Percent dry matter	Specific gravity	Percent dry matter	Specific gravity	Percent dry matter
1.001	22.7	1.070	33.8	1.045	23.0	1.214	56.5
1.012	24.5	1.072	34.2	1.053	22.7	1.275	63.8
1.014	22.8	1.080	39.3	1.055	21.6		
1.020	25.4	1.080	37.6	1.057	25.5		
1.023	28.2	1.082	41.0	1.060	24.4		
1.031	27.4	1.084	42.6	1.069	30.7		
1.033	27.4	1.085	42.9	1.080	24.6		
1.040	29.1	1.087	39.8	1.081	28.5		
1.045	28.2	1.089	39.7	1.082	26.6		
1.046	29.6	1.096	37.6	1.082	30.0		
1.049	27.4	1.104	46.3	1.097	33.4		
1.052	35.2	1.105	42.7	1.098	32.0		
1.053	28.2	1.105	45.3	1.108	32.6		
1.055	31.8	1.112	45.9	1.115	37.2		
1.057	33.3	1.113	50.8	1.120	39.1		
1.058	36.5	1.122	52.7	1.122	33.9		
1.059	32.8	1.123	47.0	1.123	40.1		
1.064	36.3	1.135	54.1	1.125	40.2		
1.065	34.6	1.137	58.1	1.144	45.0		
1.068	41.7	1.155	65.0	1.155	43.8		
1.069	35.2			1.190	51.5		

The specific gravity of a single date is determined by diluting a sugar solution until the sample sinks very slowly in it. The specific gravity of this solution is practically the same as that of the sample. The following table shows the specific gravity of the whole fruit with and without seed, at different degrees of maturity. The fruits were nearly uniform in size and color excepting that a few of the heavier ones had started to ripen.

TANNIN

DISTRIBUTION AND CHEMICAL PROPERTIES

The tannin of the date is found principally in a very thin hypodermal layer, and in a zone of giant cells or idioplasts which lies somewhat deeper. Isolated cells may be found scattered through the flesh, most abundantly in that part opposite the groove in the seed, and minute droplets of tannin occur in certain other cells.[1] The seed coat proper and the tissues in the groove of the seed also contain tannin. The outer tannin zone can be recognized readily with the unaided eye and can be pared away, leaving the unripe fruit entirely non-astringent and edible. The skin and outer layer down to the tannin zone are relatively non-astringent. This fact was observed by the hordes of migratory rats that infested the orchard in 1906. They nibbled away the outer coverings down to the principal tannin zone, but not through it. The fruits thus injured matured their seeds normally, the tannin having served as an effective protection so far as the seeds were concerned.

The distribution of tannin in the date, as well as in other fruits and plant tissues, is very easily and accurately determined by a method of fixing and staining tannin in those cells where it occurs, without disturbing the tissues. This method, which consists in exposing the uninjured fruit to the action of any volatile nitrite, preferably ethyl nitrite, originated in the writer's laboratory. By its use a large Japanese persimmon weighing one-half pound can be stained in a few hours. The exact nature of the reaction is not known, but apparently varies with the specific tanning material under observation. Ethyl nitrite or free nitrous acid forms deep yellow to blood red colors with tannic and gallic acids and the higher phenols. With some higher phenols a precipitate is also formed. Dilute juice of unripe date treated with ethyl nitrite first turns red, then after some moments suddenly forms a dense brown precipitate. The precipitation is prevented by alcohol or glycerin, in which case only a deep red solution is obtained. The juice of the unripe persimmon gives a red coloration but no precipitate. The property of forming this

1 Lloyd, Twenty-first Annual Report, Missouri Botanical Garden, 120.

precipitate and color is removed from date juice by any method which removes tannin, and the precipitates thus obtained are all readily stained brown by treatment with ethyl nitrite.

After insufficient treatment, the tannin cells in certain cases are not all stained alike. Some have taken a dark brown color, others rose and lilac tints, and some remain uncolored. This is notably true with the persimmon. The cells near the skin and those about the core stain first and most deeply. This is more likely due to differences in permeability of the cell walls than to chemical differences in the cell contents, since, after prolonged treatment, all become uniformly dark brown.

NATURAL DEPOSITION OF TANNIN

At the time of ripening, the soluble, astringent tannin passes into an insoluble form, producing hard tannin grains. When first formed these grains have the consistency of stiff jelly and are easily shattered into fragments by pressure on the cover glass while being examined microscopically[1]. In this respect the grains formed by the action of nitrous esters resemble those formed naturally but are much darker colored. Taking advantage of the relatively high specific gravity of these grains, one can obtain them in quantity sufficiently pure for chemical investigation by washing ripe date pulp with water.

There are many possible ways in which the deposition of tannin may take place chemically. It forms insoluble compounds with the proteins and is precipitated by aldehydes, phenols and oxybenzoic acids. Tannic acid is also changed to gallic acid by an enzyme, tannase, which occurs in various fungi, and is widely distributed in tannin-bearing plants. The deposition of insoluble tannin in corky tissues has been ascribed to the action of aldehyde,[2] and formaldehyde is said to occur naturally in some parts of plants. The juice of unripe dates or persimmons can be coagulated by the addition of formaldehyde, but evidence that this occurs naturally in fruits is wanting.

ENZYMIC NATURE OF TANNIN DEPOSITION

The deposition of tannin in the date, however, is very intimately associated with enzymic action as shown by the following observations. Tannin is rapidly deposited at the time of ripening in the very same cells where it has existed in the soluble form from the earliest stages of the fruit's development. The chief biochemical phenomenon on which certain other chemical changes associated with ripening will presently be shown to depend, is the change of intracellular into

1 Bigelow, Gore and Howard, J. Am. Chem. Soc., 28: 688.
2 Drabble and Nierenstein, Biochem. J., 2: 96.

extracellular enzymes. Dates which are too immature to show the general characteristics of ripening without artificial stimulation gradually lose their astringency, but after chemical or physical stimulation, which releases the intracellular enzymes and brings on premature ripening, the loss of astringency is very rapid. If, however, the treatment is carried far enough to destroy enzymes the astringency remains permanent, even though certain other phenomena, such as change of color, indicate a tendency to ripen. This is notably true when sprays of immature dates are dipped into hot water. At 70° C., for five minutes, color change and loss of astringency was general, but when held for ten minutes at that temperature the more immature individuals remained astringent. Above 70° C. permanent astringency became general. In glass the tannin of unripe date juice was not removed by long digestion with ripening date pulp. The reaction, however, may easily be indirect, the tannin combining with some product of enzymic action, the substrat for which is rapidly exhausted.

ARTIFICIAL DEPOSITION OF TANNIN

The deposition of tannin may be brought about artificially at any time by prolonged heating at about 50° C., but this treatment ruins the natural flavor. It may also be deposited chemically by substances which will penetrate the cell and combine with it. Formaldehyde will accomplish this but leaves a very disagreeable odor and flavor. Ethyl nitrite, however, in small quantities will penetrate rapidly and remove astringency, leaving the date sweet but not soft, although if fairly mature they usually ripen. In larger amounts it blackens the fruit and imparts some flavor.

NATURAL RIPENING

ITS ENZYMIC NATURE

Those processes in plant tissues which result in a change in composition of plant materials, whether the resulting products be simpler or more complex than the original, are now generally recognized to be the result of catalytic action. In those cases where complex substances are broken down naturally into simpler ones, we are frequently able to isolate catalytic agents or enzymes which bring about the same results independently. In other words, dead tissues often carry the catalyzers which effect certain transformations as readily as do living tissues. Every year witnesses the demonstration of the enzymic nature of processes once supposed to be vitalistic.

Catalytic substances act simply in increasing the speed of certain chemical reactions which would otherwise occur but slowly, or to a very limited extent. With very few exceptions, however, we remain powerless to synthesize complex substances from simpler ones by means of dead tissues or substances separated from them. Thus in living tissues we see starch disappear and cane sugar take its place. This is notably true in the sprouting potato or in the ripening apple or banana, in which the carbohydrate is stored as starch in the tissue itself. In other cases the starch stage of the carbohydrate is not formed in the fruit proper but in the stem. Such is the case with the grape[1] and the cherry, and the latter fruit has been shown to contain at times over one percent of cane sugar, which rapidly vanishes.[2] The physiological function and origin of this transient cane sugar is probably the same in all cases. When, however, we attempt to isolate an enzyme from tissues in which starch is disappearing, we get, not a substance which converts starch to cane sugar, but ordinary diastase which hydrolyses it through a series of dextrins into maltose. Sometimes a second enzyme, maltase, accompanies diastase and reduces the resulting maltose to glucose. Thus enzymes isolated from tissues in which apparently synthetic processes are occuring, break down complex bodies into simpler ones instead of building them up as we might expect. If, however, a living embryo of barley be removed from its natural nourishment and floated upon maltose, it converts the same, within its tissues, into cane sugar.[3]

In some few cases reversible actions with enzymes have been suspected or actually observed.[4] When, for example, maltase acts upon glucose some isomaltose is formed.[5] If this isomaltose could be removed as rapidly as formed, all the glucose would eventually be converted into isomaltose. Under the wonderfully intricate organization of the cell, or if need be of a group of cells, one and the same catalyzer might well be tearing down at one place and building up at another. Such organization is known to exist only in living tissues and not until we learn to duplicate the conditions of living tissues can we expect in any marked degree to accomplish without their aid those vital processes which result in synthesis. Perhaps the chief difference between living tissue and dead tissue is organization—before all else organization of chemical reaction.[6]

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1 Famintzim, Ann Oenol. 2: 242. 1871. Hilger Landw. Vers Station, 17: 245.
2 Z. Anal Chem., 30: 401
3 Brown and Morris, J Chem. Soc., 57: 458. 1890
4 Bainbridge and Beddard, synthesis of glycogen by liver tissue, Biochem. J., 2: 89, Cremer, ditto by yeast juice, Ber 32: 2062; Kutcher, reversed proteolysis, Z. physiol. Chem., 32: 59, Pantanelli, revertase in fungi, Rend della Accademia, Rome 16: 419, 1907, also Ber botan Ges 26: 494, 1908; and others
5 Hill, J Chem Soc., 73: 634, 1898; 83: 578. 1903.
6 Cf. Jacoby, Ergebrisse Physiol. 1: 240. 1902.

INTRACELLULAR ENZYMES

Many tissues even after death are known to cause various chemical reactions but do not yield enzymes to the usual solvents of those substances until they have undergone very special treatment. Such enzymes are known as intracellular or endoenzymes.

The pulp of unripe dates of the invert-sugar type was found to invert cane sugar very rapidly, but would not yield soluble invertase to water or glycerin. This inversion must then be due either to vital action of the living protoplasm or to intracellular invertase. The possibility of its being due to any sort of protoplasmic action was easily excluded by comparing the relative rate of inversion of cane sugar by fresh, unripe date pulp, and ripe date pulp in which soluble invertase was known to exist, and the effect of protoplasmic poisons in retarding this rate. The curves representing the retarding effect of formaldehyde, picric acid, and chromic acid on the rate of inversion are practically identical for either ripe or unripe pulp. If the phenomena had been due to living protoplasm we would have found a much greater retardation with the unripe pulp. The non vital nature of this inversion is confirmed by the fact that dried, unripe date pulp heated to 140° C. for thirty minutes still possessed considerable inverting power.

EFFECT OF TANNIN ON SOLUBILITY AND ACTIVITY OF INVERTASE

The cause of the failure of ordinary enzyme solvents to extract the slightest trace of invertase from unripe date pulp, while they extract it readily from the ripe fruit, is not easily determined. The unripe fruit contains much soluble tannin, which passes into an insoluble form at the same time that the invertase becomes readily soluble, so that its failure to yield soluble invertase may be supposed to have been due to tannin precipitating the enzyme. It has been shown that leaves rich in starch and also in tannin do not yield diastase readily[1] and that the diastase of malt is not soluble in hop extracts.[2] The failure of starch to disappear from bruised spots in apples has also been attributed to the effect of tannin on the diastase.[3] Experiments in this laboratory have shown that the addition of relatively large amounts of tannin does not interfere in any way with the action of invertase from ripe dates, although the enzyme is all carried down in the resulting precipitate. In the presence of glycerin, however, a large part of the invertase remains in solution, but unripe dates crushed in glycerin never give active extracts. The fortunate distribution of

1 Brown and Morris, J Chem Soc 63: 604 (640)
2 Brown and Morris, Trans Inst of Brewing, 6: 94.
3 Warcolier, Compt. rend 141: 405

tannin in the date allows positive verification of the foregoing conclusions that soluble tannin does not prevent the extraction of invertase. After the tannin bearing tissues have been removed from the unripe fruit no soluble invertase can be extracted from the remaining tannin-free tissues. Both tannin bearing and tannin-free tissues from the same variety exhibit nearly quantitatively equal inverting powers.

THEORY OF INTRACELLULAR ENZYMES

The generally accepted theory for intracellular enzymes is that they exist in colloidal solution in the cell sap and are retained by the impermeable nature of the plasmic cell wall. This theory seems to be sufficient in the case of many lower organisms, but certain phenomena in green dates can not be explained on this ground. Lower forms, such as yeast, retain some of their enzymes, while others in certain cases are secreted into the surrounding media.[1] Different strains of yeast have also been found of which some secrete invertase and others do not.[2] If left to undergo autodigestion the invertase of these organisms passes into solution. The alcohol forming enzyme, zymase, however, is destroyed during autolysis, but may be obtained by killing the cells with acetone, toluene and other reagents, or by grinding with sand so as to disrupt the cells, then pressing their contents out bodily by enormous pressure. It is well known that the plasmic cell wall loses its semipermeable nature after death, and that most substances in solution then pass through it almost as readily as through the outer cellulose wall. This would suffice to account for the release of certain intracellular enzymes by acetone, toluene, etc., but some forms, as *Monilia candida*,[3] are said not to yield their invertase after such treatment. Similarly, unripe date pulp, which has been washed to remove sugar, and dried, does not yield its invertase after treatment for several weeks with acetone, ether, chloroform or toluene, but the residue seems to retain its inverting power undiminished. Neither does the application of heat to dried unripe date pulp render the invertase soluble.

Since the tissue of the date is complex and not made up of single cells which glide freely upon one another as do the yeasts, ordinary grinding should break open an appreciable number of cells and allow the escape of their soluble contents. Extracts prepared in this way, or by soaking the pulp in glycerin, are absolutely inactive, but the residue retains its full inverting power even after washing for several

1 Effront, p 69 70
2 O'Sullivan and Thompson, J Chem Soc., 57: 873, 61: 693. Fernbach Thesis, Paris, 1890, Pottevin and Napias Compt rend soc biol 50: 237
3 Fischer and Lindner, Ber d d chem ges, 28: 3034, Buchner and Meisenheimer, Z Physiol Chem 40: 167, Fischer, Zeit Physiol Chem, 26: 77

days with glycerin and water. As long as the green fruit remains intact and holds its organization undisturbed, the inversion of the cane sugar in the fruit takes place very slowly. If, however, this mechanical organization is broken up, the cane sugar is inverted very rapidly as shown in Table I, but no soluble invertase passes into the juice. The first juice obtained under the Buchner press shows a slight inverting power but this is undoubtedly due to suspended matter, since this portion of the juice can not be filtered clear by paper, and deposits considerable insoluble matter after standing. The juice obtained under very high pressure is entirely invertase free. The experiment just referred to also shows that the amount of sugar in the juice flowing from the grinder and that in the fractions obtained under increasing pressure is constant, as shown by the uniform polarization after inversion. The soluble nitrogen, on the other hand, increases very greatly, showing that the soluble cell nitrogen passes into the juice while the invertase is retained.

The only adequate explanation for these phenomena is that the date invertase during the unripe stages forms a virtually insoluble compound with some constituent of the cell, probably some part of the protoplasm, and that on ripening this compound is broken up, yielding soluble extracellular invertase. If sugar, the substrat for invertase, were also insoluble, the invertase of unripe dates would be recognized to exist as a zymogen, but since sugar is soluble and can come into molecular contact with the insoluble invertase, the catalytic effect is produced just as when soluble diastase comes in contact with insoluble starch grains. This view is supported by the fact that the tannin-invertase precipitate shows inverting power nearly equal to an equivalent amount of soluble invertase. Furthermore, invertase is precipitated from ripe date extracts by lead subacetate, and the resulting precipitate continues to exhibit very marked inverting power.

CHANGES FROM INTRACELLULAR TO EXTRACELLULAR ENZYMES DURING RIPENING

It is probable that other enzymes of the date undergo the same changes as invertase at the time of ripening. If this be the case it is easy to see that marked chemical changes would follow the increased facility for contact between enzyme and substrat especially where the latter is insoluble. Thus the change of intracellular to extracellular enzymes is the fundamental change on which the various ripening phenomena depend, and consequently must form the basis of any rational method of artificial ripening. Invertase itself is not essential to ripening, because some dates which contain relatively little invertase even in the intracellular form, ripen normally. It is, however, a typical enzyme that can be traced readily and with accuracy, and serves as a convenient index to the behavior of other similar bodies, among which may exist substances allied to the activators, kinases and hormones now known to control many animal physiological processes.

SOURING AT RIPENING TIME

One of the greatest losses experienced in all date growing countries is that due to souring. In very wet, unfavorable seasons most varieties prove total losses, but when only a moderate degree of humidity, with little or no precipitation, prevails at ripening time, some varieties cure nicely while others sour and become the host of various insects. The underlying cause of this difference in varieties as regards souring is not at first obvious. It is noticeable that those which sour most easily become covered with flies, are sticky, and show a marked tendency of the skins to separate from the pulp. The most probable direct cause of varietal differences in curing quality is that while some are naturally "sugar cured" others have weaker juices which ferment readily. The concentration of the juices necessary to account for these differences might depend on the varying hydroscopic character of different dates. Experiments in which both souring and curing varieties were exposed first over sulphuric acid, then in a moist chamber, showed no appreciable difference in the rate at which they gained or lost moisture. A second possible cause of the difference in the concentration of the juice of different varieties, which proved to be the true one, is that some ripen only after a greater accumulation of sugar than others.

In order to gain closer insight into the relation between percentage of dry matter at ripening time and curing qualities, six varieties which had been ripening during unfavorable weather were chosen for chemical investigation. Three of these belonged to the souring and three to the curing type. Several fruits which had just ripened were selected in each case, the seeds removed and the pulp crushed and mixed. The percentage of dry matter was determined by drying in a partial vacuum over sulphuric acid for forty-six hours at 70° C. with results shown as follows:

TABLE VII.—DRY MATTER IN SOURING AND CURING VARIETIES

SOURING IN DAMP WEATHER		CURING IN DAMP WEATHER	
Variety	Percent of dry matter	Variety	Percent of dry matter
Rhars	55.8	Tadala	70.7
Birket el Haggi	60.4	Maktum	78.3
Purdy seedling, light colored	61.1	Purdy seedling, dark colored	74.0

DESCRIPTION OF SAMPLES

Rhars: Sample sweet, although a few in the lot had soured. The bunch had been infested with flies and required two thicknesses of cheese cloth for protection. This was perhaps the most troublesome tree in the orchard.

Birket el Haggi: Entire sample was sweet and curing nicely during favorable weather (last of September and first of October, 1908) In less favorable weather this date soured badly.

Purdy Seedling, light colored: The behavior of this date is little known. It resembles Rhars in its properties, was somewhat sticky, and would probably sour rapidly in unfavorable weather.

Tadala: The flesh of this date was firm and not sticky. It had given no trouble in previous years.

Maktum: This sample had laid in the packing house for a few days and had probably dried to some extent. It had behaved well in previous years and during the damp period which had just passed.

Purdy Seedling, dark colored: The behavior of this date is little known but the flesh was firm when taken from the tree. It was not sticky and showed no tendency to sour at that time.

After deducting seven or eight percent of the dry matter for materials insoluble in water (marc), we find the juice of the souring varieties to contain fifty or sixty percent of dissolved matter. This is largely sugar, with sufficient nitrogenous and mineral matter to make it a good medium for the growth of yeast and bacteria. While the concentration of the sugar is above the optimum, nevertheless many micro-organisms can tolerate such concentrations. Furthermore, any tendency toward further concentration of the juice by drying would be more than counterbalanced by the fermentation of sugar. The curing varieties evidently do not lose the protection of the living cells until the juice has reached a concentration too high for the growth of micro-organisms and is consequently self preserving. Improved cultural methods which promote earlier maturity, may assist in preventing these losses in some cases, but more is to be hoped for from methods of artificial ripening.

ARTIFICIAL RIPENING

DETERMINATION OF MATURITY

The first essential in any attempt at artificial ripening of dates is that the fruit shall have reached a certain necessary degree of maturity. This follows from the fact that the main accumulation of sugars takes place in a late period of development. If the amount of these sugars is insufficient the result is, at best, only a thin layer of tasteless flesh around a normally sized seed. It is, however, a difficult matter to trace the development of the fruit after it reaches its full size and turns color, without knowing approximately the amount of dry matter present. A rough estimation may be formed from the taste, since dates get sweeter as they approach maturity; but the sweetness is masked to a great extent by the astringent tannin. The application of the specific gravity test for maturity will probably be found the most convenient means of tracing the development of the crop, although considerable discrepancies between specific gravity and dry matter are occasionally noticeable.

In determining practically the maturity of a bunch of dates for ripening purposes, one needs but a single sugar solution. This solution is made of such strength that dates sufficiently mature to ripen artificially into good fruit, will sink while those too immature will float. For Deglet Noor dates, using the whole fruit, we may set the strength of this solution, tentatively, at sp. gr. 1.125. This is a 29 percent solution of cane sugar and corresponds to approximately 50 percent of dry matter in the date, but further experience will probably render some change in this figure necessary. The specific gravity test will show the percentage of fruits in a given sample of fifteen or twenty dates taken at random, which would probably ripen with a fair thickness of flesh at that time. Whether or not it would be profitable to artificially ripen an entire bunch at a given time must be determined by the advancement of the season. The longer the fruit can be left on the tree without danger of loss the greater will be the yield of good fruit.

In determining the relative maturity of several bunches a series of sugar solutions of known strength may be used. A score or more of fruits are taken from various parts of the bunch and placed in the weakest solution, in which the very immature individuals will float. Those that sink in this solution are transfersed to the next stronger solution and again separated. By dividing a sample into several portions in this way a fair comparison of the relative maturity of several bunches may be made.

NEED OF EVENLY MATURING VARIETIES

A considerable number of very immature fruits will be found on most bunches of nearly mature dates. The reason that some individuals receive sugar much faster then others is not evident unless it be that their power of transforming the migratory carbohydrate of the sap is much greater. In this way the rapidly maturing ones would maintain a lower osmotic pressure for the migratory form than the slowly maturing individuals. The following record of a sample of thirteen fruits removed at random Oct. 11 from a bunch of Deglet

Noors illustrates this irregularity in maturing. One fruit floated on water, four lay between sp. gr. 1.000 and 1.040, four between 1.067 and 1.080, and one each had sp. gr. 1.133, 1.137, 1.155 and 1.165, the latter two being ripe. Irregular development of this type is extremely undesirable since it means a long continued natural harvest or a considerable loss when artificial ripening is practiced. This fault is shared very generally by other varieties and offers one of the chief opportunities for commercial improvement of dates.

STIMULATION OF PREMATURE RIPENING BY NATURAL CAUSES

Early maturity of fruits is often brought about in nature by various means. Mechanical injury, insect stings and similar causes are all known to stimulate premature ripening. Following the rainy season of 1909 numerous small dark spots appeared on many Deglet Noor dates on the side turned toward the sun. They never seemed to penetrate deeper than the skin but the areas affected ripened prematurely. The ripened portion then dried and shriveled up, or if damp weather prevailed, soured before the remaining portions of the same fruit had fully ripened. The spots thus ripened were normal in flavor, although by drying too soon produced unsightly dates. The cause of the dark spots was not evident, but they undoubtedly stimulated premature ripening of otherwise normal character in their immediate vincinity.

Normally, Deglet Noors ripen first at the apical end, but frequently in unfavorable weather irregularly distributed spots occur which appear to have ripened and soured. These are probably due to invasion of some fungus, because the boundary between apparently ripe and unripe tissue is very sharply defined and the contents of the pit like spots is soft and foul tasting. Such dates are unfit for packing or artificial ripening but the trouble may possibly be avoided by appropriate spraying.

EFFECT OF NOTCHING STEMS

An unusual drought in Silesia[1] is recorded to have caused medium late pears to ripen eight to fourteen days before their usual time; and grapes which had blossomed later than usual not only made up the lost time but ripened earlier than those of the previous year. Winter fruits, however, were retarded. These observations cannot be applied to the date directly for, since the palms are usually grown where the roots have permanent access to water, it is not possible in most cases to cut off the water supply by withholding irrigation. Kearney[2] re-

1 Monatschrift f. Pomologie, 9: 272, 1863.
2 Bur. Plant Ind. U. S. D. A., Bull. 92, p. 52.

TABLE VIII.—EFFECT OF NOTCHING ON MATURITY AS SHOWN BY THE SPECIFIC GRAVITY METHOD

	Specific Gravity	Sept. 1	Sept. 15	Sept. 30	Oct. 11	Oct. 27
Notched Sept. 1	1.000–1.025	4	......	......	......	1
	1.025–1.050	3	4	......	......	......
	1.050–1.075	2	2	......	......	......
	1.075–1.100	1	2	......	......	2
	1.100–1.125	......	2	......	......	......
	1.125–1.150	......	......	......	......	3
	1.150–1.175	......	......	......	......	2
	1.175–1.200	......	......	......	......	......
Notched Sept. 15	1.000–1.025	......	1	......	......	......
	1.025–1.050	......	2	......	......	......
	1.050–1.075	......	3	......	......	1
	1.075–1.100	......	1	......	......	2
	1.100–1.125	......	1	......	......	2
	1.125–1.150	......	1	......	......	2
	1.150–1.175	......	......	......	......	......
	1.175–1.200	......	......	......	......	1
Notched Sept. 30 No. 1	1.000–1.025	......	......	......	......	......
	1.025–1.050	......	......	2	......	......
	1.050–1.075	......	......	4	......	......
	1.075–1.100	......	......	......	......	5
	1.100–1.125	......	......	3	......	2
	1.125–1.150	......	......	......	......	......
	1.150–1.175	......	......	......	......	1
	1.175–1.200	......	......	......	......	......
Notched Sept. 30 No. 2	1.000–1.025	......	......	1	......	......
	1.025–1.050	......	......	2	......	......
	1.050–1.075	......	......	1	......	......
	1.075–1.100	......	......	3	......	......
	1.100–1.125	......	......	3	......	3
	1.125–1.150	......	......	......	......	1
	1.150–1.175	......	......	......	......	2
	1.175–1.200	......	......	......	......	2
Notched Oct. 11	1.000–1.025	......	......	......	......	......
	1.025–1.050	......	......	......	......	......
	1.050–1.075	......	......	......	3	......
	1.075–1.100	......	......	......	1	2
	1.100–1.125	......	......	......	1	......
	1.125–1.150	......	......	......	1	2
	1.150–1.175	......	......	......	2	1
	1.175–1.200	......	......	......	......	3
Different bunches not notched	1.000–1.025	......	......	1	......	......
	1.025–1.050	7	3	2	......	......
	1.050–1.075	......	1	3	......	......
	1.075–1.100	1	4	3	......	3
	1.100–1.125	1	2	1	......	2
	1.125–1.150	......	......	......	......	3
	1.150–1.175	......	......	......	......	1
	1.175–1.200	......	......	......	......	1

ports that a date dealer in Tozeur, Tunis, suggested accomplishing this by notching the stems. The same method occurred independently to Mr. Simmons, in charge of the Tempe orchard, as a result of observations on the effect of the heavy hail storm of July, 1908. Some of the bunches whose stems had been severely battered seemed to be in advance of more protected ones. Consequently, several bunches were notched and appeared to mature somewhat better than unnotched bunches, but the result was not decisive. It was therefore decided to repeat the experiment in 1909 and record the effect on development by the specific gravity method as well as by field observations. In addition to notching, driving nails through the stems was also tried. This method is said to be effective in bringing cocoanut palms into fruiting. Beginning Sept. 1, one or two bunches were notched or nailed every two weeks through the season, and specific gravity determinations made on a sample of eight or ten fruits at the time of notching and at later intervals. By this method, the results of which are given in Table VIII, it will be seen that on Oct. 27 the bunches notched Sept. 1 and Sept. 15 were not as far advanced as those notched later or as unnotched bunches. One of the two notched Sept. 30 had reached about the same degree of maturity as the unnotched bunch, while the other remained somewhat behind. The bunch notched Oct. 11 made a slightly better showing than three unnotched bunches, but the difference in this case was probably not greater than the natural variation between bunches on the same tree. The net result shows at least no decided advantage due to notching and the same may be said of nailing. The experiment again illustrates very forcibly the extreme variation in rate of development of individuals on the same bunch.

At the time when Deglet Noors were ripening best, the writer visited the orchard and, with Mr. Simmons, compared the average condition of the notched bunches with unnotched ones both on the same and on other trees. In no case could we observe any advantage due to the notching. One tree, however, on which no bunches had been notched, was decidedly in advance of the others. This tree, Mr. Simmons recalled, had been pollinated with pollen from the same Purdy Seedling as had those that appeared to mature earlier the year before. No Purdy-seedling-pollinated bunches had been notched this year. While these observations by no means prove conclusively that the process of development and maturation of the pericarp is influenced by the pollen, they justify further experiments in this highly interesting field.

SPONTANEOUS AFTER-RIPENING

When bunches of dates are cut before ripening is complete, many still unripe fruits will ripen spontaneously. In some oases of northern

Africa the half-ripe Deglet Noors are picked several times and left to ripen spontaneously before the bunch is finally cut. Frequently as much as fifty percent of the dates reaching the market show no signs of actual ripening. A considerable part of these ripen to good fruit without any treatment whatsoever, while the others lose their astringency and are sold as dry dates, bringing about the same price as M'Kentichi Degla. Near Guaymas, in Sonora, Mexico, the bunches, when mature, are cut and exposed to the sun during the heat of the day. Toward evening they are carefully wrapped in blankets and carried indoors until the warm part of the next day. This process is continued until the dates are ripened, care being taken not to expose the fruit to chill temperatures.

Some varieties ripen first at the basal, others at the apical end, and still others in spots irregularly scattered. Unripe portions of such fruits often remain in that state for some time. If pressed into solid cakes so as to exclude air spaces and prevent molding, these partially ripened fruits finally become uniform throughout, but if too low in sugar content they may sour. Mr. Simmons produced a fairly good product from half-ripe Rhars in this manner. Very immature fruits lose their astringency after considerable time but do not soften. Likewise, quarters of unripe Deglet Noors, dried, become sweet and edible in the course of several months, but never soften. They resemble the hard varieties. Also, when green dates are dried for some time at about 180° F., all astringency is quickly destroyed, but at higher temperatures caramelization of the sugars takes place.

ARTIFICIAL RIPENING BY HEAT

A series of ripening experiments in which heat and moisture conditions were varied within wide ranges was carried out during the crop season of 1905. It was found that the process was greatly accelerated by temperatures ranging from 45 to 50 degrees C. for several days, the time depending upon the maturity of the fruit and the temperature employed. At that time, however, due to the young trees and unfavorable seasons, only a very small percentage of the fruit ever reached a sufficient degree of maturity to produce an edible date. When it became necessary to harvest, most of the dates were still deficient in dry matter and consequently gave only a thin layer of tasteless flesh.

Although this method was reported as producing a plump, luscious fruit, the product was not valued by the writer higher than ordinary invert sugar dates, for the following reasons: The cane sugar was inverted to a marked degree during the heating process;[1] the distinctive Deglet Noor flavor, which makes that date a favorite in the

1 Bot. Gaz. 43: 401. June. 1907.

world's markets, was either never developed or was destroyed by the heat; and, finally, the color was darkened too deeply. A plan to build a curing house for a more extensive application of the process, at first delayed for want of funds, was finally laid aside in favor of chemical methods of ripening.

Aside from its delicate flavor, which is the character that gives real permanency to the ever-increasing demand for the Deglet Noor, the features which bring the fancy prices on the European market are size and color. It is probable that the consumer has learned to associate color with flavor. The Deglet Noor, like other dates, possesses its maximum of aroma and flavor soon after it softens. Some dates which are excellent when first ripened, according to a dealer in Nefta, Tunis, lose their flavor so rapidly that they soon become unmerchantable. It is readily noticeable that as the pale, transparent amber color of the fresh Deglet Noor of excellent quality becomes darker, the original high flavor also lessens very perceptibly, although the date retains a good flavor for a long time. It is, possibly, on account of this association of color with flavor that Paris merchants demand a higher price for the lighter colored Deglet Noor dates.

ARTIFICIAL RIPENING BY CHEMICAL TREATMENT

Artificial stimulation of various plant processes has long been known and practiced. By the use of ether or chloroform, or by physical means, flower buds are brought into blossom prematurely. Also plants that contain hydrocyanic acid generating glucosides, and an emulsin, have been observed to exhale hydrocyanic acid after treatment with various chemicals or after freezing.[1] The after ripening of certain fruits by chemical treatment has been practiced for many years, such as the ripening of Japanese persimmons by storing in empty *sake* barrels. The ripening of figs, also, is said to be hastened by the injection of a few drops of olive oil.

The artificial ripening of dates by processing them with vinegar[2] has been practiced commercially for many years at Elche, Spain, where dates do not ripen naturally. This process was introduced into the cooler northern regions of Algeria several years ago by a planter named Nodal, a native of Elche, who later became a resident of the date producing district around Ghardaia in southern Algeria, whence he carried seeds and planted them at Orleansville. Here he has successfully ripened, artificially, and sold, the product of his own palms. For these achievements a medal was granted him

1 Mirande, Compt. rend., 95: 393

2 The attention of the writer was first called to this process by Dr. Aaronsohn, Director of the Jewish Agricultural Experiment Station, Caifa, Palestine, who had recently travelled through date growing countries. More detailed information was obtained and contact with Nodal established recently through the courtesy of Dr. Trabut and M. Brunel, officers of the Algerian Horticultural Society, who were instrumental in granting the medal to Nodal.

by the Algerian Horticultural Society. The process, according to Nedal, consists in soaking the sprays of dates in hot vinegar for five or six minutes, after which they are packed in boxes with cane leaves and covered with the same material. After several days the dates are said to be nicely ripened.

Several years ago attempts were made at this Station to ripen Deglet Noor dates with aldehyde and alcohol. While some indications of stimulated ripening were obtained, the attempts were, on the whole, unsuccessful, due to the unfavorable nature of that variety as regards ripening. Later, however, there was available on the campus the fruit of a seedling date which proved very sensitive to chemical influences. The slightest tendency to ripen was very strikingly marked by the appearance of a distinct translucency of the light colored skin. As ripening advanced the color changed gradually into a dark chocolate brown. The effects on this date of over one hundred separate substances were studied either by exposing the fruits to the vapors of the volatile compounds, or by soaking them in solutions of the non-volatile ones.

The first results seem to indicate that the ripening effect was dependant on chemical structure, since certain molecular groups gave very marked results while others did not. Acetic acid and ethyl acetate were equally effective and five percent solutions of sodium or potassium acetate also gave good results. Aniline acetate vapor acted slowly but perfectly. Solutions of both benzoic and salicylic acid acted very promptly and completely. Oxalic acid gave marked results; but malonic, succinic, and lactic acids, and the acid amides appeared to act even better. Citric, tartaric, and malic acids gave only imperfect results. Many substances which are not easily volatile, acted quickly by direct contact but very slowly by their vapors In general, the more volatile the substance the quicker it acted; thus benzene and toluene acted very completely over night, but xylene, in the same time, affected only the bottom of the column of fruit above it, the effect traveling slowly upward. Oil of eucalyptus acted quite readily, while pennyroyal and cassia acted very slowly, excepting by contact. Eugenol acted by contact but its vapor was without effect even after many days exposure. Camphor and naphthalene were not sufficiently volatile to give any result. Among the more peculiar results were those obtained with iodoform. With this substance the entire column turned uniformly, there being no difference between the fruits in actual contact and those farther away. A detailed account of the action of the various substances used, grouped according to their efficiency, is given in the Journal of the American Chemical Society, Vol. 31, p. 203.

Ethyl and amyl nitrite penetrated rapidly and reacted chemically with the contents of the tannin cells, causing the tannin to precipitate and form insoluble grains at once. Due to the darkening of the fruit the effect on ripening, other than the removal of astringency, was difficult to follow. In smaller quantities it slowly stimulated the other ripening phenomena and very palatable fruits were prepared by its use. Ammonia in small quantities caused a general reddening of the fruits with shrinking at the basal end. The general ripening phenomena followed fairly well and after some days the fruits were edible but had a noticeable flavor.

The stimulation due to solutions was not so easily traced as that due to vapors. The first effect usually manifested itself by the appearance of translucent spots instead of a general ripening effect. Many substances cause the skin to crack and curl badly, sometimes with ripening, sometimes not. Saturated solutions of benzoic and salicylic acids over night produce first effects very similar to those produced by vapors, while malonic, succinic and lactic acids in three percent solutions, and the acid amides, were almost equally effective.

The following substances in solution caused all or nearly all the treated fruit to ripen: Benzoic acid, salicylic acid, sodium benzoate, sodium salicylate, sodium acetate, potassium acetate, oxalic, malonic, succinic, and lactic acids, acetamide, formamide, hippuric acid, cinnamic acid, and hydroxylamine chlorhydrate. Hydrazine chlorhydrate started the process, but normal ripening did not follow.

THEORETICAL CONSIDERATIONS

The great dissimilarity in chemical structure of the various substances which set up premature ripening, excludes all possibility of the phenomenon being a purely chemical one. In fact, very few of these substances react chemically with any known constituent of the date. After treatment over night with acetic acid vapor, however, a very appreciable reaction for the hitherto insoluble invertase could be obtained with the glycerol extract of the translucent date. While invertase is not essential to ripening, its behavior is probably typical for many other catalytic substances involved in the process. The mobility thus given the enzymes permits free molecular contact, with consequent reaction, between substances previously kept apart by the living protoplasm. In broad terms, we may formulate a theory of the artificial ripening of fruits as follows: Any substance which will penetrate the tissues and kill or stimulate the protoplasm in such a way as to release the previously insoluble intracellular enzymes without rendering them inactive, will bring about ripening, provided the fruits have reached a certain necessary degree of maturity.

This theory was tested by an experiment devised to accomplish the same result by purely physical means. Sprays of the same seedling date used in the chemical stimulation experiments were heated in water for five and ten minutes at every five degrees between 60° C. and 95° C. Below 60° C. they lost their astringency but remained very light colored, like untreated fruits. Above 60° C. the color became darker, reaching a maximum at about 75° C. At 80° C. the general aspect of the sprays was more uneven, and even the darkest individuals remained exceedingly astringent and very sweet. Above 80° C. the color of the entire spray became a light sulphur yellow, matching exactly the more immature individuals heated below 60° C. Unlike the results obtained by treatment with chemicals, the effects of heat stimulation became plainly manifest only after the lapse of several days. The results, however, show clearly that if dates are heated sufficiently to destroy protoplasm but not enzymes, the ripening phenomenon will follow quite completely, while at higher temperatures normal ripening ceases.

PRACTICAL APPLICATION OF CHEMICAL TREATMENT

In selecting some substances from the large list of available ones for practical use in artificial ripening, we must consider efficiency in bringing about the process, effect on the flavor of the ripened fruit, and convenience of application. Treatment by vapor is much more convenient and less liable to injure the fruit than soaking in solutions. The amount of reagent required, and, consequently, the cost, is also very much less when a vapor is applied; but somewhat more extensive appliances will be required for the most economic and satisfactory results. The effectiveness of a reagent is probably determined by the quickness with which it acts. These considerations limit one to the first list of substances given above. Of these, ordinary gasoline is one of the best, but its flavor in the ripened fruit is persistent and unendurable. The same is true of ether and all the organic acid esters. After some days the flavor of chloroform disappears entirely as does that of the other chlorine and bromine esters. The flavor of benzene and toluene is retained tenaciously but to some tastes is not altogether disagreeable. Allylisosulphocyanate would probably prove effective in exceedingly small amounts, but it imparts a permanent mustard-like flavor. The fatty acids—acetic, propionic and butyric, meet all the requirements to be desired; and as acetic acid is the cheapest and most available of the three, it would naturally be selected for practical use. The best results will be obtained by treating the fruits in closed chambers with saturated vapor from the glacial acid, exposed in open vessels, just long enough to start the process. Some varieties do not respond at once to this treatment, and, if this is continued too long, the dates become very sour, due to absorption of acid. Acid in such amounts probably interferes with enzymic action and the dates never ripen. This is notably true of the Deglet Noor. Very immature individuals are not susceptible to chemical stimulation, possibly because the ripening enzymes do not yet exist in them.

Deglet Noor, and probably other difficultly ripening varieties, can be treated quite successfully with very small amounts of nitrous ether. The penetrating power of this reagent is very great and it has the added advantage of removing part of the astringency by direct combination with the tannin. If the dates are fairly mature they slowly ripen into fruits of medium good quality. By using two or three volumes of twenty percent alcoholic solution of nitrous ether to every ten thousand volumes of space loosely filled with dates on the stem, a very large percentage of usable fruit can be obtained from material that would otherwise dry up or decay. This amount of nitrous ether darkens the fruit but very slightly, and leaves no perceptible flavor. It is probably all destroyed chemically, but if not the original amount used is so small that it could scarcely exhibit any therapeutic effect on the user of the product. One individual, in less than a month, ate twenty-five pounds or more of the nitrite treated dates and experi ienced no noticeable effects of **any** kind.

COMMERCIAL CONSIDERATIONS

DETERIORATION OF RIPE INVERT-SUGAR DATES

Cured dates are among the cheapest dried fruits in the World's markets, but the fresh ripe fruit will undoubtedly meet with popular favor at a remunerative price if it can be put on the market in prime condition. Much of the luscious quality of the fresh fruit is due to cane sugar, but in the ordinary invert-sugar sorts the cane sugar is rapidly changed to the less sweet invert sugar. Thus fruits which contained ten percent of cane sugar when first ripe were found to contain only one quarter percent after curing for fourteen days. In the case of many varieties the peculiar fruity flavor of the fresh date also lasts but for a few days after it is developed.

With some varieties it promises to be practical, after some experience, to treat the fruits at such a time that they will be at their best when the market demands them. In the case of the seedling date used most extensively in these experiments, it was possible to develop all the delicate flavor of the tree-ripened fruit, practically as desired.

TRANSPORTATION IN UNRIPE CONDITION

Fresh ripe dates bear transportation poorly. Even in local markets the naturally ripened product is handled with more or less difficulty, due to its soft, sticky nature and tendency to sour. There appears to be no reason, however, why the unripe fruit can not be shipped in that condition and ripened at its destination. Unripe dates can be handled in large bunches with little danger of loss since they are very hard and do not shell off badly. Much experience in the selection of properly matured fruit for shipment and ripening will necessarily be required to give satisfaction and make this a commercial success. The fruits may also be treated before shipment and allowed to ripen during transportation. Several small samples were

Fig. 2.—The date harvest in Tozeur, showing wasteful and slovenly methods which may be improved in Western practice.

treated in this way and sent out by express. One arrived in Chicago and one in Washington in excellent condition, but a third was received in Philadelphia in poor condition. Another, sent to California, surprised the addressee, who is familiar with the behavior of ripe dates of the juicy class, by the fact that it was not sour.

KEEPING QUALITY OF ARTIFICIALLY RIPENED DATES

Artificially ripened dates are much superior to the natural fruit in keeping quality. This may be due in large part to the sterilizing action of the treatment. The strong vapor of acetic acid probably kills all yeast cells and bacteria on the skin before the natural resist tance of the underlying tissues is broken down. After treatment the dates are more readily protected from flies and insects than when left to ripen in the orchard. Although large quantities of artificially ripened fruit were strewn about the laboratory, there was a notice noticeable absence of various flies and other insects that are usually associated with soured or decayed fruits. It will therefore probably prove expedient to ripen artificially such varieties as Rhars and Birket el Haggi even for local markets. The nitrous ether treatment used with Deglet Noor dates effectually stopped further erosion of decaying spots but could not be expected to correct the foul flavor. Such fruits must be carefully removed and rejected.

Date culture outside of certain well defined date growing areas has been recognized as hazardous, due both to failure in ripening sufficiently early and to souring in damp weather. Even in the most favored oases losses from these causes are sometimes considerable. Artificial ripening, as described in this publication, however, promises to afford a means of avoiding these losses. When the dates begin to show the effects of unfavorable weather, the bunches may be removed to shelter and there ripened. This treatment not only stops further souring, but has the added advantage of ripening the bunch evenly, thus eliminating the prolonged harvest which in the case of many varieties has been a serious drawback to their economic production where labor is expensive.

SUMMARY

The principal results of this investigation, of more purely scientific interest, have been summarized on page 405. Those of more immediate practical application are as follows:

1. During the early period of its growth the date does not differ materially from other non-starchy fruits in the percentage of dry matter it contains. After apparent maturity in size the rapid accumulation of sugar begins. This continues till the date begins ripening. It is thus desirable, even if artificial ripening is to be practiced, to leave the fruit on the tree as late as possible. If cut too early, the flesh about the seed must necessarily be thin and insipid.

2. Some varieties of dates begin ripening when they contain not more than 55 or 60 percent of dry matter. Their sugar content is not quite high enough to make them self-curing without further concentration of the juice. This does not occur in humid weather, and fermentation soon starts which further lowers the sugar content

until the dates sour rapidly. Other varieties begin to ripen only after a much higher percent of sugar is present and consequently are sugar cured before the protection of the living tissue of the unripe date is broken down by ripening. These differences determine souring and curing varieties.

3. After dates have reached sufficient maturity they may be ripened artificially either by heat or by chemical stimulation. The naturally ripened dates have a delicate aroma which vanishes rapidly in the case of some varieties and persists for many days with others, notably Deglet Noor. This aroma is not developed by heat ripening. Many varieties ripen quickly after treatment with various chemicals, of which acetic acid is the best in most cases. They may be treated with the vapor of the strong acid or soaked a short time in vinegar. Those that ripen after this treatment develop the aroma of the naturally ripened fruit. Less responsive varieties, as Deglet Noor, yield readily to the vapor of nitrous ether, which is effective in exceedingly small amounts. It does not destroy the flavor and only slightly deepens the color.

4. By the application of chemical methods of stimulating ripening, it will probably be possible to ripen inferior varieties, which deteriorate rapidly, at distant markets, and to so time the process that they may be delivered to the consumer in their best condition. This process may make possible the use of varieties which can be grown successfully under a wider range of climatic conditions than the Deglet Noor

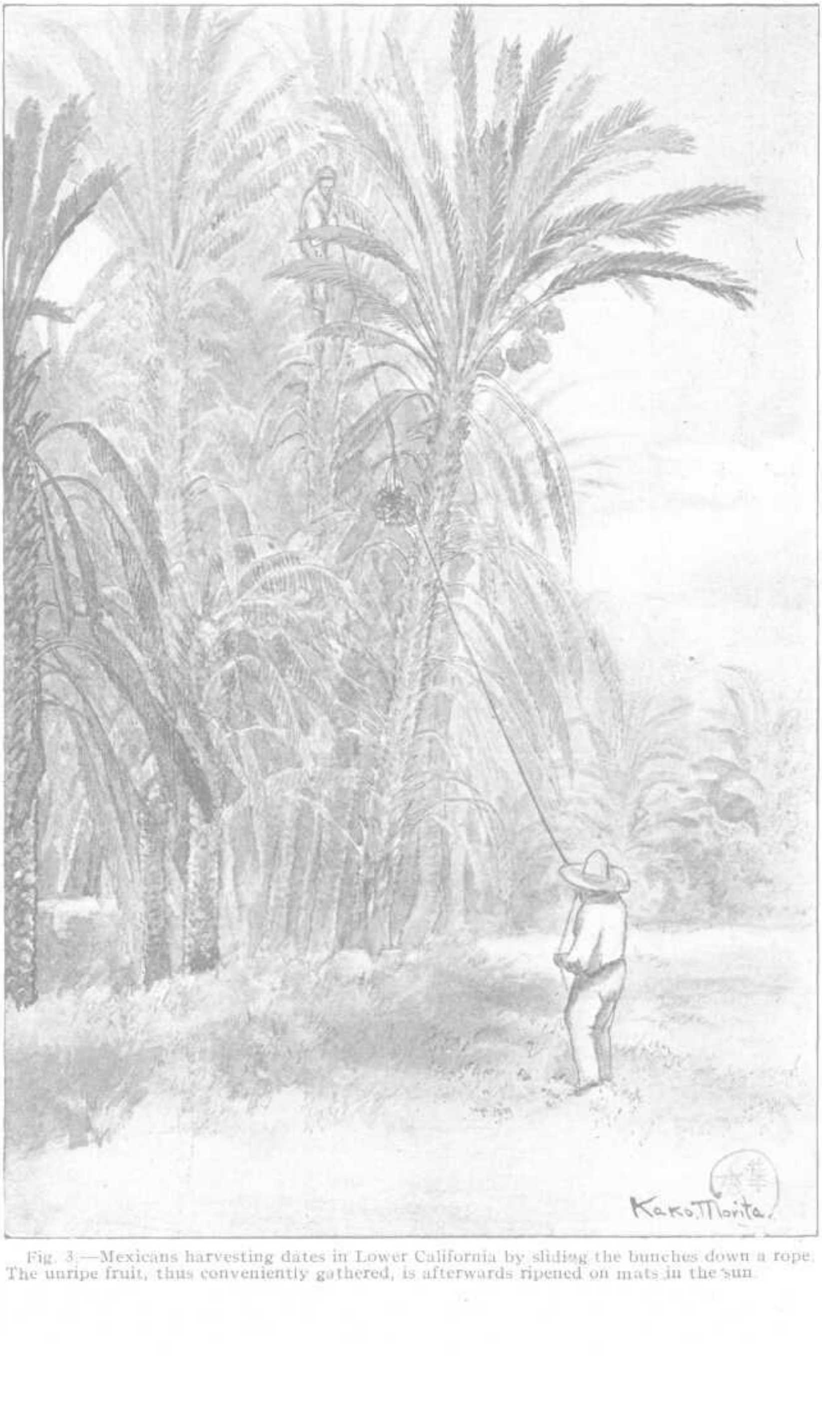

Fig. 3.—Mexicans harvesting dates in Lower California by sliding the bunches down a rope. The unripe fruit, thus conveniently gathered, is afterwards ripened on mats in the sun.

RIPENING DATES BY INCUBATION

By G. F. Freeman

INTRODUCTION

The method herein described of ripening dates artificially by means of heat and moisture is not entirely new. The Mexican date growers of Lower California "cut the bunches of dates after the fruit has passed from the astringent to the sweet stage, but before it becomes soft. The harvested bunches are next put in piles, which in the open are covered at night with palm leaves, or otherwise, to protect them from the dew which would possibly contribute to their decay. Being left in this situation for a varying period of several days, the berries are next picked from the bunches and spread out on mats in the hot sun, the riper being separated from the greener fruit, day by day. At night, during the process, the fruit is protected by covering or piling it, thus measurably maintaining its temperature and keeping it from damage by fog or dew. As the fruit matures it is packed for storage or shipment."[1] The writer suspects that the heat of the sun during the day and the sweating effects doubtless brought on by piling or covering at night, offer conditions and produce results more or less similar to the artificial ripening process which he has used Vinson reports that a certain fruit dealer in Algiers whose dates are considered superior, is said to have a secret process by which they are treated in order to soften the hard and imperfectly ripened individuals Other fruit dealers of the same locality are quoted as suspecting that this process consists in steaming or soaking the fruit.

Dr. Vinson recognized the effect of heat and moisture in date ripening as early as 1907. Speaking of Deglet Noor dates he says, "under normal conditions, 20 to 25 percent of invert sugar is formed, but under the conditions necessary for artificial ripening, 45 to 50 degrees C. for several days, a much larger proportion, is inverted."[2]

During the crop season of 1910, while Dr. Vinson was absent in France and Africa, the writer became interested in the subject and

1 R. H. Forbes, Date-Palm Culture in the Southwest unpublished MSS
2 The Function of Invertase in the Formation of Cane and Invert Sugar Dates. Botan. Gaz., 43: 393-407. 1907.

developed the economic method of ripening dates by incubation described on the following pages. In presenting the method, acknowledgement is made of the many suggestions and criticisms offered by Director R. H. Forbes, in the course of the work. In the "Chemical Study," moreover, the writer again desires to acknowledge the active cooperation of Mr. Forbes, who contributed materially to the plan of investigation and who executed the chemical analyses therein reported.

THE RIPENING PROCESS

PRELIMINARY WORK

Dates in various stages of ripeness were first washed and the water drained from them, after which they were placed in a glass

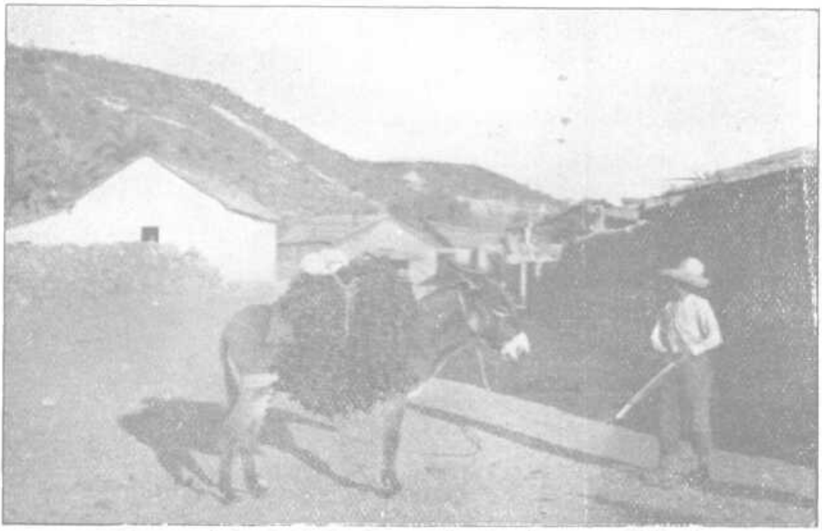

Fig. 4.—Bringing in the date harvest, San Ignacio, Lower California.

damp chamber, set in an oven and maintained at a temperature of 45 degrees C. four days. At the end of this time many of them had ripened into excellent fruit. Some, however, which were most green to begin with remained so, while others which had shriveled down into a typical hard or dry date, also refused to be affected. In these preliminary experiments, the writer soon found that he had to deal with three classes of dates:

Class 1. Those which were too green to ripen by this process.

Class 2. Those which were readily susceptible to it.

Class 3. Those which, though mature, were too dry to ripen.

When the Deglet Noor is fully mature but not yet beginning to ripen, the seed is hard, the skin is firm and the external layers of the flesh are opaque. At this time the color of the fruit is light orange yellow with a strong blush of reddish orange on the sunny side. The first sign of ripening is shown by a slight translucence of the flesh just below the skin. As this increases and progresses toward the center of the date, the fruit begins to soften and wrinkle; and it loses volume with its loss of moisture in ripening. In the early, naturally ripened, invert sugar varieties the skin is, for the most part, rather thick and brittle and as the date shrinks it becomes separated from the flesh, dries out and cracks. These cracks offer access to predaceous insects and are ideal receptacles for catching and holding the moisture of occasional showers, thus hastening the souring and decay of the fruit.

Not more than ten percent of Deglet Noor dates have ever yet come to a state of perfect ripeness in this climate. In the vast majority of cases, soon after the first translucence appears, the date begins to shrivel rapidly and to dry out. The fruit never becomes soft and palatable but dries down into a hard, brittle "mummy". In this condition it is a typical dry date, since it is still sweet and has but little astringency. After the Deglet Noor becomes fully mature we may therefore recognize three distinct states:

1. The fully mature green date.
2. The beginning of translucence and softening which may progress into the perfectly ripe condition or else dry down into
3. The dry mummy state.

These three stages correspond exactly with the three classes of dates mentioned in the description of the preliminary experiments in artificial ripening. Moreover, it is seen that only dates of the second class were rendered marketable.

EXPERIMENTAL RESULTS

In the immediately subsequent work, the dates were first graded into the three classes above described and only those belonging to the second class chosen for experiment. Larger quantities of more uniform quality were now used and some excellent product obtained. Experiments were also begun in varying the factors of moisture and temperature in order to determine the limiting conditions for the successful ripening of this class of dates, and also the optimum amounts of heat and moisture required to produce the highest possible quality of product and the least possible waste.

EFFECTS OF TEMPERATURE

The rapidity of ripening increases with a rise in temperature until a point is reached where both the protoplasm of the date and the enzyme which brings about ripening are destroyed. This temperature is stated by Vinson[1] to be about 75 degrees C. The writer finds that even 65 degrees C. is too high to get a good quality of date. Ripening at a temperature of 45-48 degrees C. finishes the process in three or four days and seems to give the best fruit. Ripened at a lower temperature, a longer time is required and much fruit is liable to sour. At temperatures above 46 degrees C. there seems to be little danger of souring during the ripening process.

The temperature used also profoundly affects the color of the finished product. The higher the temperature the darker the product. Naturally ripened Deglet Noors are of a translucent golden

Fig. 5.—Bunches of dates piled and covered to begin the ripening process, San Ignacio, Lower California.

color. In artificial ripening this is changed to a translucent mahogany. This reaches its highest perfection in dates ripened at 44-45 degrees C. At about 50 degrees the dates become deep mahogany, lose their translucency and are much less attractive. These higher temperatures also cause the syrupy juice of the date to exude and render the fruit sticky and disagreeable to handle. Continued exposure to a lower temperature seems to have much the same effect as exposure to a higher degree for a short time. Thus dates over-ripened (dark colored and opaque) after exposure for five or six days to a temperature of 45 degrees C. have much the same appearance as do dates ripened for three days at 52-55 degrees C. The greener the date the lower the temperature at which the ripening process must

1 Ariz. Agr. Exp. Sta. Rept. XX (1909), p. 591.

start. When mature dates which show none of the translucent appearance of the beginning of the ripening process are set immediately in an oven having a temperature of 48–51 degrees C. most of them soon darken and instead of ripening into soft, juicy dates, produce a tough, insipid product with a dull grayish appearance and leathery texture. But when these dates are first set in a moist chamber (which, however, must contain no free water) at 38–40° C. for three or four days, a considerable portion of them will begin to ripen and show the normal translucence and softening. When this occurs, such as are beginning to ripen may be transferred to the higher temperature and promptly finished into a good quality of fruit. I was unable to start more than half of these green dates by this preliminary sub-temperature incubation on account of the moulds which seemed inevitably to take possession of the fruit in the ripening trays at the end of about five days. Such dates, therefore, as showed no sign of ripening at the end of four days were considered worthless. It would be interesting, here, to know just what stage in maturity marks the dividing line between the dates that would and would not ripen. Does it depend upon the amount of invertible sugar present or upon the first appearance of the inverting enzyme?

After the date is well along toward ripeness, high temperatures are not so harmful except to darken the color and make the date sticky on the outside. After the date is ripe the temperature may be raised until the date is candied. These candied dates, however, lose some of the characteristic date flavor and are therefore disapproved by most people.

While high temperatures and over ripening darken the product and candy the dates, they also increase the keeping qualities. The very plump, light colored and juicy date that we have at the first completion of the ripening process is attractive in appearance and delightful to the palate, but many of these, if packed as such, will sour. It is best, therefore, to continue the ripening until the fruit is distinctly shrunken and the juice forms too strong a solution for the growth of yeast and bacteria. [1]If the ripening is continued until the dates are thus sugar cured, they will keep indefinitely, provided they are kept in tight boxes or in a dry room. Another and by no means unimportant effect of the temperature upon dates which are ripened by this method is the destruction of insect eggs. Dates of the Arechti and Deglet Noor varieties which had naturally ripened on the trees were carefully selected with respect to quality and freedom from insects and were packed September, 1910, in tightly covered

1 Ariz. Agr. Exp. Sta. Ann. Rept. XIX (1908) p. 366.

tin boxes lined with oiled paper. The boxes were then securely wrapped in oiled paper with a final wrapping of two layers of ordinary paper. Nevertheless, when the boxes were opened about December 15, practically every date was found to be infested with one or more worms. There is no possible chance that these worms could have entered the boxes subsequently to wrapping, so they must have hatched from eggs laid on the dates before they were packed.

Wherever naturally ripened Arizona dates have been packed and put on the market this same complaint has occurred. Wormy dates have therefore been a rather serious handicap to the commercial development of our date industry. With the artificially ripened product, however, this difficulty is at once and completely overcome, for all insects and their eggs seem to succumb to the continuous moist heat of the ripening pans.

Ovens and Ripening Pans

The oven used for most of the work was of zinc and had a double wall to prevent loss of heat. It was large enough to receive eighteen ripening pans holding about five pounds each. Two other ovens were used, carrying about twenty-five pounds each. The total capacity of the plant used by the writer was therefore about one hundred and fifty pounds. Flat graniteware pudding pans of five to eight pounds capacity were found most satisfactory for use as ripening pans. Tightly fitting tin covers were used on these but graniteware covers do not corrode and would be better if they could be secured.

Influence of Moisture

The dates, after sorting, should be washed to remove the dust and dirt which inevitably collects upon them. They should then be drained thoroughly before being put into the ripening pans. From poorly drained dates water is liable to collect in the bottom of the pans and cause cracking of the skin, and souring or stickiness of the finished product. Unless the dates are already shrunken, five or six hours contact with free water will cause the skin to break on many of the fruits.

In a commercial plant it would probably be best to dry the washed dates for a few hours on wire drying racks in an oven. The temperature should be about 40° C., with free air circulation. When there is no moisture left on the exterior of the dates they are ready for the ripening pans.

It is advisable to place cloths or low wire screen racks in the bottoms of the ripening pans in order to absorb, or raise the dates above, any syrup that may drip from the fruits.

The soft or translucent dates lose about ten percent of weight in ripening. This loss is water, and the bulk of the date decreases coincidently with a decided shriveling and wrinkling of the skin.

The ripening pans are at first left open (usually twenty-four to thirty-six hours) until the skin begins to wrinkle perceptibly. The covers should then be fitted on tightly so that the remainder of the

Fig. 6.—Ripening dates on mats in the sun, San Ignacio. At night the fruit is kept warm by putting it in the rolled-up matting shown in the picture.

process of ripening takes place in a saturated atmosphere. If the covers are put on too soon, souring is more likely to occur. An additional and more serious danger is that the dates ripen into exceedingly soft and juicy fruit. If packed in this condition such fruit will not keep. On the other hand if the dates are dried down to packing weight, the shrinking flesh pulls away from the skin, leaving the latter to dry into an undesirable loose, papery shell. But when the date begins to shrivel in the early part of the ripening process, the skin will continue to cling to the flesh. This keeps the skin soft and tender and results in a finished product which is a shrunken but still translucent and clean (not sticky) fruit. It is an important consideration in the production of a fancy confection date that it may be eaten from the hand without soiling the fingers. As the ripening process continues the date should be observed from time to time. If the flesh becomes light brown and hard instead of softening and coloring to a translucent mahogany, the date is too dry to ripen and must be soaked in water for a few hours. Sometimes, when a pan of dates begins to lag in the ripening process on account of becoming too dry, the fruit may be freshened up by removing the cover and lightly sprinkling the upper layers. Care however, should be exercised not to add so much water that it runs down through the dates and collects at the bottom of the pan, as this is liable to cause souring or stickiness.

When especially juicy dates are being ripened, they may sweat to such an extent, after the covers are put onto the pans, that, should these be allowed to remain, the skin and exterior of many of the dates will become water soaked. This destroys the rich color and translucence and, moreover, so weakens the juices at the basal end that souring is liable to occur. Such a condition can be easily remedied before the injury is done by removing the covers for an hour or two until the dates dry off.

The relation of water content to keeping quality has been worked out by Vinson. As a matter of practice it may be observed that so long as the juice of the date is a watery fluid, the packed product will sour; but if the drying consequent upon continued ripening be carried so far that the juice reaches the state of a fairly thick syrup there is little danger of losing the fruit by fermentation.

The Ripening of Dry Dates

The ripening process discussed above applies particularly to dates in Class 2, already described. This process also applies,in the main, to Class 3 (dates which have dried down to the firm, wrinkled state without ripening), but there are several pronounced modifications necessary in order to produce the largest possible percentage of marketable dates. These dates are too dry to ripen. If placed in the oven some few will soften and color perceptibly, but the majority of them will remain nearly unchanged. In order, therefore, to properly ripen these dates it is necessary to add sufficient water to soften them and allow the enzymic reaction to exercise its fullest energy. This is best realized by first washing to remove dirt and then soaking in water for six or seven hours. This may be done in vats of cold water, or the dates may be put into ripening pans and water enough added to cover them, whereupon the pans are then set in the oven and kept for the required time at a temperature of 40-45° C. Soaking at this higher temperature hastens the absorption of water but it also hastens souring which will quickly occur if the dates remain in the warm water too long. Dates allowed to remain in warm water for twelve hours became so sour that half of them were unfit for market. If the soaking is done in cold water, souring does not occur so quickly, but the fruit does not absorb sufficient water in the same length of time. After soaking, the dates should be drained clear of water, dried off as quickly as possible and incubated in the same manner as is done in the case of dates of Class 2. The same procedure applies to the two classes with the exception that somewhat higher temperatures can be used for Class 3 than for Class 2, the ripened product being somewhat darker colored. The dates are also more wrinkled and markedly more firm. The flavor varies somewhat, being that of a juicy syrup in the case of the softer fruit while Class 3 has the characteristic aroma imparted by a sweet and mellow flesh.

SORTING AND PACKING

When the dates are ripe, the pans should be set out to cool and the covers removed at once. If allowed to cool while covered, moisture is condensed on the dates and they are thus rendered sticky. After cooling they are ready to be sorted and packed. In sorting, four grades are made up, as follows:

1. "Tops." These are dates which are as near perfection as can be found. They should be of a rich, translucent mahogany color, uniformly mellow throughout, with no hard or firm, not completely ripe parts. The skin should adhere perfectly to the flesh throughout, having no raised or blistered areas, and the date should not be sticky.

2. "Bottoms." These should be of high quality as to flesh, color and ripeness, but are not fit for tops on account of being sticky or slightly blistered.

3. "Packers." These are dates which are off in color or badly blistered, but are still of good quality as to flesh and ripeness.

4. "Waste." This is fruit that includes soured, imperfectly ripened dates, and dates otherwise unfit to go into any of the above classes. This waste can be made into excellent vinegar.

The packers are pressed into blocks of one or two pounds and wrapped in waxed or oiled paper. Experimental sales show that retailers will take these dates at twenty-five cents a pound in preference to the imported bulk dates at twenty cents. Moreover, clerks in grocery stores where both kinds are on sale will push the block dates rather than the imported bulk dates for the reason that sales can be made without soiling the hands. Another reason for the better sale of the pressed dates in small, neat packages is that, in addition to their more sanitary packing and handling, their cleanly appearance is not without weight in the mind of the customer.

The two classes, tops and bottoms, go into the same package as fancy or confection dates. The packages, used by the writer, are stamped tin boxes, made by the American Can Company at San Francisco. The dimensions of these boxes are as follows: length, 7 7-16 inches; width, 2 7-16 inches; depth, 1 1-16 inches. These make very neat packages which, with their content of dates and their wrappings,

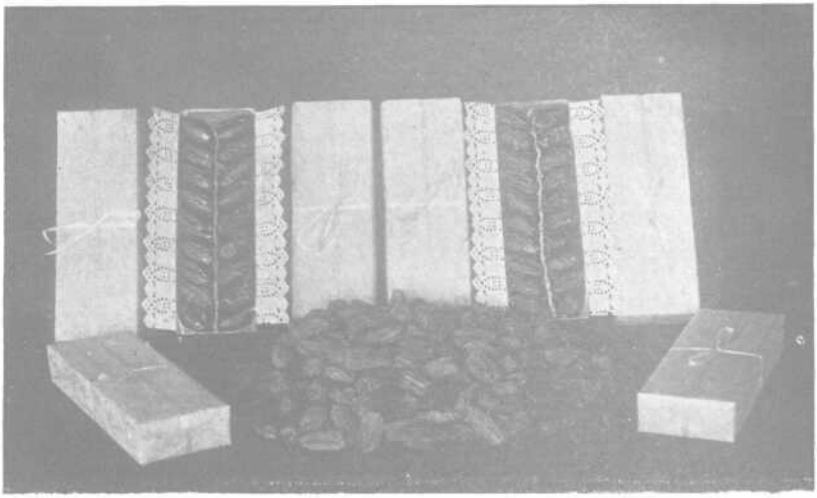

Fig. 7.—Deglet Noor dates, grown in the cooperative orchard near Tempe, Arizona, and ripened by incubating, with addition of moisture, at a temperature of 49° C.

weigh about eight-tenths of a pound. The box and wrappings weigh about two ounces.

To begin packing, the box is first lined with oiled paper. This is handily done by using two strips, one which covers the bottom and ends, the other the bottom and sides. The dimensions of the former are 9 8-16 x 2 6-16 inches, and the latter 7 7-16 x 4 7-16 inches. These papers are pressed with the fingers quickly into position and a layer of dates packed upon them. The dates are laid in two rows, the bases of the dates in each row being at the center of the box with their longest diameters inclined about forty-five degrees to the central line of the box. For this layer bottoms are used. Upon this, a second layer of dates is packed in a like manner using, however, this time, tops For this layer a good packer will pick out dates of uniform size and may develop considerable skill in producing an artistic and attractive pack. The packing is finished by laying between the two top rows a fruiting stem of the date, from which the fruiting caylices have been removed. This gives the dates the pleasing appearance of being still on the fruiting twig. A strip of translucent embossed paper is now laid on the dates, embossed paper lace edging is inserted between the tin and the side oiled paper and creased inward, and the cover is put on. The whole box is neatly wrapped in white embossed paper 9 7-16 x 9 inches and tied with ribbozine. Such boxes whether open or closed, make an attractive exhibit, serve as an appropriate covering for the luscious fruit which they contain, and on the whole make a package which is appreciated and readily accepted by the trade at a price which will yield thirty to fifty cents a pound for the dates.

SHIPPING QUALITIES

Experimental shipments have shown that dates ripened and packed as above described will reach the following widely scattered points in excellent condition: Seattle, Washington; Fargo, North Dakota; Chicago; New York City; Washington, D. C., and Paris, France. We may feel confident, therefore, that dates artificially ripened and packed in Arizona can be safely shipped throughout the United States, at least With such a widely extended market there would be little danger of over production in the limited areas of southern Arizona and California in which this fruit may be grown.

CHEMICAL STUDY

The artificially ripened Deglet Noor date is decidedly a different product from that which naturally ripens on the tree. The former is an invert sugar date, while the latter, as has long been recognized, contains principally cane sugar. This may be seen in the following table of analyses:

TABLE I.—COMPOSITION OF DEGLET NOOR DATES

Lab No.	Kind of dates	Moisture	Cane sugar	Fructose and glucose	Total sugars
			Calculated to water free material		
		percent	percent	percent	percent
4585	Naturally ripened....	17.23	61 30	26 72	88 02
4584	Dry mummies (Class 3) .	21.21	60 73	22.75	83 48
4576	Artificially ripened (Class 2)	24.95	18 51	61 01	79 52
4581	Artificially ripened (Class 3)	28.75	13 64	72 22	85.86

The principal factors governing the amount of inversion are heat and moisture. The influence of each separately and in combination is shown in the following table:

TABLE II.—EFFECTS OF THE VARIATION OF HEAT AND MOISTURE ON INVERSION

Lot No and Kind of dates	Treatment	Duration of incubation	Temperature of incubation	Moisture content when ripe	Cane sugar	Total sugars	Inversion during expt
					Calculated to water-free		
		Hrs	Deg C	percent	percent	percent	percent
1 Soft mummies	Soaked in water 7 hrs. at 49° C	117	49	29.15	12.69	84.37	34.11
2 Soft mummies	Left dry	117	49	23.16	26.98	87.11	19.82
3 Soft mummies	Soaked in water 7 hrs at 20° C.	117	20	33.44	37.80	85.82	9.00
4 Soft mummies	Left dry (check)	117	20	23.28	46.80	83.97	
5 Hard mummies	Soaked in water 7 hrs. at 49° C.	117	49	28.75	13.61	85.86	47.09
6 Hard mummies	Left dry	117	49	19.63	41.89	83.51	15.84
7 Hard mummies	Soaked in water 7 hrs. at 20° C.	117	20	25.91	47.52	82.59	13.21
8 Hard mummies	Left dry (check)	117	20	21.21	60.73	83.48	.

The dates used in these experiments had been lying in the laboratory at room temperature for about a month. However, the inverting process had probably been going on slowly in them for the two months after they first began to ripen. There were two classes of dates. Those in which partial ripening had occurred and which were therefore somewhat soft, but not sufficiently ripe to be marketable, were termed "soft mummies"; and those which had dried down to a hard and brittle condition were termed "hard mummies." Under natural conditions slow inversion had occurred in both but it seems to have been more active in those which were most advanced in ripeness. Thus we see by deducting the cane sugar found from the total sugars present that, in wholly untreated samples 4 and 8, representing these two classes, there was 37.17 percent of invert sugar in the soft mummies and 22.75 percent in the hard mummies. It is interesting, moreover, to note that the percent of moisture at the time the analysis was made was slightly higher in the soft than in the hard mummies. The slow inversion in these two samples was most probably due to the fact that though there was sufficient heat and moisture for feeble activity of the inverting agents present, neither was at or near the optimum degree of intensity. When the temperature alone was raised there was an increased inversion amounting to 19.82 percent in the one case and 15.84 percent in the other. (Lots 2 and 6). Again, when the water content alone was increased by first soaking for seven hours and then setting at room temperature during the incubation of the other samples, we find also an added inversion of 9.00 percent in the soft mummies and 13.21 percent in the hard dates. (Lots 3 and 7). Now let both these factors work in conjunction, as in Lots 1 and 5, and the maximum inversion will occur, amounting to 34.11 percent in the soft and 47.09 percent in the hard dates. It thus appears that, taking the average of the two kinds in each case, 4 and 8 with 1 and 5, as much or more inversion occurred in 117 hours with plenty of moisture present and a temperature of 49 degrees C. than occurred during the whole preceding history of the date under natural conditions.

With respect to the influence of temperature alone, Table II gives only two instances, 20 degrees and 49 degrees C. In another experiment, the results of which are given in Table III, dates were first soaked in water until swollen and then ripened at intervals of ten degrees from 40 degrees to 90 degrees C. The column headed "amount of inversion" gives the percent of cane sugar less than that found in the check or untreated sample and shows the amount of inversion actually occurring during the course of artificial ripening.

TABLE III.—EFFECT OF DIFFERENT TEMPERATURES, AND MOISTURE, ON THE INVERSION OF CANE SUGAR

Lot No.	Temperature of soaking	Time soaked in water	Temperature of incubation	Time incubated	Moisture	Acidity as H_2SO_4	Cane sugar	Fructose and glucose	Total sugars	Amount of inversion
						Calculated to water-free material				
	Deg. C.	Hrs.	Deg C.	Hrs.	percent	percent	percent	percent	percent	percent
21	Check	none	..	..	19.90	.309	54.92	29.99	84 91	..
27	40	12¾	40	95¾	28.67	.317	26.55	57.06	83.61	28.37
28	50	13	50	79	31.41	.354	9.94	75.01	84.95	44.98
29	60	8¼	60	25¼	30.86	.334	24.88	59.00	83.88	30.04
30	70	6¾	70	24¼	34.52	.403	23.73	58.43	82.16	31.19
31	80	4¼	80	13½	29.08	.382	38 67	45.36	84.03	16.25
32	90	2¾	90	10	22.65	.428	42.23	41.55	83.78	12.69

From this table it may be seen that the temperature most favorable to the production of a well appearing marketable date is also most favorable to the inversion of cane sugar. Attempts to conserve cane sugar by ripening the dates at or below 40 degrees C. result in prolonging the exposure necessary for the completion of the process and strongly increases the liability to sour. On the other hand, at temperatures above 55 degrees C. (55 to 65), although not more than half of the time necessary for ripening at 50 degrees C. is required, great care must be exercised in order to prevent the production of dark colored, sticky dates. Although there is more cane sugar present, dates ripened at these high temperatures do not have so pleasing a flavor as do those ripened with less heat. However, one promising suggestion for the improvement of the commercial process as already described is a slight increase of the temperature used accompanied by very careful watching to prevent over-ripening and darkening of the resulting finished product. From 70 to 90 degrees C. the amount of inversion rapidly falls off but the quality at the same time also suffers a rapid decline. The dates become clammy and cadaverous, very dark in color and rather strong tasting. The same criticisms apply in a less degree to dates scalded at 80 degrees C. and then ripened at 50 degrees C.

Soaking in 1-10 normal ammonia strongly lessens inversion and gives dates of good taste and quality. These are, however, distinctly darker than dates ripened with water or weak acetic acid. Although these dates have neither the taste nor the smell of ammonia, analysis shows them to be alkaline to a degree ranging from .05 to .06 percent water-free. Letters to food authorities inquiring as to the effect on human health of these quantities of ammonia in a food, brought conflicting opinions. In order, therefore, to avoid all danger, treatment with ammonia to prevent inversion is not recommended. The artificially ripened, invert Deglet Noor, however, is a date of very excellent flavor, which, though not possessing the characteristic flavor and aroma of the imported Deglet Noor has thus far been accepted by the trade at fancy prices.

The fact that ripening may occur naturally with very little inversion of cane sugar (20 to 30 percent) is in accordance with Vinson's statement that the softening of the date and precipitation of the tannin, occurring in both natural and artificial ripening, is more or less independent of the changing of cane into invert sugar. As final evidence it was found that dry mummy dates which had been scalded in water at 80 degrees C. for twenty minutes and soaked in one-tenth normal ammonia for seven hours, ripened completely although this treatment reduced the amount of inversion when compared with the ordinary process, nearly 22 percent. Since, however, the conditions for bringing about this softening, and tannin precipitation, in the artificial process herein described, are also very favorable to the activity of the inverting agents of the Deglet Noor date, and the two processes go on at the same time, the final product is a ripened invert instead of cane sugar date.

Notwithstanding the fact that not more than ten percent of the Deglet Noor dates as grown in Arizona ripen naturally, their prompt response to the artificial process indicates that they contain ripening and also inverting agents which are remarkably active when the proper conditions of heat and moisture are supplied. Slade had long ago noticed the fact that "the amount of heat, for instance, required to ripen the fruit varies greatly with different varieties," and Vinson's observations that while certain varieties when treated with acetic acid or chemicals would ripen perfectly in three days, others (Deglet Noors, for instance) responded slowly to these stimulants, "would seem to indicate that it has long been recognized that there is a difference in the enzymatic composition of different varieties, such that rather distinctly different combinations of temperature and other environmental factors are necessary for each in order to bring about complete and rapid ripening. It is therefore easy to conceive that a set of conditions which would start into activity the ripening enzymes of a Rhars date and bring about a completion of the process within three days, would scarcely affect the Deglet Noor at all, or at least might start such feeble activity that several weeks or even months might elapse before full ripening would occur and in the meantime the date would have completely dried out or else dried to such an extent that the lack of moisture would of itself stop further activity. The work of these enzymes does not seem to be automatic in such a manner that the activity which results from a certain stimulation will continue after the stimulation has ceased, except in cases where the activity is dependent upon the release of the enzyme from an insoluble condition. On the other hand it seems that the activity resulting from the stimulating effect of heat and moisture upon the ripening enzymes of dates continues only during the time during which both of these factors maintain a degree of intensity lying between certain definite maxima and minima and that the degree of their activities is dependent upon the approach of each of these factors conjointly to their optima. We may safely assume, therefore, that the minima of these factors for complete normal ripening vary with the different varieties. The finding of the proper combination of conditions for the ripening of any particular variety is therefore like fitting a key to an unknown lock. All of the different essential notches, extensions, ridges and grooves of the key must be found and used at once. If only one be lacking the door refuses to open. If only one essential condition of the necessary environmental factors be beyond the limiting maximum or minimum the date refuses to ripen or does so imperfectly, producing an unmarketable product. In order to throw more light on the conditions affecting the ripening of these dates, and with a view to possible improvements in the commercial process, the following experiments were planned:

1. To determine whether or to what extent inversion of cane sugar will occur in mummy dates after heating to a temperature which is ordinarily considered to destroy invertase.

2. To determine whether an increase in the amount of acid in normal mummy dates will cause an increase in the inversion of cane sugar.

3. To determine whether neutralization of the acid present in normal mummy dates will inhibit or decrease the inversion of cane sugar.

4. To determine whether the presence of added acetic acid in dates heated to destroy the invertase will increase the inversion of cane sugar.

5. To determine whether, in dates heated to destroy invertase, the neutralization of the acids already present, by means of ammonia, will decrease or inhibit the inversion of cane sugar.

6. To determine the amount of inversion occurring in the normal artificial process of ripening in the original sample of mummy dates used in the above experiments. This experiment was the check with which the results of the other experiments were compared.

The material used consisted of a good uniform quality of firm dry mummies. In the execution of these experiments the individual lots of dates were treated as follows:

Lot No. 10. Original reserve sample. Dates weighed up dry and left in a closed chamber at room temperature. (Check)

Lot No. 11. Soaked in water 7 hours at 49 degrees C., water drained off and incubated at 49 degrees C. for 65 hours. (Experiment 6)

Lot No. 12. Soaked in one-tenth normal acetic acid for 7 hours at 49 degrees C., solution drained off and incubated at 49 degrees C. for 65 hours. (Experiment 2)

Lot No. 13. Soaked in one-tenth normal ammonia for 7 hours, solution drained off and incubated at 49 degrees C. for 65 hours. (Experiment 3)

Lot No. 14. Scalded for 20 minutes in water at 80 degrees C. Soaked in water 7 hours at 49 degrees C., water drained off and incubated at 49 degrees C. for 65 hours. (Experiment 1)

Lot No. 15. Scalded for 20 minutes in water at 80 degrees C. Soaked in one-tenth normal acetic acid for 7 hours at 49 degrees C., solution drained off and incubated at 49 degrees C. for 65 hours. (Experiment 4)

Lot No. 16. Scalded for 20 minutes in water at 80 degrees C. Soaked in one-tenth normal ammonia for 7 hours at 49 degrees C., solution drained off and incubated at 49 degrees C. for 65 hours. (Experiment 5)

The dates for Lots 14, 15, and 16 were scalded in one batch. 2,645.35 grams of dates were tied up in a cloth. A thermometer bulb was inserted into a good large date on one side of and adjoining the seed and the date was then tightly wrapped and tied with several turns of a string so that it fitted closely and tightly around the neck of the thermometer. The date covered thermometer was then placed near the middle of the mass of dates tied up in the cloth; the whole was then immersed in the hot water so that all the dates were covered. The temperatures within the dates were between 20 and 70 degrees C. for four minutes; between 70 and 80 degrees C. for fifteen minutes, and between 80 and 83 1-2 degrees C. for twenty minutes. After drying off the free water and weighing, the dates were divided into three lots numbered 14, 15, and 16, and further treated as above noted. When ripe the dates treated with ammonia were perceptibly darker than those soaked in water alone, and the acid dates were a little lighter in color. This difference was even more apparent in the solutions which were poured off the dates after soaking. The acid solution came off perfectly clear. The water poured off was a pale straw color. The ammonia solutions, on the other hand, were changed to an orange straw color much deeper than the water solution. These differences are probably due to organic coloring matter soluble in alkaline solutions.

Table IV. gives the results of the analyses of these samples.

TABLE IV.—ANALYSES OF DATES VARIOUSLY TREATED BEFORE RIPENING BY INCUBATION

Ex. No.	Treatment of dates	Calculated to water-free material				
		Acidity as H_2SO_4	Sucrose	Fructose	Glucose	Total sugars
		percent	percent	percent	percent	percent
12	Soaked in 1-10 normal acid; incubated at 49° C.	.505	14.63	35 99	34.89	85.51
11	Soaked in water;incubated at 49°C	.348	15.75	34 66	33 58	83.99
13	Soaked in 1-10 normal ammonia; incubated at 49° C.	Ammonia .055	28.87	28.28	27.93	85.08
15	Scalded at 80° C.; soaked in 1-10 normal acid; incubated at 49°C	.418	24.60	29.12	28.41	82.13*
14	Scalded at 80° C.; soaked in water; incubated at 49° C.	.368	29.09	26.73	26 57	82.39*
16	Scalded at 80° C.; soaked in 1-10 normal ammonia; incubated at 49° C.	Ammonia .052	37.01	22.88	23 00	82 89*
	Check, untreated	.326	49.12	17.62	17 05	83.79

*Lost sugar when scalded in water at 80 degrees C.

TABLE V.—CHANGES IN THE INVERSION OF CANE SUGAR DUE TO THE ADDITION OF ACID, TO THE NEUTRALIZATION OF THE NORMAL ACID PRESENT, AND TO SCALDING AND THEN TREATING WITH ACIDS OR ALKALIES

Exp. lots compared	Additional treatment	Increased inversion due to addition of acid	Decreased inversion due to addition of ammonia	Decreased inversion due to scalding
		percent	percent	percent
11 and 12...	Not scalded.......	1.12	....	....
14 and 15...	Scalded..........	4.49	....	....
11 and 13...	Not scalded.......	....	13.12	....
14 and 16...	Scalded..........	....	7.92	....
11 and 14...	Untreated........	....	....	13.34
12 and 15...	Acid added.......	....	....	9.97
13 and 16...	Acid neutralized...	....	....	8.14

A study of the above table will show that there was 1.12 percent of increased inversion due to adding acid in one case (Nos.11 and 12) and 4.49 percent in the other (Nos. 14 and 15); that there was a decrease of 13.12 percent of inversion when a slight excess of ammonia was added in one case (Nos. 11 and 13) and 7.92 percent in the other (Nos. 14and 16). When the scalded dates are compared with the unscalded we find three pairs as follows: Nos. 11 and 14, difference 13.34 percent; Nos. 12 and 15, difference 9.97 percent; and Nos. 13 and 16, difference 8.14 percent. These figures seem to indicate that under the conditions of the experiment an increase in the acidity of the date of .05 to .15 percent may give rise to an increase in inversion, amounting to from one to four percent; that dates containing their normal acidity were capable of inverting from eight to thirteen percent more cane sugar than dates under similar conditions having their acids neutralized and a slight excess of alkali present; and that a temperature of 80 degrees C., under the conditions used, so affected the inverting agents present as to reduce their inverting power from eight to thirteen percent. When, however, we compare No. 16, which was scalded to destroy enzymes and soaked in ammonia until it was alkaline, with the check it is seen to have inverted 12.11 percent cane sugar. (Table IV). The question now arises as to the cause of this inversion. Did it occur during the scalding, in the soaking process before the penetration and neutralization of the normal acid of the date, or did it occur during the regular incubating period. The details of an experiment to throw light on this subject are shown in the following table:

TABLE VI.—EFFECT ON INVERSION OF SCALDING AND SOAKING IN WATER OR AMMONIA

Lot No.	Treatment of dates	Moisture	Acidity	Cane sugar	Fructose & glucose	Total sugars
			Calculated to water free material			
		percent	percent	percent	percent	percent
21	Check, untreated	19.90	.309	54.92	29 99	84 91
22	Scalded in water at 80° C. for 20 minutes................	25 31	339	54 38	29 98	84 36
23	Scalded in water at 80° C. for 20 minutes; soaked in water at 50° C. for 7 hours................	33.21	.271	53.57	30.10	83 67
24	Scalded in water at 80° C. for 20 minutes; soaked in 1-10 normal ammonia at 50° C. for 7 hrs....	33.90	Ammonia 077	52 65	30 80	83 45
25	Scalded in water at 80° C. for 20 minutes; soaked in water at 50° C. for 7 hrs; incubated at 50° C. for 62 hours.................	31.72	.379	21 26	64 31	85 57
26	Scalded in water at 80° C. for 20 minutes; soaked in 1-10 normal ammonia at 50° C. for 7 hrs; incubated at 50° C. for 62 hrs. ..	32.39	Ammonia .064	34.86	48.51	83 37

It is interesting to note that although there was a regular decrease in the cane sugar found in the series 21, 22, 23, and 24, this decrease was apparently not due to the inversion of cane sugar but to the passage of cane sugar out into the solution, thus reducing the total sugar content. Fructose and glucose remained, within the limits of experimental error, the same in all four of the samples. We may therefore assume that the amount of inversion occurring during the scalding and soaking is negligible. When, however, we compare samples 25 and 26 we find a difference of 13.60 percent cane sugar due to the addition of ammonia. Again, when we compared each of these with its corresponding scalded and soaked, but not incubated lot (23, 24) we find a difference of 32.31 percent cane sugar in the one case and 17.79 percent in the other. Now comparing No. 26, which had been scalded to destroy enzymes and soaked in ammonia to neutralize acid, with the check, No. 21, we still have an unexplained inversion amounting to 20.06 percent. We have thus again shown a marked effect due to the neutralization of the acid and the rendering of the date slightly alkaline. The effect of some inverting agent which is not completely destroyed at 80 degrees C. is also again clearly demonstrated.

MATURITY AND SEPARATION OF THE CLASSES

The stage of maturity at which a date will ripen is a matter of primary importance in its practical as well as its scientific aspect. This may be determined by the appearance and texture of the date, or, more exactly, by means of specific gravity solutions. Vinson states that Deglet Noor dates having a specific gravity so low as to float in a 29 percent cane sugar solution, can not be artificially ripened into a first class product. He therefore recommends testing and separation by this means.

This method, or a slight modification as to the strength of solution used, works admirably for separating Classes 1 and 2 in the process described above, but for the separation of Classes 2 and 3 it does not give satisfaction. This is caused by the fact that in drying down to the mummy state, the flesh draws away from the seed in some dates, leaving an air space while in the other this does not occur. Irregular and misleading apparent specific gravities are the result. Since, therefore, hand picking is necessary for the separation of Classes 2 and 3, which should make up 85 or 90 percent of the dates, Class 1 can be at the same time quickly and easily thrown out. After some experience the separation of the classes proceeds rapidly, since the operator soon learns to distinguish instantly by touch to which of the three classes the dates in his hand belong.

SUMMARY

1. The inverting agents of the Deglet Noor date do not reach their greatest activity under the conditions surrounding the trees as grown up to the present time in Arizona. Such of these dates as naturally ripen in this climate, therefore, have very little of their sugar inverted. Their inverting agents require for their greatest activity, temperatures distinctly higher than occur naturally during the ripening season in Arizona.

2. The ripening of a cane sugar date is a process separate and distinct from the inversion of the cane sugar present.

3. Conditions favorable for the rapid ripening of the Deglet Noor date may be produced artificially in an oven by regulating the degree of moisture and temperature. In this ripening process the tissues of the date are softened and the tannin is precipitated, thus relieving the date of its astringency.

4. The same conditions of moisture and temperature used by the writer in ripening Deglet Noor dates were also favorable for great activity of the inverting agents present in these dates. The artificially ripened product therefore differs from that naturally ripened in having nearly all of its sugar in the inverted form.