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BUREAU OF CHEMISTRY—BULLETIN No. 141.

H. W. WILEY, Chief of Bureau.

EXPERIMENTS ON THE PROCESSING OF PERSIMMONS TO RENDER THEM NONASTRINGENT.

BY

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Assistant Chemist, Division of Foods, Bureau of Chemistry,

WITH AN INTRODUCTION BY

DAVID FAIRCHILD,

*Agricultural Explorer, in charge, Foreign Seed and Plant Introduction,
Bureau of Plant Industry.*

WASHINGTON:
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1911.

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1911.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF CHEMISTRY,
Washington, D. C., May 25, 1911.

SIR: I have the honor to submit for your approval a report of experiments on the treatment of Japanese persimmons to render them nonastringent, which have been conducted in this bureau by Mr. H. C. Gore, of the Division of Foods, during the past four years. During the progress of this investigation Mr. Gore has had the continuous cooperation of Mr. William A. Taylor and Mr. David Fairchild, of the Bureau of Plant Industry, who have selected the fruits to be tested and suggested the lines along which the work should be conducted in order to be of the most direct interest to persimmon growers. Explicit directions for processing under commercial conditions can not, however, be based on the laboratory work herein reported, and the study is to be regarded only as preliminary. I recommend that this manuscript be published as Bulletin 141 of the Bureau of Chemistry, that the growers and others interested in the industry may be informed of the tentative results of the investigation.

Respectfully,

H. W. WILEY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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EXPERIMENTS ON THE PROCESSING OF PERSIMMONS TO RENDER THEM NONASTRINGENT.

INTRODUCTION.

By DAVID FAIRCHILD,

Agricultural Explorer, Bureau of Plant Industry.

The popularity of the oriental persimmon or kaki is not what it deserves to be, and one of the chief reasons for this lies in the fact that Americans have not learned how to process them as the Japanese do, to remove the tannin and leave the fruit almost as hard and firm as apples. There is a general objection to the mucilaginous character of the fully ripe, soft Japan persimmon which seems to be difficult for the American growers to overcome, and although its sale is increasing steadily in this country, this industry, which in China and Japan ranks among the most important of fruit industries, is in its infancy, notwithstanding the fact that the Japanese called their persimmons to the attention of Americans a half century ago.

The first description in American literature which the writer has discovered of the method used by the Japanese in the processing of their persimmons is that of Prof. Tamari in the Transactions of the Michigan Horticultural Society for 1886. Prof. Tamari was one of the first students of American agriculture sent by the Japanese Government to study our agricultural institutions, and it is a curious fact that this description which he gave affecting a transplanted Japanese plant industry should have been so entirely overlooked by those who were engaged in the attempt to make it a success.

In 1899 Dr. S. A. Knapp, while traveling in Japan as an agricultural explorer, sent in a collection of Japanese persimmon plants, and in his description of them he made reference to the method of processing used by the Japanese, but no one growing the fruit seems to have taken note of his reference.

That the processing of persimmons had been untried by the growers in this country until 1906 is an indication of the complicated nature of the whole problem of transplanting an industry from one country to another, and the value of special investigations by experts in those countries from which the plant industries come to us.

The first trial of the Japanese method of processing persimmons ever made in this country was that made at the writer's suggestion,

by Mr. George C. Roeding, of Fresno, Cal., in 1906. This suggestion came naturally as the result of observations made in Japan in 1902 when the writer was surprised to find that many of the persimmons which are served there are so hard that they are pared and eaten quite as apples are in America. As this observation was made just before sailing for America, the writer did not have an opportunity to fully investigate the method employed by the Japanese, and when two years later in conversation with Mr. Roeding, the question of how to utilize the persimmon crop came up, the writer was able only to suggest that the experiment be made.

In the autumn of 1905 Mr. C. L. Watrous, of Iowa, made a trip to Japan and very kindly offered to investigate any horticultural matters which the department wished to have investigated. Among other matters he was requested to secure as complete details as possible regarding the methods of processing persimmons in use among the Japanese.

In May, 1905, Mr. Watrous made a report to the Secretary of Agriculture covering the details of the process, from which the following quotation is taken:

Dr. Fairchild asked me to make investigations as to the methods used by the Japanese for removing or changing the superabundance of tannin in the persimmon at its maturity, without waiting for the fruit to come near to decay as is the natural way. Upon my arrival at Yokohama, whither I went for this purpose, Mr. Suzuki kindly took me to various places where experts make a business of that work, packing hundreds and thousands of casks annually, as he stated. I will give the substance of the talks of various informants rather than make a detailed statement of what was said by each one. It appears that they have experimented extensively for many years in this work and have thus far been thoroughly successful in only one way; that is, to take casks in which their beer, called sake, has been stored and have the fruit put in the casks as soon as they have been emptied. The head of the cask must be immediately returned to its place and the package made air-tight. So treated, if the sake be of very pure quality and not adulterated with alcohol, the fruit, in 5 or 8 or 15 days, according as the weather may be quite warm or less so, may be removed from the package in a firm, sound condition, ready to be shipped long distances, but with the astringency all gone and the flavor fine. They have tried many other ways to cure the kaki but nothing has succeeded except the sake casks, used as above described. They say they find that if the sake is adulterated with alcohol or if the fumes of alcohol be used the astringency is soon removed from the fruit, which when first opened looks and tastes as it should, but within a few days turns black, loses its high quality, and is utterly ruined, tasting like an old turnip. The only casks used by the Japanese for this purpose are made of the wood of the *Cryptomeria*, closely resembling our cypress. The wood is quite soft and tasteless, as I found upon personal test. If, upon first opening the cask, the fruit is found not quite cured, the plan is to close the cask again as quickly as may be, then bore two small holes in opposite sides near the top and blow through, thereby removing the outer air from the top layer of fruit. Then the small holes are tightly plugged and the fruit left for further amelioration according to the judgment of the operator. All agreed that the proper curing of the kaki is expert work, requiring skill and judgment. New casks of *Cryptomeria* wood are made ready for curing kaki by wetting the inside thoroughly with good sake. This is then turned out and the cask allowed to dry. This operation is

repeated four or five times, thoroughly wetting each time the inside of the cask and the lid and allowing both to dry, absorbing as much as possible of the sake into the wood. From all that I was able to learn from the Japanese experts, I believe that if our growers desired to grow persimmons for market, the best way would be to make casks, holding about one half barrel, from the wood of our southern cypress. Then import first-class sake from Japan and use as above described. All with whom I consulted agreed that success would be reasonably certain if the work was properly done.

A copy of this report was sent at once to Mr. Roeding, and in the autumn of 1905 he made the first trial of what we termed the sake-barrel method of treating the persimmon. The results of his experiment were very encouraging, and on November 15, 1905, he sent the writer a few treated fruits, writing as follows in regard to them:

I am also sending you a few persimmons, which I have been experimenting with, in accordance with the instructions given in Mr. Watrous's letter in his report to the Hon. James Wilson. I secured a sake tub from which the liquor had just been emptied and corked it up tight for 11 days, and opened it this morning. It is really astonishing to see how completely the bitterness has left the persimmons, although they are just as hard as the day they were put in. What I am interested to know now is how they will carry, and I am therefore sending you this sample, and would be pleased to have you give me your views.

These fruits were submitted to Mr. W. A. Taylor and Col. Brackett, of the Office of Pomological Investigations, and pronounced a success, and it was not apparent that the processing had in the least injured their shipping quality. At the writer's suggestion Mr. Roeding sent a few days later a shipment to Mr. Watrous, upon whose report the experiment was made.

Fortunately at this time the whole subject of the ripening and growth of persimmons was under investigation by Messrs. W. D. Bigelow, H. C. Gore, and B. J. Howard,¹ of the Bureau of Chemistry, and these investigators were immediately informed of the experiment and shown the fruits. Appreciating the practical bearing which the adoption of some simple method of processing persimmons would have on the industry, experiments were then undertaken by the Bureau of Chemistry and continued from season to season for four years. This bulletin is the outcome of these investigations. It represents the first logical constructive work on this important subject and lays the foundation for a rational method of processing the oriental persimmon in such a way as to make it possible in the future for the retail fruit dealer to offer for sale nonastringent persimmons as hard as apples, which can be eaten at once without puckering one's mouth.

The researches of Mr. Howard² upon the localization of the astringency of the persimmon on ripening brought out the very interesting fact that the tannin of the fruit becomes localized in

¹J. Amer. Chem. Soc., 1906, 28:688.

²Tannin Cells of Persimmons, Bull. Torrey Botanical Club, 1906, 33: 567-576.

certain giant cells of the pulp. The size of these cells is of itself quite remarkable. They are large enough to be seen easily with the naked eye, sometimes reaching a length of 1 mm, but vary greatly in size and shape according to the species of persimmon. The tannin seems to be collected in them in the shape of a liquid having a higher refractive index than the contents of the ordinary cells surrounding them. Quite similar cells with apparently a similar function, i. e., the storage of tannin, occur in the carob-bean pod (*Ceratonia siliqua*), and have been observed by Mr. Walter T. Swingle in the tissues of the date fruit, which, like the persimmon, is very strongly astringent when green and loses its astringency when ripe.

In a partly ripe persimmon these giant cells do not break immediately when they are placed in the mouth but absorb water from the saliva, swell slowly, and burst, emptying their contents of thick liquid tannin-bearing substance on the tongue. Probably it is for this reason that in biting into a half-ripe persimmon it takes a fraction of a minute to get the full force of the astringency.

In the ripening process the contents of these cells undergo a change, becoming more refractive and so hard that water produces but little swelling effect. The fruit then entirely loses its astringency, presumably as a result of the hardening of the contents of the giant cells. Miss K. G. Barber, of the Bureau of Chemistry, finds that processing causes a similar change in their contents.

Encouraged by the first experiment, Mr. Roeding processed a second lot of persimmons in the autumn of 1906 and sent one of the sake tubs full of treated fruit to the writer for examination. These fruits were exhibited at a meeting of the Washington Botanical Society and specimens were sent to some of the principal fruit dealers in New York and the verdict was that the use of this method would make of the kaki a very desirable commercial fruit within a very few years.

As it seemed desirable that this or some better method of treating the persimmons be tried in a section where the fruit is grown, cooperative arrangements were made by the Office of Pomological Investigations with Mr. William Macklin, of Dinsmore, Fla., one of the largest growers of persimmons in America, and the results obtained were carefully studied during the autumn of 1907. Throughout the four seasons that these experiments were made, the writer has been an interested and sympathetic spectator, and has passed judgment on the relative freedom from tannin of the different experimental lots of fruit.

The substitution of carbonic-acid gas for the fumes of sake, the rice wine of the Japanese, and the use of dry starch to prevent the cracking of the fruit during the processing, are two very important matters which have resulted from the experiments, while the differ-

THE GIANT TANNIN CELLS OF THE JAPANESE PERSIMMON.

These are so large that by smearing some of the soft pulp of the persimmon on a glass slide and holding it up to the light they can be easily seen with the naked eye. They turn bluish-black like ink if treated with iron chlorid. These cells are the tannin containers, and as the fruit ripens their contents change in character and become highly refractive and apparently insoluble.

FIG. 1.—A SAKE BARREL SUCH AS IS USED BY THE JAPANESE IN PROCESSING PERSIMMONS.

An improvement in this process has been made and is described on page 27.

FIG. 2.—PROCESSED PERSIMMONS IN A SAKE BARREL.

These fruits were some of the first to be processed in this country, and first attracted attention to the feasibility of treating this oriental persimmon in America. These were processed by Mr. George G. Roeding, of Fresno, Cal., according to the directions furnished by the department.

FIG. 1.—PERSIMMONS AS THEY ARE NOW OFFERED FOR SALE.

A photograph taken in one of the best fruit stores of Washington, showing the soft, mushy persimmons, some actually dripping with juice and others already decaying with blue mold.

FIG. 2.—PROCESSED PERSIMMONS SUITABLE FOR EATING.

If persimmons were offered to the public in this attractive shape, as they could be when properly processed, and each fruit were guaranteed to be nonastringent, which it could be, the sale of this important fruit ought to very rapidly increase until there would be an active demand for all of the fruits which the grower could produce.

ence in the ease with which the tannin can be removed from the different varieties is a matter which bears directly on the development of the treated-persimmon industry.

As the fact may have a decided bearing on the persimmon industry as a whole, it seems appropriate to remark that since these investigations were begun the important discovery has been made that there exist in China one or more excellent varieties of the oriental persimmon which are nonastringent even while quite hard and firm. In other words, they do not require processing. One or more of the Japanese varieties, as well, are free from tannin while still hard. The writer does not believe, however, that this fact diminishes the importance of the processing, as this is so simple and inexpensive, and is so successful with some of the very best flavored varieties, that it will probably come into general use among the fruit retailers of the country.

How soon this use of the carbon dioxid treatment becomes general will depend more on the growers than on the dealers. In the writer's opinion they should see that it is perfected and advertised until the public realizes that it is no longer necessary to keep persimmons until they are mushy and mucilaginous before serving them, for, until the persimmon can be pared and eaten without a spoon it will probably never hold the position it deserves in our estimation.

RECORD OF THE EXPERIMENTAL WORK.

By H. C. GORE,

Assistant Chemist, Division of Foods, Bureau of Chemistry.

SUMMARY OF THE RESULTS OBTAINED IN 1907, 1908, AND 1909.

Experiments on the processing of persimmons have been carried on for four seasons. During the first season a large number of experiments were undertaken in Florida, Mr. William Macklin, of Dinsmore, cooperating with the department, in the attempt to apply the Japanese method as given in the report of Col. Watrous. Studies were also carried on at Washington during the same season and during 1908, 1909, and 1910. It is only the work of 1910, however, that has yielded any fundamental knowledge of the conditions under which processing occurs.

Experiments of 1907.—The results of the experiments of the fall of 1907 showed: (1) That the Japanese method unmodified could be applied with fair success to certain varieties of Japanese persimmons. Hyakume, Okame, and Zengi processed with ease. Hachiya and Tane-nashi processed, however, with difficulty, while Costata and Triumph did not yield at all. (2) The processing caused the normal rate of softening of the fruit to be considerably accelerated in case of the varieties Okame, Hachiya, Tane-nashi, Costata, and Triumph, but this effect was barely perceptible in the case of Hyakume. (3) Butter tubs whose walls were saturated with dilute alcohol were found to serve as well as sake tubs soaked with sake. (4) In using freshly picked fruit gathered during moist weather, much cracking of the epidermis and consequent spoilage occurred. Hyakume was most seriously affected. This was probably due to the condensation of water on the fruit, a result of the excessive humidity unavoidable by the method.

Experiments of 1908.—During the season of 1908, 5-gallon oak kegs, closed by oilcloth held tightly in place by one of the hoops, were employed instead of sake tubs, and dilute alcohol was used instead of sake.

Hyakume yielded very readily, becoming nonastringent in three days in experiments in which only 5 per cent alcohol was used. The rate of softening was not perceptibly affected by processing.

The Tane-nashi variety processed in from eight to nine days when alcohol stronger than 10 per cent by volume was used. Again, as with Hyakume, the rate of softening was neither hastened nor retarded by the treatment.

The Hachiya variety yielded less readily than Hyakume and more readily than Tane-nashi. At the end of four days the tannin had disappeared from the fruit held in kegs whose walls were saturated with alcohol of 15 per cent strength or stronger. The rate of softening was distinctly accelerated by the processing.

In these experiments alcohol of 40, 25, and 15 per cent by volume processed more rapidly than alcohol of 5 or 10 per cent. Alcohol of 40 per cent strength had practically the same effect on the rate of disappearance of the tannin as alcohol of 25 or 15 per cent and produced no noticeable injurious effects.

A number of other varieties were also experimented with, using 25 per cent alcohol. Yemon and Taber's 23 processed in three days, these varieties resembling Hyakume in this respect. An unnamed late-ripening Japanese persimmon grown at Rosslyn, Va., processed successfully, requiring, however, six days. Costata was tried again this year. It yielded slightly to the treatment, but softened considerably in process. Tsuru failed to yield perceptibly after 12 days in process, and also softened. A number of named varieties of native persimmons were tried, with unsuccessful results. Josephine, Miller, and Ruby all softened in from three to five days and did not become nonastringent until soft.

The results of the season, taken as a whole, were fairly satisfactory, as a number of important varieties gave good results.

Experiments of 1909.—In the experiments of 1909 the effort was made to simplify the method as far as possible. Five-gallon kegs were used, made tight by soaking the walls with water. They were wiped dry just before use and filled with fruit. A pad of paper pulp wet with 25 per cent alcohol was then placed in the upper part of each keg, resting on the fruit. In these experiments the fruits softened in advance of the check lots and it became evident that such softening must be controlled if processing was to be a success on a commercial scale. Deterioration due to cracking of the epidermis was not encountered during 1908 or 1909, probably because the fruit was less turgid than the freshly gathered fruit used in 1907 at Dinsmore.

EXPERIMENTS OF 1910.

At the beginning of the experimental work of 1910 two problems awaited solution. First, the fruit must be kept firm while in process. Prinsen-Geerligs¹ has observed that on keeping bananas in an atmos-

¹ Intern. Sugar Journal, 1908, No. 116, 10: 372.

phere deprived of oxygen the fruit remained firm; accordingly the use of some inert gas in which to keep persimmons while exposed to the vapors of alcohol suggested itself. Experiments in the use of the inert gas most readily available, namely, carbon dioxid, were, therefore, started with the first fruit received in 1910. This gas, while more active chemically than hydrogen or nitrogen, could, it was thought, have but slight effect on the vital processes of the fruit, as it was continually being formed by the fruit itself. Second, the fruit must be kept from cracking by lessening the humidity during processing. These two problems were considered together when practicable.

PREVENTION OF SOFTENING DURING PROCESSING BY KEEPING IN CARBON DIOXID.

Experiment 1.—Five firm and well-colored fruits of Hachiya were placed in each of two desiccators. In the upper part of each desiccator, resting on the fruit, was placed a block of paper pulp weighing about 100 grams and wet with 200 cc of an alcoholic solution containing 18 per cent by volume.¹ A slow constant current of air was drawn through one of the desiccators, while the other was unaerated. After several days the aerated persimmons were found to be perceptibly softer than those unaerated.

Experiment 2.—A similar experiment was begun on September 28, using Tane-nashi persimmons which had been received from Florida on September 21 and held in cold storage. Fourteen fruits, all firm and well colored and equally mature, as judged by color, were used. Three were held as checks. These became soft during an interval of five days. Four were inclosed in a desiccator, in which the air was continually renewed, with a pad of paper pulp charged with the 18 per cent alcohol. At the end of five days three of these persimmons were soft and one remained firm. Four fruits were kept in a third desiccator containing a pad of paper pulp wet with the alcohol and in which the air was displaced by carbon dioxid.² These fruits were all firm at the end of five days. Three other fruits were kept in a fourth desiccator in which no alcohol was used and in which the air was displaced by carbon dioxid. At the end of five days all of these fruits were firm.

Experiment 3.—A third set of experiments was begun on October 3, using Hachiya and Tane-nashi persimmons which had been received

¹ The alcohol contained 1 part in 20,000 of mercuric chlorid to prevent possible acetification. It has been suggested that acetic acid might possibly be the active agent in the sake tubs. The results of these experiments negative this possibility.

² The carbon dioxid used was obtained from a steel cylinder of liquefied carbon-dioxid gas. This is by far the most convenient and economical source of carbon dioxid in the quantities likely to be used in persimmon processing. It can be had from dealers in soda-water supplies in cylinders holding 20 pounds at about 10 cents per pound. This amounts to a cost of about 1 cent per cubic foot of carbon-dioxid gas at atmospheric pressure. It is necessary to use a reduction valve in releasing the gas from the very high pressure at which it is confined in the cylinder, as otherwise it tends to solidify in the stem of the needle valve, and when this occurs the delivery of the gas becomes quite unmanageable.

on September 21 and kept in cold storage. The fruits selected were firm and equally well colored.

One Hachiya and four Tane-nashi persimmons were placed in a desiccator. A pad of paper pulp soaked with 18 per cent alcohol ¹ was used as in experiment 2. A slow continuous current of air was passed through the desiccator. At the end of four days the Hachiya specimen had softened, while of the four Tane-nashi three were soft and one was just beginning to mellow. In another desiccator under identical conditions, except that carbon dioxid was used to displace the air, the Hachiya specimen softened slightly in four days, while of the four Tane-nashi one was softening and three were firm. Two Hachiya and three Tane-nashi were placed in a third desiccator in which carbon dioxid alone was used. One of the Hachiya was firm and one was softening slightly at the end of four days, and of the three Tane-nashi used one was beginning to soften while two were firm. Again the retention of firmness by displacing the air by carbon dioxid was shown.

As fruits which had been subjected to cold storage had been employed in experiments 2 and 3 and but few specimens were used, it was not considered safe to draw conclusions at this time. The results were regarded as indications only of the possible value of replacing the air by carbon dioxid.

Experiment 4.—On October 12 a fourth experiment was started on a much larger scale than any of the foregoing. Thirty-two large, well-colored, firm Tane-nashi, just received by express from Florida, were divided into four equal lots. Each lot was placed in a 10-inch tubulated desiccator which could be supplied either with a current of air or with carbon dioxid. Lot A was supplied with a continuous current of air. At the end of five days all of the fruits were soft. Lot B was similarly supplied with a steady current of air and a block of paper pulp wet with dilute alcohol was placed in the desiccator. All of these fruits also softened at the end of five days. In lot C the air was displaced by carbon dioxid. Six of these fruits remained firm and two others were just beginning to show signs of softening at the end of five days. In lot D dilute alcohol was used spread on paper pulp and the air was displaced by carbon dioxid as in lot B. At the end of five days six specimens were still firm and two were beginning to soften. Lot C was showing injury due to cracks caused by the high humidity of the chamber, and lot D was very badly injured from this cause. No such injury appeared in lots A and B.

From these four experiments, in each of which the samples, kept either without renewal of the air supply or in carbon dioxid, tended to retain their firmness while the control fruits softened considerably, it may be concluded that keeping the fruit in carbon dioxid, and so excluding oxygen, causes it to remain firm.

¹ Containing 1 part in 20,000 of mercuric chlorid as before mentioned.

STUDY OF METHODS OF APPLYING ALCOHOL.

The next study was undertaken to determine experimentally if the alcohol which it was supposed was necessary in causing the tannin to become insoluble in advance of the softening of the fruit could not be applied in such a way that the humidity would be greatly reduced. By using glass or metal containers so arranged that they could be closed air-tight, and thus avoiding the use of wooden vessels which must be soaked to be made tight, by applying concentrated alcohol in several successive small charges if found necessary, and by using an absorbent for water vapor, it was hoped to be able to process the fruit without the intense humidity incident to the Japanese method. With these objects in view, the three following experiments were made. The results were surprising. It was found that persimmons readily become nonastringent while remaining firm when merely kept in carbon dioxid without using alcohol.

Experiment 5.—In this case alcohol was applied in varying amounts to persimmons kept in carbon dioxid. Five 10-inch tubulated desiccators were employed as containers. Each was fitted with two-holed rubber stoppers carrying delivery tubes and was provided with a strip of blotting paper 24 inches long by 5 inches wide, which was so placed in the upper part of each desiccator as to nearly completely line the sides. Okame persimmons just received direct from Florida by express were used. Seventy-one fruits were divided into six lots, and each lot was weighed. One contained 11 fruits, the others 12 each. The selection was so made that as far as possible each lot consisted of equal proportions of specimens of different degrees of ripeness as judged by color. Five lots were placed in desiccators, and the sixth lot was kept outside as check. In lot A no alcohol was used. In lots B, C, D, and E the desiccators were charged with 5, 10, 15, and 25 cc of 95 per cent alcohol, respectively, by distributing it on the strips of blotting paper. After filling each desiccator with fruit and closing it, the air was displaced by carbon dioxid. In displacing the air in the desiccators charged with alcohol, the carbon dioxid was first saturated by running it through a Reiset absorption tube¹ containing alcohol, an apparatus consisting of a wide glass tube containing silver or platinum diaphragms for "scrubbing" gases.

The experiment was begun on October 17 and the fruits were examined four days later. The results were as follows: In lot A, where carbon dioxid only was used, all of the fruits were firm. The most highly colored specimen was nonastringent, the next in point of color was also nonastringent. A fruit showing a considerable proportion of green in its epidermis contained traces of soluble tannin, while still more tannin was found in a more immature specimen.

¹ Hempel's Gas Analysis, p. 83.

In lot B, in which carbon dioxid and 5 cc of alcohol were used, the highest colored fruit contained perceptible amounts of soluble tannin, although not enough for the fruit to be inedible. A specimen showing a slight amount of green near the calyx was more astringent, while the most immature fruit, as judged by color, contained much soluble tannin. The lot, on the whole, processed slightly less readily than lot A.

In lot C, using carbon dioxid and 10 cc of alcohol, the most highly colored specimen was beginning to soften. The firmer portions of the fruit contained perceptible amounts of soluble tannin, but it was edible. The highest-colored firm fruit contained slightly larger amounts of tannin, while specimens less mature than this were decidedly more astringent. On the whole, less effect of the treatment in accelerating the tannin change was shown than occurred in lots A and B.

In the case of lot D, in which carbon dioxid and 15 cc of alcohol were employed, the highest colored fruit was also found to be softening slightly. All of the remaining fruits were firm and nonastringent. Here, therefore, the presence of alcohol had accelerated the rate of processing. The fruits tasted perceptibly of alcohol.

In lot E, where carbon dioxid and 25 cc of alcohol were used, all fruits were nonastringent. Alcohol again had accelerated slightly the rate of processing.

From this experiment the fact was revealed that persimmons would process in carbon dioxid alone. Mr. Fairchild and Mr. Dorset, of the Bureau of Plant Industry, looked over the fruits critically and considered that the fruits processed in carbon dioxid alone were equal in flavor and superior in texture to those processed in carbon dioxid with alcohol, as their flesh was distinctly more crisp.

The changes in the weight of the fruit in the desiccators were very small. The largest loss in weight was 9 grams, or 0.4 per cent, which was lost from 2,181 grams of fruit. The check lot, however, lost 102 grams from an initial weight of 2,374 grams, or 4.3 per cent. The figures are given in the following table:

Changes in the weight of fruit in experiment 5.

Description.	Number of fruits.	Weight.		
		At start.	After four days.	Loss.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Lot A: In carbon dioxid, no alcohol.....	11	2,181	2,172	9
Lot B: In carbon dioxid and 5 cc alcohol.....	12	2,598	2,596	2
Lot C: In carbon dioxid and 10 cc alcohol.....	12	2,510	2,507	3
Lot D: In carbon dioxid and 15 cc alcohol.....	12	2,509	2,509	0
Lot E: In carbon dioxid and 25 cc alcohol.....	12	2,275	(¹)	-----
Lot F: Check lot.....	12	2,374	2,272	102

¹ Not weighed.

Experiment 6.—This experiment was begun before the results of experiment 5 were known. The variety Taber's 23 was used. Carbon dioxid was employed as in experiment 5, the five desiccators containing 0, 5, 10, 15, and 25 cc of alcohol, respectively. A sixth desiccator was charged with 15 cc of alcohol, and 400 grams of oven-dried starch were added to reduce the humidity. The air in each desiccator was displaced by carbon dioxid as in experiment 5. The desiccators were opened on October 22, after three days. All fruits, including the specimens in the check lot, had remained firm. All of the fruits in the desiccators were nonastringent. They suffered practically no changes in weight during the three days except in the case of the fruit in the desiccator containing starch. Here the loss was 48 grams, or 2.45 per cent, while the check lot lost 44 grams, or 2.55 per cent. The following table shows the losses in weight of the different lots of fruits used in this experiment:

Loss of weight of fruit used in experiment 6.

Description.	Number of samples.	Weights.		
		At start.	After three days.	Loss.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Lot A: Carbon dioxid alone.....	16	1,985	1,983	2
Lot B: Carbon dioxid+5 cc of alcohol.....	16	1,778	1,778	0
Lot C: Carbon dioxid+10 cc of alcohol.....	16	1,819	1,822	(¹)
Lot D: Carbon dioxid+15 cc of alcohol.....	16	1,847	1,847	0
Lot E: Carbon dioxid+25 cc of alcohol.....	16	1,825	1,834	(¹)
Lot F: Outside control.....	16	1,727	1,683	44
Lot G: Carbon dioxid+15 cc of alcohol+400 grams of starch....	15	1,958	1,910	48

¹ These lots apparently gained in weight by 3 and 9 grams, respectively.

None of the fruits cracked, and therefore no advantage was shown in the use of starch to reduce humidity. The most highly colored specimens in the controls were very astringent. A few of the fruits in the desiccator in which 25 cc of alcohol were used showed browned areas on the epidermis, probably due to the alcohol.

Experiment 7.—The Tsuru variety was processed, using carbon dioxid and varying amounts of alcohol as in experiments 5 and 6. This experiment was begun on October 19, and the desiccators were opened three days later. Seventy-two fruits were used in all, divided into six lots of 12 fruits each. In lots A, C, and E 400 grams of dried starch was placed as in experiment 6. The following results were recorded when the persimmons were examined on October 22:

Lot A.—The fruit was kept in carbon dioxid without alcohol. All fruits were firm, and a well-colored specimen contained tannin, the "pucker" being apparent a moment after tasting and becoming very marked. The fruit was nearly processed, as samples of the same color in the check lot instantly showed the presence of much soluble tannin, but the change was not quite complete.

Lot B.—This fruit was kept in carbon dioxid and 5 cc of alcohol. All specimens were firm. A well-colored fruit contained a slight amount of tannin, rather less than was found in the fruit of lot A.

Lot C.—The fruit was kept in carbon dioxid and 10 cc of alcohol. All samples were firm and edible but contained perceptible traces of tannin, which became more noticeable the longer the pulp was held in the mouth.

Lot D.—The fruit was kept in carbon dioxid and 15 cc of alcohol. All specimens were firm and thoroughly processed. Here a distinct effect of alcohol in accelerating the disappearance of the soluble tannin was produced.

Lot E.—Carbon dioxid and 25 cc of alcohol were used. Fruits were all firm and completely processed. Of the 12 specimens used, 8 showed superficial injury, consisting in a browning of the surface extending over one side of the fruit, similar in appearance to the discoloration observed in experiment 6 and probably an effect of the alcohol. The persimmons seemed rather tough in texture—that is, lacking turgor or crispness.

Lot F.—Check lot. Two fruits were softening slightly. These softened fruits were extremely astringent, the “pucker” developing instantly on tasting.

The fruits in the presence of starch lost in weight slightly more than the control and much less moisture collected on the walls of the desiccator containing starch than on the walls of the others, indicating a distinct effect in lessening the humidity. As again no fruits cracked, as in experiment 6, the results can not be said to demonstrate clearly the value of the use of starch.

The following table shows the loss in weight for the several lots of fruit used in this experiment:

Loss of weight in samples used in experiment 7.

Description.	Number of samples.	Weights.		
		At start.	After three days.	Loss.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Lot A: Carbon dioxid alone+400 grams of starch.....	12	1,836	1,786	50
Lot B: Carbon dioxid+5 cc of alcohol.....	12	1,853	1,854	(¹)
Lot C: Carbon dioxid+10 cc of alcohol+400 grams of starch....	12	2,141	2,100	41
Lot D: Carbon dioxid+15 cc of alcohol.....	12	1,949	1,955	(¹)
Lot E: Carbon dioxid+25 cc of alcohol+400 grams of starch.....	12	1,961	1,927	34
Lot F: Check.....	12	1,731	1,699	32

¹ These lots apparently gained in weight by 1 and 6 grams, respectively.

PROCESSING BY KEEPING IN CARBON DIOXID ALONE.

As a result of the discussion of these results with Mr. Taylor and Mr. Fairchild, it was decided to abandon the use of alcohol in the experiments on processing during the remainder of the season, since

the exclusion of oxygen is probably the controlling factor, not only in the retention of firmness but in the disappearance of the tannin. Alcohol, while accelerating the rate of processing in some cases, seemed wholly unnecessary, and, as used in experiments 5, 6, and 7, seemed to cause loss in turgor, or crispness, while in some cases, as in experiments 6 and 7, where 25 cc of alcohol were used, superficial injury resulted.

Experiment 8.—Three small lots of persimmons, Seed and Plant Introduction Nos. 13835, 13841 (Japanese), and No. 22367 (Chinese), fruiting for the first time in this country, were received from Mr. Dorset and from Mr. Bisset, Bureau of Plant Industry, and treated with carbon dioxid. All processed successfully in five days.

Experiment 9.—Five lots of hard but well-colored native persimmons (*D. Virginiana*), picked from different trees in the vicinity of Washington, D. C., were placed in carbon dioxid. After five days the fruits were still excessively astringent. They were again placed in carbon dioxid and examined 10 days later. All of the fruits by this time had softened somewhat and many had decayed. Three of the lots, however, were nonastringent before they became very soft, while the controls were astringent until very soft, and thus a slight but perceptible effect due to the processing may be assumed.

Experiment 10.—In experiment 10 processing was undertaken on a large scale. The fruit was placed in a galvanized-iron can provided with a narrow, deep trough about the upper rim, into which fitted the turned-down edges of the cover. When the trough was filled with water and the cover placed in position, the can was sealed air-tight. The arrangement proved to be not sufficiently positive, however, and it can not be recommended. Sixty-five hard Okame persimmons, purchased on the local market, were processed from November 1 to November 5. All became nonastringent. Sixty fruits were firm on November 5 and 5, or 8 per cent, had softened. In the control, consisting of 11 fruits, 4, or 36 per cent, were soft. Of the 60 firm persimmons, 4, or 7 per cent, showed superficial cracking as a result of the humid conditions in the can. Forty-eight of the sound, firm, processed fruits were wrapped and divided into two equal lots. One lot was stored at a constant common-storage temperature of about 21° C. (69.8° F.), and the other was kept in cold storage at about 2° C. (35.6° F.). A record was made of the rate of softening of each lot. Too few fruits were used for the results to have the degree of validity desirable, but they are of interest in showing the effect of processing on the rate of softening in common and cold storage. The processed fruits kept in common storage softened slightly more rapidly than the control in common storage. Seventy per cent of the processed fruit so stored had softened in nine days after removal from the can, and 63 per cent of the check lot kept at the same temperature

became soft during the same interval. None of the fruit in cold storage softened up to this time or until five days later. From then on it slowly softened. After a total storage period of 37 days, 12 specimens, or 50 per cent, were soft. After softening, the processed fruits darkened and were then inferior in flavor to softened unprocessed fruits.

Experiment 11.—Two six-basket carriers of Tane-nashi persimmons, purchased on the local market, were placed in process in the iron cans on November 2. This fruit had been in cold storage. Nine days were required for the processing and much injury, due to cracking, occurred. The results of the experiment were far from satisfactory. It is possible that some air had access to the fruit, coming through the water seal as a result of contraction due to cooling, and also of the contraction which is always noticed when carbon dioxid is first used.¹ The fruit behaved abnormally, due probably to some unknown cause and not to cold storage, as was at first thought, as it was found later that cold-storage fruit processed normally (see p. 23).

Experiment 12.—On November 9 an experiment which consisted in treating Okame persimmons, purchased on the local market, with carbon dioxid in the iron cans was begun. This fruit, too, failed to process satisfactorily, requiring eight days, and seemed to be distinctly injured, as when received the firm fruits lacked the turgor, or crispness, of normal persimmons. The fruits did not crack badly, though the humidity in the cans was pronounced. After processing, the fruit browned as it softened and developed a disagreeable "cooked" flavor. Physiological death had probably occurred as a result of processing.

The results of experiments 11 and 12, though not successful, are useful in showing that abnormal fruits may be found which, perhaps because of some injury to their physiological processes, do not quickly become nonastringent when asphyxiated. The results also indicate the great need of some method of diminishing the humidity when processing in large quantities.

A number of problems now arose in the consideration of processing in carbon dioxid on a commercial scale, and the succeeding experiments were planned to answer as many of them as practicable. Some of these problems were as follows:

1. How is the rate of softening affected by processing?
2. Is the fruit injured by overprocessing, and if so, how?
3. Can fruit be cold stored and then withdrawn and processed?
4. Is there a simple relation between the tannin content of the

¹ This is noticeable when considerable amounts of fruit are used, and is probably due to the solution of carbon dioxid in the fruit juices.

fruit and the relative ease of processing so that from an analysis one may tell how readily fruits will process?

5. Can processing be successfully conducted by keeping the fruit under water or under other solutions?

6. Can processing be successfully conducted by allowing the fruit to asphyxiate itself by closing it up tightly?

EFFECT OF PROCESSING IN CARBON DIOXID ON THE RATE OF SUBSEQUENT SOFTENING.

Experiment 13.—In this experiment the effect of processing on the rate of softening was studied. Five varieties of persimmons were placed in tubulated 10-inch desiccators and the air displaced by carbon dioxid. Triumph, Tane-nashi, and Zengi required three days, and Hachiya and Tsuru five days before the fruit became non-astringent. The fruits were removed from the containers when processed and all except the specimens used in tasting were wrapped and kept in baskets beside the respective check lots. Counts of the number of softened fruits were made at the end of two and three days. The most immature specimens, as judged by color, were used in testing to determine whether or not processing was complete. It was assumed that these would soften last had they not been used in tasting, and they were so considered in the counts. The data are given below in tabular form and are shown graphically in figures 1 to 5, inclusive.

Proportion of different varieties softening after processing at intervals varying from 5 to 33 days.

Interval in days.	Hachiya.		Tane-nashi.		Triumph.		Tsuru.		Zengi.	
	Pro- cessed (23). ¹	Check (17).	Pro- cessed (16).	Check (12).	Pro- cessed (32).	Check (21).	Pro- cessed (21).	Check (17).	Pro- cessed (29).	Check (18).
	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
5.....	13	29	6	67	0	10	0	6	0	6
8.....	52	65	25	83	0	29	14	18	0	22
10.....	91	76	63	100	0	62	48	18	42	39
12.....		88	94		19	71	90	24	48	39
14.....		88			38	81		29	69	39
16.....		100			97	90		29	83	39
19.....						90		29	93	56
22.....						100		29	97	67
24.....								59		89
27.....								71		100
29.....								76		
33.....								100		

¹ The total number of fruits used in each lot is given at the top of each column. It varied from 12, in the case of the large Tane-nashi persimmons, to 32 of the small Triumph variety.

Hachiya softened a little while in process and afterwards softened slightly more rapidly than its control.

Tane-nashi softened very slightly while in process, while the control softened to the extent of 67 per cent. On withdrawal, the processed fruits softened about as rapidly as the check lot.

Processed Triumph remained firm for 10 days from the beginning of the experiment, while during this interval the check lot softened to the extent of 62 per cent. The processed fruit then softened rapidly, all becoming soft during the next six days.

FIG. 1.—Hachiya: Effect of processing on the rate of softening (processed for five days).

FIG. 2.—Tane-nashi: Effect of processing on the rate of softening (processed for three days).

Tsuru showed marked and unmistakable acceleration in rate of softening caused by processing. Although no specimens softened in process during the five days, while 6 per cent softened in the check lot, all of the processed fruit was soft seven days after removing from the desiccator, whereas but 24 per cent of the check lot were soft at this time.

Zengi softened more rapidly as a result of processing. No softening occurred in the processed fruit until 10 days from the beginning of the experiment when 42 per cent of the fruit were found to have softened while only 39 per cent of the control were soft.

FIG. 3.—Triumph: Effect of processing on the rate of softening (processed for three days).

FIG. 4.—Tsuru: Effect of processing on the rate of softening (processed for five days).

FIG. 5.—Zengi: Effect of processing on the rate of softening (processed for three days).

Not enough fruits were used for the data to have more than a qualitative value. Taken as a whole, however, they show conclusively that processing accelerates the rate of softening.

INJURY TO THE FRUIT BY OVERPROCESSING.

Experiment 14.—In this instance a study was made of the injury to the fruit by overprocessing. Two varieties, Triumph and Zengi, were kept in carbon dioxid in desiccators for 3, 6, 9, 12, 14, 17, 20, and 23 days. A desiccator of fruit was opened at each of these intervals. The specimens withdrawn were wrapped and stored at room temperature beside the respective check lots. Twenty-three to 28 fruits of Triumph and 20 fruits of Zengi were kept in each desiccator and in each check lot. Triumph softened gradually while in the desiccators. After 17 and 20 days, 38 and 57 per cent, respectively, had softened. Zengi remained much firmer. Five and 15 per cent had softened after the same two intervals. After removal, all of the processed fruits softened more rapidly than their respective controls but the rate of softening after removal was not distinctly changed by overprocessing.

The interesting fact was brought out that the abnormality mentioned on pages 18 and 19, developing after or during softening and consisting of the development of a brown color and a disagreeable "cooked" flavor, occurred much more often in the case of persimmons which were kept in carbon dioxid for prolonged intervals than with fruits processed for three days or unprocessed.¹ Frozen persimmons developed a somewhat similar appearance on keeping at room temperature after thawing and it is probable that physiological death is indicated; in other words, that the normal life processes failed to resume action upon the restoration of air, when it had been withheld for more than a brief period. In no case, however, did the abnormality occur until after the fruits had begun to soften. In the case of Triumph, none of the softened fruits of the check lot showed the abnormality. One of the fruits processed for three days became abnormal after softening, the remainder of the softened fruits remaining normal. Fifty-seven per cent of the lot processed for six days became abnormal after softening. All of the fruits in the lots processed for still longer periods became abnormal on softening.

With the variety Zengi, while the check lot and the fruit processed for three days remained normal, 25, 50, and 70 per cent of the lots withdrawn after 6, 9, and 12 days, respectively, became abnormal on softening.

EFFECT OF PREVIOUS KEEPING IN COLD STORAGE ON PROCESSING IN CARBON DIOXID.

Experiment 15.—In this experiment Triumph, Tsuru, and Zengi persimmons kept in cold storage at about 36° F., from November 9 to December 6, an interval of 27 days, were withdrawn and placed in

¹ This is probably the same phenomenon as that described by Mr. Watrous (see p. 6) as occurring in processing by the Japanese method when sake adulterated by alcohol, or alcohol itself, is used.

carbon dioxid. At the end of four days all fruits had become non-astringent. Nine specimens of Triumph were used, and of these three softened during the four-day period in the carbon dioxid. During the next two days 70 per cent softened. One specimen each of the Tsuru and Zengi varieties softened while in process and during the next two days storage at room temperature 70 per cent of the Tsuru and 15 per cent of the Zengi became soft. None of these softened fruits developed the abnormality described on page 18, with the exception of one specimen of Zengi. The experiment shows that persimmons may be cold stored and then processed, but that they may be expected to soften quickly after removal from the carbon dioxid.

RELATION BETWEEN CHEMICAL COMPOSITION AND EASE OF PROCESSING.

Experiment 16.—As experience had shown that the different Japanese varieties vary greatly in regard to the ease with which they become nonastringent when placed in carbon dioxid, a study was made of the chemical composition of the five varieties received on November 9 to determine if ease of processing could be correlated with the chemical composition. The analyses are given in the following table:

Analyses of five varieties of Japanese persimmons used in the experiment.

Variety.	Solids.	Marc. ¹	Ash.	Soluble alkalinity as K ₂ CO ₃ .	Protein (N×6.25).	Reducing sugars as invert.	Total sugars as invert.	Polarization (normal weight in 200 mm. tube).		Sucrose by—		Tannin. ²
								Di-rect.	In-vert.	Red-uction.	Polar-ization.	
Hachiya....	<i>Per ct.</i> 25.06	<i>P. ct.</i> 4.09	<i>P. ct.</i> 0.49	<i>Per ct.</i> 0.30	0.64	17.75	17.71	-4.85	-5.3	None.	0.34	0.88
Tane-nashi...	18.52	3.66	.39	.27	.42	14.52	14.59	-4.0	-4.2	0.07	.15	.13
Triumph.....	20.82	3.45	.41	.28	.40	14.93	14.74	-4.0	-4.2	None.	.15	1.39
Tsuru.....	21.08	3.52	.46	.30	.61	14.72	14.46	-3.55	-3.6	None.	.04	1.54
Zengi.....	21.83	5.29	.49	.33	.73	14.82	14.72	-3.9	-4.0	None.	.08	.41

¹ 100-gram samples extracted with alcohol as in J. Amer. Chem. Soc., 1906, 28: 688.

² By Proctor's modification of Lowenthal's method. U. S. Dept. Agr., Bureau of Chemistry Bul. 107, Rev., p. 150.

It was expected that the amounts of soluble tannin in the persimmons would vary roughly in the same way as the relative ease with which the fruits processed. It was found, however, that while the Tsuru variety, the most difficult to process of the five, contained 1.54 per cent of tannin, calculated as gallo-tannic acid, and the variety Zengi, processing with great ease, contained 0.41 per cent, Hachiya, with 0.88 per cent of tannin, was clearly more difficult to process than Triumph, which contained 1.39 per cent of tannin, and Tane-nashi, containing but 0.13 per cent of tannin, yielded less readily than Zengi.

The data, however, are not conclusive, as too little attention was paid to the stage of ripeness at which the persimmons were analyzed. The more mature the persimmon the more readily does it process and the less its content of soluble tannin, so that while there may be a relation between ease of processing and tannin content, in the analyses given, it may have been obscured by differences in the degree of maturity of the fruits. The figures are of interest in showing the high food value of persimmons and accord in this respect essentially with earlier analyses.¹

PROCESSING BY KEEPING FRUIT UNDER LIQUIDS.

Experiment 17.—To determine whether processing could be successfully conducted by keeping the fruit under a liquid several varieties of persimmons were so kept for several days. It was anticipated that water alone would injure the fruit because of the operation of plasmolysis and, therefore, other liquids of higher osmotic strength were also used. The fruit was kept under water, brine, 33 per cent sugar, and 33 per cent glycerin solutions. From four to eleven specimens each of Tsuru, Triumph, and Zengi persimmons were placed under these four liquids for six days and were then examined.

All of the fruit kept under water was ruined by the formation of cracks in the epidermis. The water became very turbid and developed a disagreeable odor, indicating butyric fermentation. It gave a reading of 1° Brix, showing that solid matter had been extracted from the fruit. Triumph seemed to be slightly less astringent, but still contained soluble tannin. Tsuru did not yield perceptibly, but Zengi became nonastringent. The specimens, though they had lost soluble material to the water, had gained in weight. The weights before and after keeping under water are as follows:

Gain in weight of three varieties of persimmons kept under water.

Varieties.	Number of samples.	Before treatment.	After treatment.	Gain.	
				Grams.	Per cent.
Triumph.....	6	Grams. 525	Grams. 557	32	6.09
Tsuru.....	4	632	654	22	3.48
Zengi.....	6	610	620	10	1.63

¹ For a summary of these analyses, see J. Amer. Chem. Soc., 1906, 28: 688.

The fruits kept under saturated brine lost their turgor and were salty and astringent. The fruits all lost weight, the weights before and after processing being as follows:

Loss in weight of three varieties of persimmons kept under saturated brine.

Varieties.	Number of samples.	Before treatment.	After treatment.	Loss.	
				Grams.	Per cent.
		<i>Grams.</i>	<i>Grams.</i>		
Triumph.....	6	581	553	28	4.81
Tsuru.....	4	693	661	32	4.61
Zengi.....	6	716	661	55	7.68

In case of fruits kept under 33 per cent sugar solution, no cracking or other abnormality was apparent, but all fruits were astringent. Very slight losses in weight occurred, as follows:

Loss in weight of varieties kept under a 33 per cent sugar solution.

Varieties.	Number of samples.	Before treatment.	After treatment.	Loss.	
				Grams.	Per cent.
		<i>Grams.</i>	<i>Grams.</i>		
Triumph.....	11	1,065	1,059	6	0.56
Tsuru.....	4	633	629	4	.63
Zengi.....	5	572	565	7	1.22

Of the fruits kept under a 33 per cent glycerin solution, Triumph and Tsuru both developed cracks, destroying the commercial value of the specimens so affected. Triumph and Zengi were nonastringent, but Tsuru contained much soluble tannin. Considerable losses of weight occurred, as follows:

Loss in weight of varieties kept under a 33 per cent solution of glycerin.

Varieties.	Number of samples.	Before treatment.	After treatment.	Loss.	
				Grams.	Per cent.
		<i>Grams.</i>	<i>Grams.</i>		
Triumph.....	13	1,308	1,253	55	4.20
Tsuru.....	4	673	659	14	2.08
Zengi.....	5	601	582	19	3.16

On the whole the results were distinctly unfavorable to processing by keeping under liquids, as the fruits failed to process readily and in many cases were ruined for commercial purposes.

PROCESSING BY AUTOASPHYXIATION.

Experiment 18.—This experiment was undertaken to determine how rapidly the fruits themselves would exhaust the oxygen from the atmosphere surrounding them. It seemed possible that processing

might be successfully conducted by keeping the persimmons in air-tight containers and relying on the fruit itself to exhaust the oxygen of the air instead of replacing the air by carbon dioxid.

The rate of respiration of the several varieties was first determined, using persimmons just received from Florida by express. The fruit was kept in desiccators in an automatically regulated constant temperature chamber at 20.8° C. The method of conducting the measurement is that described in Chemistry Bulletin No. 142, "Studies on Fruit Respiration." The carbon dioxid evolved by the several varieties is expressed in the table below in terms of milligrams per kilogram per hour and in terms of the volume of carbon dioxid evolved per kilogram of fruit during 24 hours.

Rate of respiration of the several varieties of persimmons used.

Varieties.	Number of specimens.	Weight in grams.	Interval in hours.	Carbon dioxid evolved.			
				Grams.	Milli-grams per kilogram per hour.	Cubic centi-meters per hour.	Cubic centi-meters per 24 hours.
Hachiya.....	16	2, 130	17	0.8404	22.3	12.22	293.3
Tane-nashi.....	10	2, 276	17	.9636	24.0	13.15	315.6
Triumph.....	18	1, 752	17	.5324	17.2	9.43	226.3
Tsuru.....	16	2, 571	17	1.0430	23.0	12.61	302.7
Zengi.....	20	2, 484	17	1.1090	25.3	13.87	332.9

As the varieties studied evolved from 226 to 333 cc of carbon dioxid per kilogram in 24 hours, or roughly from one-fourth to one-third of their volume, it could reasonably be expected that self-asphyxiation would be successful, as if the air spaces between the fruits in the container equaled the volume of the fruits, the oxygen in the air inclosed would be well exhausted at the end of 24 hours.

In the asphyxiation experiments which were begun on November 9, using the same varieties of persimmons from the same shipment as those in the preceding respiration test, the fruits were shut up tightly in 10-inch tubulated desiccators. These were fitted with delivery tubes reaching to the top and bottom, respectively, so that samples of the gases for analysis could be withdrawn at the conclusion of the experiment before opening. Four desiccators were employed. One contained the fruit only, another contained the fruit and 400 grams of oven-dried starch, a third was filled with fruit and dry, clean sand, which was poured around the persimmons so as to diminish considerably the volume of the air spaces. In the fourth desiccator the air was displaced by carbon dioxid.

The desiccators were securely closed. Vaseline was used as a lubricant between the ground-glass surfaces. The stoppers and covers were kept tight by tying. The tube leading to the bottom of each desiccator was capped with a rubber tube carrying a glass plug.

To the other tube a simple mercury trap was attached so that gases could readily find their way out but could not enter the desiccator. In no case, however, were any changes of pressure observed.

After five days samples of the gases were drawn from the top and bottom of each desiccator. The analyses of the gases were made by the usual Hempel methods, taking due precautions to avoid contamination with the outside air. The analyses are given in the following table:

Analyses of gases from desiccators filled with persimmons, after standing five days.

Lot.	Description.	Analyses of gases.		
		Carbon dioxid (CO ₂).	Oxygen (O ₂).	Nitrogen by differ- ence (N ₂).
A	Nothing added; top.....	45.7	0.8	53.5
	Nothing added; bottom.....	46.4	1.0	52.6
B	Starch added; top.....	52.6	.6	46.8
	Starch added; bottom.....	54.6	.0	45.4
C	Sand added; top.....	47.8	2.7	49.5
	Sand added; bottom.....	54.4	.3	45.3
D	Carbon dioxid added; top.....	84.1	1.1	14.8
	Carbon dioxid added; bottom.....	89.6	.0	10.4

They show that a fairly complete absorption of oxygen occurred in lots A, B, and C. In lot C the sample of gas withdrawn from the top of the desiccator was from above the surface of the sand next the cover. The oxygen was here much higher than in the other samples. As is usual in such experiments, the oxygen was found to have been displaced by much more than an equal volume of carbon dioxid, an illustration of the well-known fact that carbon dioxid evolution continues when anaerobic conditions are imposed. Each desiccator contained some of all of the five varieties. In the desiccator containing the fruit alone, Tsuru was found to be softening slightly, but the fruits were extremely astringent. The two Hachiya specimens were both softening and were very astringent. Of the three Tane-nashi fruits used, two were firm and one was softening. The softening fruit was but very slightly astringent and processing was perceptible. Eight specimens of Triumph were used and all were firm save one, which was just commencing to soften and was distinctly astringent. The variety Zengi was firm and nonastringent.

The five specimens of Tsuru from the desiccator containing starch were all firm and very astringent. Of the five Hachiya fruits employed, two were beginning to soften and were very astringent. The two fruits of Tane-nashi were both firm. One was nonastringent, while the other contained enough tannin to be inedible. Two of the nine Triumph fruits employed were soft and free from soluble tannin; and the firm fruits seemed rather less astringent than normal per-

simmons, indicating that partial processing had occurred. All of the variety Zengi processed completely.

In the desiccator containing sand three out of four of the variety Tsuru were softening and were very astringent. One of the three Hachiya persimmons used was firm, one was softening, and one was soft. This last fruit was nonastringent, but the softening specimen contained much soluble tannin. One specimen of the three Tane-nashi used was beginning to soften and was slightly astringent, while the other two were firm and very full of soluble tannin. Seven specimens of Triumph were used and all remained firm. The most highly colored fruit was free from tannin, but another specimen tried was slightly but perceptibly astringent, indicating that here, as in the fruit of this variety from the other two desiccators, it yielded slightly but distinctly. Zengi were completely processed and all were firm.

In the desiccator in which the air was displaced by carbon dioxid four of the five Tsuru fruits were firm and one was softening. Of the two Hachiya, one was soft and the other was beginning to soften. Both of the Tane-nashi fruits used were firm and seven out of eight of Triumph remained firm. All of the Zengi were hard. All of the fruit was nonastringent and the fact is clearly brought out that processing by removing the air by carbon dioxid at first is far preferable to allowing the fruit itself to exhaust the oxygen, as processing occurs much more promptly and completely.

The outside control gave the following results with regard to the rate of softening. Of the four Tsuru, two were firm and two were softening. Of the three Hachiya persimmons two were softening and one was already soft. The three Tane-nashi were all soft. The seven Triumph were all soft and of the seven Zengi used six were firm, while one had softened. The firm fruits, including Zengi, were all very astringent.¹

Taken as a whole, two facts of interest are brought out as a result of the experiment: First, as already stated, processing occurs far more promptly when carbon dioxid is used in displacing the air about the fruit than when the oxygen is removed by the respiratory processes; second, the relative ease with which the different varieties process, already brought out in experiments 13 and 17, is again well illustrated. Tsuru failed to yield perceptibly, Hachiya yielded but slowly, while Tane-nashi and Triumph processed with greater ease in the order named. Zengi was extremely easy to process. Auto-asphyxiation, plus a slight accelerative effect due to vapors of alcohol, evidently causes processing in the Japanese method. Displacing the air by carbon dioxid appears to be a marked improvement over this procedure.

¹ Unprocessed, firm Zengi are here noted as astringent because at times highly colored, hard specimens of yellow-fleshed fruit of this variety are edible, containing no perceptible soluble tannin.

GENERAL SUMMARY OF RESULTS.

1. The study of the Japanese method of processing persimmons during the first three seasons showed that while some varieties, such as Hyakume and Taber's 23, would process with ease, other varieties, such as Tane-nashi and Hachiya, processed with more or less difficulty, while Triumph and Tsuru did not yield perceptibly.

2. The use of the Japanese method was but partly successful, even with the fruits which processed easily, because they often cracked as a result of the high humidity incident to the process and often softened unduly while in the casks.

3. Experiments 1 to 4 of the season of 1910 (p. 12) showed that if persimmons are kept in carbon dioxid during processing they tend to remain firm, the lack of oxygen apparently retarding the life processes which result in softening.

4. Experiments 5, 6, and 7 (p. 14) developed the fact that by keeping the fruits in carbon-dioxid gas for from three to five days the fruit processes, becoming nonastringent, while remaining firm.

5. In carbon dioxid in the presence of alcohol vapors the rate of processing was at times more rapid than in carbon dioxid alone, but the fruits lost somewhat in the quality of crispness, and in two instances showed superficial injury.

6. The presence of well-dried lump starch in the containers with the fruit caused losses in weight during processing by carbon dioxid, indicating that the intensely humid conditions occurring when fruit is closed up tightly may be lessened by such means. By the use of starch or other absorbent for water vapor it is hoped that losses by cracking may be avoided.

7. The Japanese varieties Tane-nashi, Triumph, Hachiya, Zengi, Okame, Taber's 23, Tsuru, S. P. I. Nos. 13835 and 13841, and the Chinese variety S. P. I. No. 22367, processed successfully in carbon dioxid in from three to five days. Hyakume and Yemon will also probably yield successfully, as they processed easily by the Japanese method.

8. Two lots of Japanese varieties, Okame and Tane-nashi, failed to process satisfactorily, requiring eight and nine days, respectively, in carbon dioxid before becoming edible. These lots were not received direct from the growers, as were most of the other lots, and probably had suffered prior physiological injury.

9. Native persimmons (*D. virginiana*) failed to yield successfully.

10. The rate of softening of persimmons was on the whole slightly but distinctly accelerated by processing. In the case of Okame persimmons (experiment 10) softening after processing was controlled by the application of cold storage.

11. On overprocessing in carbon dioxid a large proportion of the persimmons became dark in color on softening subsequently, probably suffering physiological death as a result of the treatment.

12. Processing by keeping the fruit under water or other liquids was unsuccessful, as the processing did not occur rapidly and the fruit was often badly injured.

13. Processing by autoasphyxiation was unsuccessful, as the fruit failed to process as promptly as when the air was displaced by carbon dioxid, and some varieties failed to yield at all.

14. Persimmons processed readily in carbon dioxid after a cold-storage interval of 27 days, but softened rapidly after processing.

15. Chemical analyses of five varieties of persimmons showed no relation between tannin content and ease of processing; the results here are not conclusive, however, as insufficient attention was given to maturity.