EFFECT OF STORAGE CONDITIONS ON DRIED SCALLIONS

by

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Submitted in Partial Fulfillment
of the Requirements for the
Degree of Bachelor of Science

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

January, 1962

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LETTER OF TRANSMITTAL

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Cambridge, Massachusetts

January 17, 1962

Professor N. S. Scrimshaw
Head, Department of Nutrition,
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Massachusetts Institute of Technology
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Dear Sir:

A thesis entitled "Effect of Storage Conditions on Dried Scallions" is hereby submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Food Technology.

Respectfully submitted,

Signature redacted

CHOKYUN RHA SONG

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INTRODUCTION

The scallion, sometimes called the green onion or the Welsh onion, is a leaf vegetable which forms green tubular long leaves directly from white stems.

"The Vegetable Encyclopedia and Gardeners Guide", Tiedjens (1943) gives following description for scallions: The Ciboul or Welsh onion (Allium fistulosum), sometimes called the two bladed onions, is native of Siberia. It forms a slight swelling at the base of the leaves and does not form large onions. It is grown primarily for its leaves, which are used in salads.

Although in the United States scallions are eaten fresh or mixed with salad or used to garnish gravy and soup, in most families the use of it is not very frequent. However in the eastern countries, such as China, Japan, Korea and the Philippines, the use of scallions is almost as frequent as that of salt in the western countries. In these countries the scallion is chopped fine and put on dishes already cooked and ready to eat or, if added in cooking, it would be the last ingredient to be added.

In Southeast Asian countries the scallion is highly seosonal and prices of this vegetable may vary as much as four hundred to five hundred percent during different seosons.

Because of its frequent use, high price during off-seosons and the work involved in chopping it, the preservation of scallions is of great importance in Asian countries.

Preservation of Scallions involves problems associated with flavor and color change. However, no studies have been made on the flavor and color change of the scallion due to preservation although many studies of this type have been done on other food materials.

Considering this situation, it was felt that a study of undesirable changes in dried scallions might someday help the food industry, especially the underdeveloped food industries of the Asian countries.

LITERATURE RESEARCH

I. The Composition and Nutritional Value of Scallion

While the nutritional value of scallion seems to be of little importance in western countries because of its limited use, it is of considerable importance in eastern countries, such as China, Japan, Korea or the Philippines. In these countries scallions are used in food almost as frequently as the salt is in the western countries as mentioned in previous page.

Scallions are used as seasonings in small amount. However, scallions provide a convenient source of ascorbic acid for the people in the isolated areas during winter months.

The composition of scallions so listed in "Standard Tables of Food Composition in Japan"(1954, Committee on Food Composition) is as follows:

Welsh onions (Allium fistulosum L.)

	Fresh	White part	Green part	Green
Calories	29	25	24	25
Water(g)	91.8	93.0	92.4	92.5
Protein(g)	1.5	1.4	1.7	1.6
Fat(g)	0.1	0.1	0.2	0.2
Carbohydrate(g)	6.1	5.1	4.9	5.0
Ca (mg)	50	29	100	0.7
P (mg)	51	24	51	-
Fe (mg)	1.0	0.3	1.0	-

	Fresh	White part	Green part	Green
Vitamin A(I.U.)	400	0	1,400	-
Vitamin B_1(mg)	0.5	0.5	0.06	-
Vitamin B_2(mg)	0.1	0.03	0.05	-
Vitamin C(mg)	25	20	40	-
Niacin(mg)	0.5	0.9	0.5	-
Refuse	15	0	0	15

The composition of scallions listed in "Food Composition Table for Foods Commonly Used in Latin America" (1961, Incap Icnnd) is as follows:

	Leaves	Stems
Calories	31	27
Moisture(g)	90.3	91.6
Protein(g)	1.6	1.2
Fat(g)	0.2	0.1
Carbohydrate(g)	7.1	6.6
Fiber(g)	1.7	1.3
Ash(g)	0.8	0.5
Ca(mg)	64	27
P(mg)	40	31
Fe(mg)	0.7	0.4
Vitamin A(mcg)	210	-
Thiamine(mg)	0.06	0.04
Riboflavin(mg)	0.09	0.04
Niacin(mg)	0.6	0.04
Vitamin C(mg)	15	15
Refuse	-	-

Woot Tseun Wu Lenny gives the composition of the scallions in "Composition of Foods used in Far Eastern Countries"(1952) as follows:

	Edible Parts	As Purchased
Refuse(g)	0	35
Water(g)	90.5	58.8
Food energy(cal.)	31	20
Protein(g)	1.9	1.2
Fat(g)	0.4	0.3
Carbohydrate(g)	7.5	4.8
Ash(g)	0.7	0.5
Ca(mg)	18	12
P(mg)	49	32
Fe(mg)	-	-
Vitamin A(I.U.)	-	-
Thiamin(mg)	0.05	0.03
Riboflavin(mg)	-	-
Niacin (mg)	-	-
Vitamin C(mg)	27	18

There are some variations among the compositions of scallions given above, but in general the compositions showed agreement between them.

All above analysis seem to be for the fresh samples. Although it is known that there are commercial dried scallions available in the Philippines the data on this product was not found.

Since the flavor of the scallion is similar to onion and garlic, although milder, the flavoring component probably is allyl-prophyl-disulphide($C_6H_{12}S_{12}$).

Most vegitables loose their water soluble vitamins in cooking, blanching or rinsing. Usually scallions are added uncooked to ready-to-eat foods. Therefore, the vitamins in scallions are retained in the foods and carried through to the human body without waste. Then the significance of vitamin C content in scallions becomes obvious.

II. Problems in the Preservation of Dried Foods

A. Effect of Moisture

Water is universary present in all foods as found in nature and is a major component of most food materials.

A very large number of studies in food science have been made on the subject of the properties of water in foods, because of its most important role in the biological, chemical, mechanical, and physical behavior of foods.

The water existing in foods is held in the system because of chemical or physical energy, or a combination of the two. It is known that physical absorption is the major mechanism of holding water while the chemical binding also contributes considerably. This means that the water is held by secondary forces, of which the hydrogen bonding is most important. But all the water molecules absorbed on the food do not have the same binding energy.

First, some water molecules are absorbed on polar sites of food components such as proteins and carbohydrates. After all these sites have been filled, additional water molecules are adsorbed by the water molecules already attatched to the polar sites, forming several layers of water molecule until condensation of excess water appears in pores and capillaries of the food.

As more water molecules are sorbed, it increases the number of sites available for adsorption and changes the number and size of capillaries available for bulk condensation.

It is known that the water molecules which are adsorbed directly on polar sites are bound much more tightly than the water molecules layers on subsequent layer and much more than the water condensed in capillaries.

The difference in the binding energies are reflected also in the relative availability of different portions of the water for chemical reactions, and for bacterial growth.(Acker and Kaiser, 1959; Scott, 1957). Therefore, the higher the water content of the sample, the faster or greater would be the deterioration or denaturalization. This relationship seems to be more dramatic when the food sample has been denatured such as in drying or processing.

B. Browning

After when fruit and vegetable tissues are injured in any way or cut and peeled during processing, a darkening of the tissue called browning occurs. Some browning reactions are enzymatic and only occur in fresh living tissue or at least in tissue that still contain active enzymes. Therefore when enzymes are denatured by heat or any other agent, this reaction no longer occurs. Other types of browning are nonenzymatic, and more browning in food materials are of this types.

Nonenzymatic Browning

A great numbers of studies were devoted to the nonenzymatic browning of foods. Early workers stressed the importance of the Maillard reaction, or the condensation of carbonyl groups of sugars with amino groups of amino acids, or of proteins.

Recent studies have emphasized the complexity of reactions that may be involved in browning. Hodge(1953) suggested that there are three types of reactions causing browning in food system. He stated that all three types of browning is caused by formation of colored polymers which involves the presence of di- or polycarbonyl compounds, and differs in the initial reactions preceeding the formation of colored compounds.

The first type is initiated by the Maillard reaction. The condensation products undergo the Amadori rearrangement, and after intermediate steps are converted to colored products by aldol condensation and polymerization.

The second type of browning is known as caramelization and the initial reactions involve sugars or polyhydroxy-carboxylic acids. This types of browning is not often involved in the browning at low temperatures.

The third major type of browning is initiated by oxidation of compounds such as polyphenols, or of ascorbic acid to di-, or polycarbonyl compounds.

Although the Hodge's presentations are generally accepted Schroeder et al.(1955), from the experiments concluded that Maillard reaction is not involved in browning. They thought that the effect of pH on sugars is responsible for the browning and the Maillard reaction occuring at the same time without being directly connected.

On the other hand, Lea(1958), Joslyn(1957) and Wagner (1955) all concluded that Maillard-type of reaction is the first and most important cause of browning.

Effect of Water on Browning

There are considerable data and organoleptic analysis on the subject of the effect of water on browning, although the clear answer, explanation, and interpretation of how water influences browning is not presented.

Harper and Tappel(1957), Regier and Tappel(1956 a,b), and Tappel et al.(1958) concluded that, in the absence of oxygen, browning was found to be the most important cause of deteriorating change in their study on freeze-dried meat. In the presence of oxygen, oxidative racidity was the most important change. They considered nonenzymatic browning as being initiated by the Maillard reaction, and found it to be very sensitive to moisture content. Analytical relation between browning and moisture content was not found, but browning definitely increased with water content over the whole range of investigated moisture contents.

Ross(1948) studied the storage change in dehydrated potatoes of 1.2 to 7.5 percent moisture content and found a linear relation between the logarithm of rate of browning and the moisture content. Similar relationship was found by Coulter(1950) for dehydrated milk.

Legault et al.(1931) studied the browning of dehydrated sulfited vegetables, and concluded that browning of sulfited vegetables preceeds through an apparent induction period followed by an approximately linear increase in browning. The induction period is considerably less in nonsulfited vegetables. Over the moisture contents, of 5 to 8 percent for potatoes and carrots and 2 to 8 percent for cabbage, browning increased exponentially with moisture content. In 1954 Legault et al. reported that browning was slowed down eight fold by the additional removal of moisture by a desiccant.

Recently, Salvin(1959) proposed that a minimum rate of browning and a minimal rate of other reactions occurs when water is present in monolayer quantities.

It is difficult to generalize or draw a logical conclusion of the effect of water on the browning of foods. It is also not possible to determine the methamatical relationship between the moisture content and the rate of browning from the studies made in the field up to now. It is believed that in dehydrated foods browning is very slow at zero water content and that browning increases with moisture content at least up to moisture content of 10 percent.

III. Off-Flavor Development

Control and preserve of flavor and aroma in processed food is of utmost importance in determining the quality and selling price of the product. Conditions and methods of processing should be always chosen so as to prevent off-flavor development in the product. In the production of foods, control of temperatures, length of processing time, packaging and storage conditions, all affect the flavor of the end product.

The sensations of flavor are very complex relations, and it is impossible to measure them with any simple chemical or physical test. Since the flavor of food products is so important in determining their commercial value, many methods for measuring flavor have been developed. Expert tasters, panel of taster, different tests, dilution tests, and the flavor profile method are commonly applied for the evaluation of the flavor.

EXPERIMENTAL PROCEDURES

I. Preparation of the Samples

Fresh scallions were purchased from the local market. The scallions were trimmed of roots and cleaned leaving only the edible portions. These were then washed, cut into lengths of two to three inches, and sliced lengthwise to about one sixteenth inch in width. The prepared scallions were placed on stainless steel wire mesh trays, the trays placed in the cabinet drier and the product dried in hot air.

The drying temperature of the scallions was 100 to 120 F which was found to be low enough to prevent the browning during drying and high enough to prevent browning due to prolonged drying time. The relative humidity of the air was about 41 percent.

During the drying the trays were turned around and the position of the trays were shifted to give the uniform or nearly uniform drying conditions. Some of the scallions which seemed to dry faster were taken out from the dryer earlier than the rest in an attempt to make the moisture content uniform throughout the sample.

The dried samples were cut to approximately .0016 $inches^2$ or smaller with a food chopper. (The Habart Food Cutter, Habart MFG Co., Troy, Ohio) The dried samples were put into jars and placed in constant temperature rooms at 20°, 37° and 57° C.

II. Determination of the Moisture Content of the Samples

The moisture of the samples were determined by vacuum oven method described in "Official Methods of Analysis of the Association of Official Agriculture Chemist"(1955,22.3).

III. Determination of the Percent Transmission of Extracts

Browning was determined by measurement of the percent transmission of clarified extracts of dried scallions. The methods of clarification (Karel, 1960, Hendel et all., 1950, Notter et al., 1958, Stephenson et al., 1958) were modified as described below.

1. A sample of dried scallions equivalent to 1.25 gm of dry solids was suspended in 50 ml of distilled water.

2. The suspension was blended for 3 minutes in an osteryer then another 50 ml of distilled water was added.

3. The suspension was filtered through a coarse filter paper(S & S, No 595, 100 cycles, 9 cm, Black Ribbon).

4. The filtrate was then passed through a millipore filter paper, using a millipore filter assembly(Millipore Filter Corporation, 1955). The filter paper used was "AA millipore filters, pore size 0.8 micron ".

5. The filtrate was collected and the percent transmission of the filtrate was measured using "Lumetron Colorimeter, Model No. 401, Photovolt Corporation". Distilled water and the water extract from the sample stored at 20°C were used as the blanks references at 420 mμ and 490mμ respectively. Optically matched test tubes were used for the determination.

IV. Determination of Color of the Dried Scallions

The visual color of the samples of the dried scallions with different moisture contents and different storage periods and temperatures were determined by matching the color with color plates of "Dictionary of Color" 1st ed., Maerz and Paul, McGraw-Hill Book Company, Inc., New York.

V. Dtermination of Off-Flavor by Organoleptic Method

The panel was asked to judge the samples for the determination of off-flavor. Samples(3 gram Portions) were placed in 50ml beakers. The panel was then asked to indicate the order of preference between sets of 3 samples stored at 20°, 37° and 57°C.

The panel was also asked to indicate their preference among them with their eyes closed. This test was carried out for samples with and without added water.

RESULTS

I. Moisture Content of the Sample

In preparation of the samples of dried scallions, when drying temperatures of 100° to 120° F, and relative humidity of about 41 percent were used, the samples obtained were satisfactory.

The dried scallion samples with different moisture content were obtained by varying the drying period. The samples obtained with this methods contained moistures of 2.3, 2.7, 2.9, 3.3, 3.6, 4.1, 5.7, 6.8, 7.0, 7.3, 8.4, 10.0, 10.4, 11.7, and 11.8 percent.

II. Determination of the Percent Transmission of Extracts

The tables and graphs presented on following pages show the percent transmission obtained for different samples by the method described in the experimental procedures.

TABLE I

Moisture, Period of Storage, Temperature of Storage, and Percent Transmission and Optical Density of the Extract of the Samples

Moist. (%)	Period of Storage (months)	Temp. of Storage (°C)	A %Trans. 420 mμ	A O.D. 420 mμ	B %Trans. 490 mμ	B O.D. 490 mμ
2.3	0.66	20	51	2.92	100	0
2.3	0.66	37	40.3	3.9	75	1.25
2.3	0.66	57	27	5.6	58	2.35
2.7	12.5	20	61.6	2.12	100	0
2.7	12.5	37	46.3	3.32	90	0.5
2.7	12.5	57	4	14	19.2	7.02
2.9	0.66	20	48.5	3.13	100	0
2.9	0.66	37	38.5	4.2	69	1.58
2.9	0.66	57	36.5	4.35	77.5	1.13
3.3	7.5	20	46	3.4	100	0
3.3	7.5	37	34	4.6	87	0.55
3.3	7.5	57	4	12.5	15	8.05
3.3	20.5	20	8	11	-	-
3.3	20.5	37	7	11.3	-	-
3.3	20.5	57	5.5	11.5	-	-
3.6	9	20	38	2.38	100	0
3.6	9	37	39	5.98	78.7	1.05
3.6	9	57	3	15	9.3	10.2
3.6	22	20	28	5.57	100	0
3.6	22	37	17	7.5	65	2.85
3.6	22	57	1.5	17.5	3	14.5

TABLE I (Continued)

Moist. (%)	Period of Storage (months)	Temp. of Storage (°C)	A %Trans.	A O.D. 420 mμ	B %Trans.	B O.D. 490 mμ
4.1	8	20	61	2.15	100	0
4.1	8	37	41	3.82	82.2	0.63
4.1	8	57	24.8	6.5	67	1.7
4.1	21	20	26	5.8	100	0
4.1	21	37	3	14.5	30.5	5.7
4.1	21	57	1	19	0.04	20
5.7	20.5	20	43.4	3.62	100	0
5.7	20.5	37	15	8	62	2.16
5.7	20.5	57	2	17.5	8	10.7
6.8	14.5	20	53	2.8	100	0
6.8	14.5	37	25.5	5.7	72	14.2
6.8	14.5	57	2.7	16	11	9.5
7.0	14.5	20	43.5	3.6	100	0
7.0	14.5	37	23.2	6.3	73.5	16.5
7.0	14.5	57	3	17	17	7.6
7.3	20.5	20	21	6.8	100	0
7.3	20.5	37	14.5	8.2	58	2.38
7.3	20.5	57	8.1	10.8	12.2	9
8.4	20.5	20	15.7	7.95	100	0
8.4	20.5	37	10.8	9.6	48.9	3.1
8.4	20.5	57	8	10.8	11.2	9.5
10.4	14.5	20	38	4.4	100	0
10.4	14.5	37	14	8.4	61	2.15
10.4	14.5	57	1.8	17	10.2	9.8

TABLE I (Continued)

Moist. (%)	Period of Storage (months)	Temp. of Storage (°C)	A %Trans. 420 mμ	A O.D. 420 mμ	B %Trans. 490 mμ	B O.D. 490 mμ
11.7	0.66	20	51.5	2.85	100	0
11.7	0.66	37	38	4.16	68.1	1.65
11.7	0.66	57	10.8	9.7	26	5.8
11.8	20.5	20	22.5	6.3	100	0
11.8	20.5	37	8	10.7	15.2	8
11.8	20.5	57	7.6	11	9.8	10

Note: Moist. = Moisture content.
Temp. = Temperature.
% Trans. = % Transmission.
O. D. = Optical density.
A = Distilled water was used as blank.
B = Extract from the sample stored at 20° C was used as blank.

TABLE II

Moisture, Period of Storage, Temperature of Storage, and Percent Transmission and Optical Density of the Extract of the Samples after 20 Days of Storage

Moist. (%)	Temp. of Storage (°C)	A %Trans. 420 mμ	A O.D. 420 mμ	B %Trans. 490 mμ	B O.D. 490 mμ
2.3	20	51	2.92	-	-
2.3	37	40.3	3.9	75	58
2.3	57	27	5.6	1.25	2.35
2.9	20	48.5	3.13	-	-
2.9	37	38.5	4.2	69	1.58
2.9	57	36.5	4.35	77.5	1.13
11.7	20	51.5	2.85	-	-
11.7	37	38	4.16	68.1	1.65
11.7	57	10.8	9.7	26	5.8

Note: Moist. = Moisture content.
Temp. = Temperature.
% Trans. = % Transmission.
O.D. = Optical Density.
A = Distilled water was used as blank.
B = Extract from the sample stored at 20°C was used as blank.

TABLE III

Moisture, Temperature, Percent Transmission, and Optical Density of the Extract of the Samples After 14.5 Months of Storage

Moist. (%)	Temp. of Storage (°C)	A % Trans. 420 mμ	A O.D.	B % Trans. 490 mμ	B O.D.
6.8	20	53	2.8	-	-
6.8	37	25.5	5.7	72	14.2
6.8	57	2.7	16	11	9.5
7.0	20	43.5	3.6	-	-
7.0	37	23.2	6.3	73.5	16.5
7.0	57	3	1.7	17	7.6
10.4	20	38	4.4	-	-
10.4	37	14	8.4	61	2.15
10.4	57	1.8	17	10.2	9.8

Note: Moist. = Moisture Content.
Temp. = Temperature.
% Trans. = % Transmission.
O.D. = Optical Density.
A = Distilled water was used as blank.
B = Extract from the sample stored at 20°C was used as blank.

TABLE IV

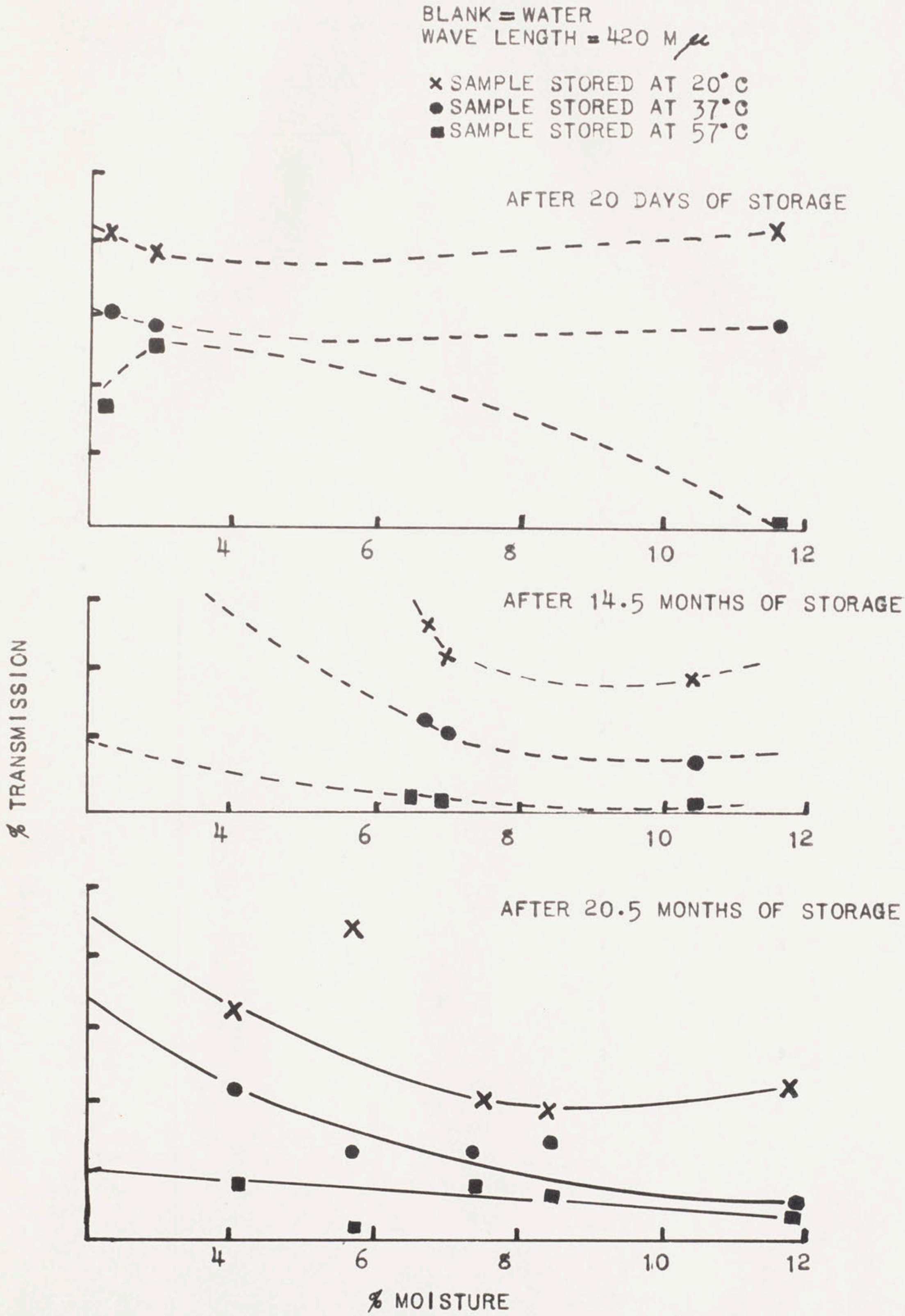
Moisture, Temperature, Percent Transmission, and Optical Density of the Extract of the Samples after 20.5 Months of Storage

Moist. (%)	Temp. of Storage (°C)	A % Trans. 420 mμ	A O.D.	B % Trans. 490 mμ	B O.D.
4.1	20	36	4.4	-	-
4.1	37	21	6.8	6.3	1.98
4.1	57	8	10.6	12	9.2
5.7	20	43.3	3.62	-	-
5.7	37	15	8	62	8.16
5.7	57	2	17.5	8	10.7
7.3	20	21	6.8	-	-
7.3	37	14.5	8.2	58	2.38
7.3	57	8.1	10.8	12	9
8.4	20	15.7	7.95	-	-
8.4	37	10.8	9.6	48.8	11.2
8.4	57	8	3.1	3.1	9.5
11.8	20	22.5	6.3	-	-
11.8	37	8	10.7	15.2	8
11.8	57	7.6	11	9.8	10

Note: Moist. = Moisture content.
Temp. = Temperature.
% Trans. = % Transmission.
O.D. = Optical density.
A = Distrilled water was used as blank.
B = Extract from the sample stored at 20°C was used as blank.

GRAPH I

% TRANSMISSION VS. % MOISTURE

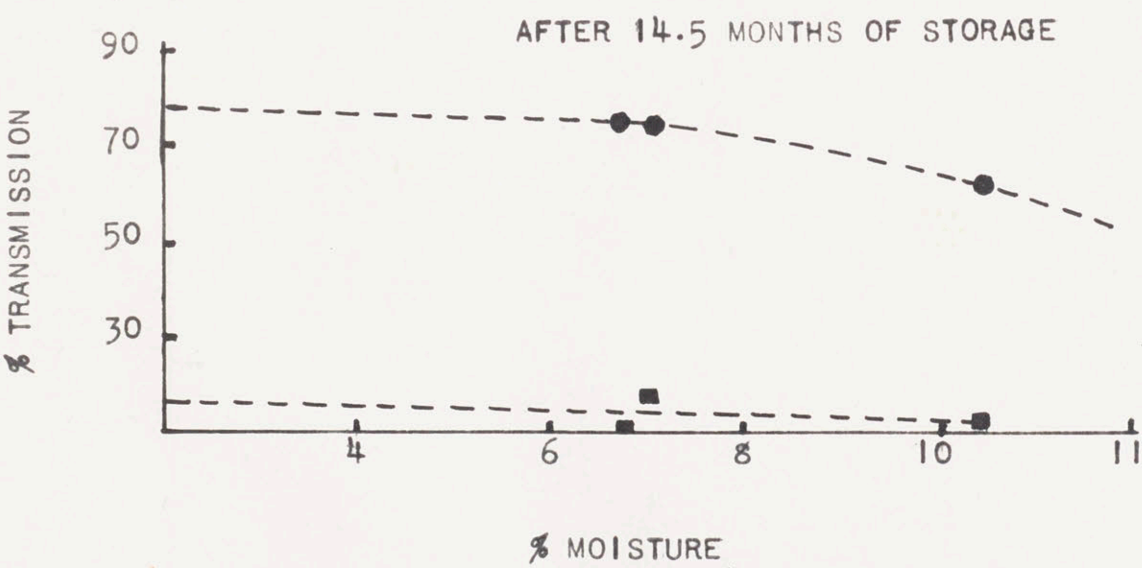


GRAPH II

% MOISTURE VS. % TRANSMISSION

BLANK* = SOLUTION OF THE SAMPLE STORED AT 20°C
WAVE LENGTH = 490 Mμ

● SAMPLE STORED AT 37° C
■ SAMPLE STORED AT 57° C



* THIS GRAPH IS TO SHOW THE RELATIVE CHANGE IN THE % TRANSMISSION BETWEEN THE SOLUTION OF THE SAMPLES STORED AT 20°C AND 37°C, AND 20°C AND 57°C BY USING THE ABOVE BLANK.

TABLE V

Storage Period, Temperature, Percent Transmission, and Optical Density of the Extract of the Samples with 3% Moisture Content

Period of Storage (months)	Temp. Of Storage (°C)	A %Trans. 420 mμ	A O.D. 420 mμ	B %Trans. 490 mμ	B O.D. 490 mμ
0.66	20	48.5	3.13	-	-
0.66	37	38.5	4.2	69	1.58
0.66	57	36.5	4.35	77.5	1.13
7.5	20	46	3.4	-	-
7.5	37	34	4.6	87	0.55
7.5	57	4	12.5	15	8.05
12.5	20	61.6	2.12	-	-
12.5	37	46.3	3.32	90	0.5
12.5	57	4	14	19.2	7.02
20.5	20	8	11	-	-
20.5	37	7	11.3	-	-
20.5	57	5.5	11.5	-	-

Note: Temp. = Temperature.
% Trans. = % Transmission.
O.D. = Optical Density.
A = Distilled water was used as Blank.
B = Extract from the sample stored at 20° C was used as blank.

TABLE VI

Storage Period, Temperature, Percent Transmission, and Optical Density of the Extract of the Samples with 4.1 Moisture Content

Period of Storage (months)	Temp. of Storage (°C)	A % Trans. 420 mμ	A O.D.	B %Trans. 490 mμ	B O.D.
7.5	20	47	4.72	-	-
7.5	37	22.8	6.4	71	1.5
7.5	57	4.7	13.2	24	6.2
8.0	20	61	2.15	-	-
8.0	37	41	3.82	82.2	67
8.0	57	24	6.5	6.3	1.7
19.0	20	36	4.4	-	-
19.0	37	21	6.8	63.5	1.98
19.0	57	8	10.6	12	9.2
21.0	20	26	5.8	-	-
21.0	37	3	14.5	30.5	5.7
21.0	57	1	19	0.04	20

Note: Temp. = Temperature.
% Trans = % Transmission.
O.D. = Optical Density.
A = Distilled water was used as blank.
B = Extract from the sample stored at 20°C was used as blank.

TABLE VII

Storage Period, Temperature, Percent Transmission, and Optical Density of the Extract of the Samples with 11% Moisture Content

Period of Storage (months)	Temp. of Storage (°C)	A %Trans. 420 mμ	A O.D. 420 mμ	B %Trans. 490 mμ	B O.D. 490 mμ
0.66	20	51.5	2.85	-	-
0.66	37	38	4.16	68.1	1.65
0.66	57	10.8	9.7	26	5.8
14.5	20	38	4.4	-	-
14.5	37	14	8.4	61	2.15
14.5	57	1.8	17	10.2	9.8
20.5	20	22.5	6.3	-	-
20.5	37	8	10.7	15.2	9.8
20.5	57	7.6	11	8	10

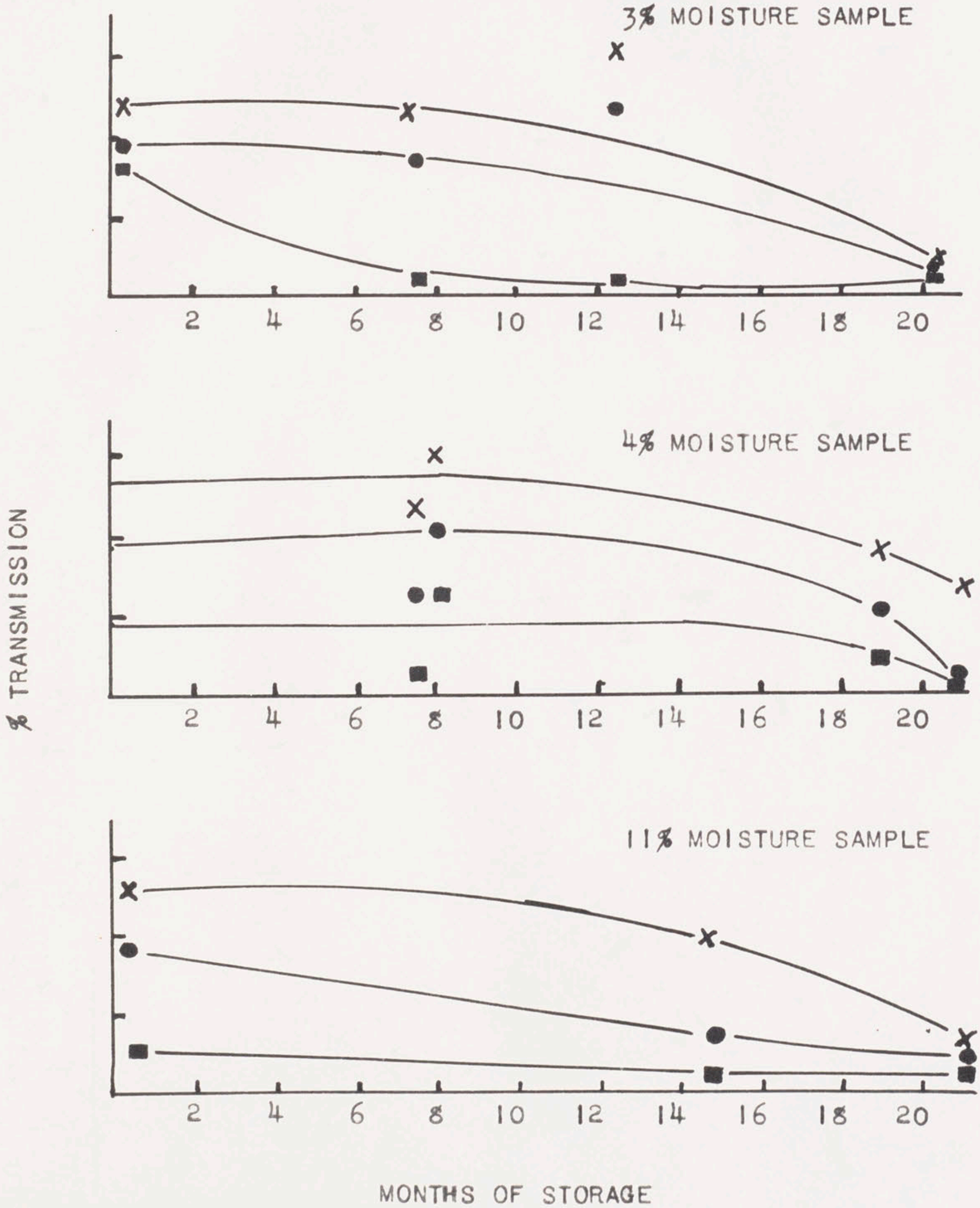
Note: Temp. = Temperature.
% Trans. = % Transmission.
O.D. = Optical Density.
A = Distilled water was used as blank.
B = Extract from the sample stored at 20° C was used as blank.

GRAPH III

% TRANSMISSION VS. MONTHS OF STORAGE

BLANK = WATER
WAVE LENGTH = 420 Mμ

× SAMPLE STORED AT 20°C
● SAMPLE STORED AT 37°C
■ SAMPLE STORED AT 57°C

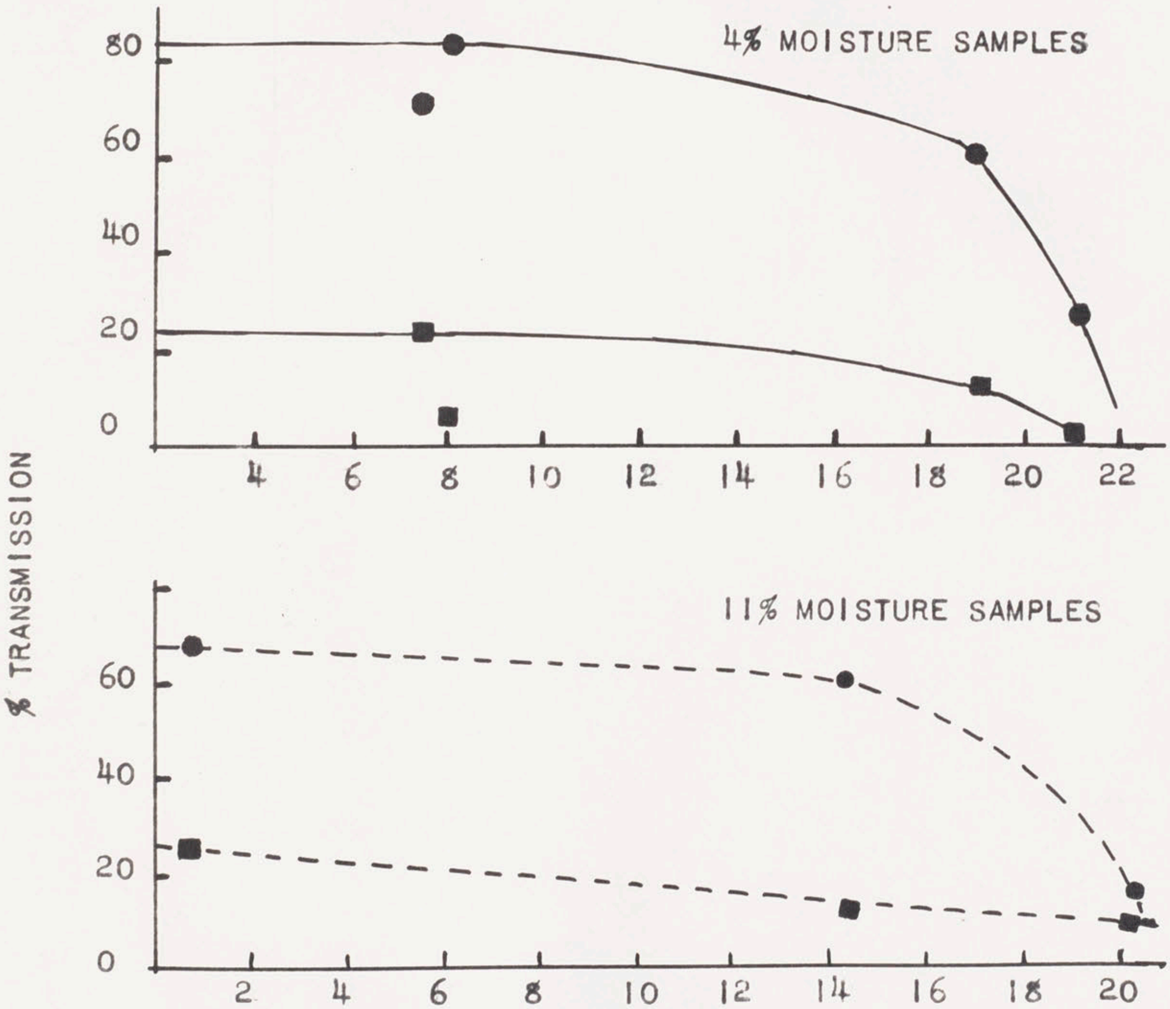


GRAPH IV

% TRANSMISSION VS. MONTHS OF STORAGE

BLANK* = SOLUTION OF THE SAMPLE STORED AT 20°C
WAVE LENGTH = 490 mμ

● SAMPLE STORED AT 37°C
■ SAMPLE STORED AT 57°C



MONTHS OF STORAGE

* THESE GRAPHS ARE TO SHOW THE RELATIVE CHANGE IN THE % TRANSMISSION BETWEEN THE SOLUTION OF THE SAMPLES STORED AT 20°C AND 37°C, AND 20°C AND 57°C BY USING THE ABOVE BLANK.

III. Determination of the Color of the Dried Scallions

The Plate No, and number and letter assigned to described color, in the "Dictionary of Color", which matched the color of the samples are given in the table on the following page.

TABLE VIII

Description*of the Color of the Samples

% moisture Content	Storage Period in Months	Storage Temperature of 20° C	Storage Temperature of 37° C	Storage Temperature of 57° C
2.3	0.66	PL 18 K7	PL 18 J7	PL 20 A7
2.7	12.5	PL 20 E7	PL 20 L8	PL 14 A8
2.9	0.66	PL 20 A7	PL 21 B7	PL 20 A7
3.3	20.5	PL 21 G6	PL 21 G7	PL 15 L12
3.6	22	PL 19 H7	PL 20 I5	PL 15 I12
4.1	19.5	PL 21 G6	PL 21 G7	PL 15 L12
5.7	20.5	PL 20 H6	PL 13 F2	PL 13 I6
6.8	14.5	PL 21 H6	PL 22 G5	PL 15 H7
7.0	14.5	PL 20 L6	PL 14 J1	PL 14 J6
7.3	20.5	PL 20 I6	PL 20 J5	PL 14 A7
8.4	20.5	PL 21 G4	PL 21 G5	PL 15 H12
10.4	14.5	PL 14 C1	PL 14 L4	PL 14 K8
11.7	0.66	PL 20 H8	PL 14 L1	PL 14 J6
11.8	20.5	PL 13 L2	PL 14 K8	PL 15 A12

*This description of the color of the samples was derived from "Dictionary of Color" 1st ed., Maerz and Paul, McGraw-Hill Book Company, Inc., New York, 1930.

IV. The Determination of Off-Flavor by Organoleptic Tests

Sample used in this experiment has moisture content of 11.7 percent and was stored for 20 days at 20°C, 37°C, and 57°C.

1. Twelve expert testers were presented with the 3 gm sample and asked to determine the orders of preference of the samples with respect to the color and odor. Among twelve of them eleven agreed that they preferred the colors of the sample stored at 20°C best, the 37°C sample next and the sample stored at 57°C least. Among twelve testers, nine agreed that they preferred the odor of the scallions in order of storage temperatures according to the following: that stored at 20°C better than that stored at 37°C better than that stored at 57°C.

2. The samples were put into 50ml beaker and six testers were asked to close their eyes and tell the order of preference of the samples. Three of them liked the 57°C sample best, the 37°C sample next and 20°C sample least. Two of them liked the 57°C sample best 20°C sample next and 37°C sample least. Only one of them liked the 20°C sample best the 37°C sample next and the 57°C sample least.

3. The same samples were suspended with 20 ml of water. Ten panel members were asked to close their eyes and tell the order of preference of the samples. Among

them eight liked the 20°C sample best, the 37°C sample next and the 57°C sample least. One of them liked the 20°C sample best but the 37°C sample least. Only one of them liked the 57°C sample best, the 20°C sample next and the 37°C sample least.

V. Determination of Color by Vision

Table IX listed in the following page divides the samples into four groups according to the colors: no browning, a trace of browning but still acceptible, considerable browning not acceptible as a commercial product, and a maximum of browning. The storage temperature and periods are given for each sample. The storage periods do not necessarily represent the first day at which the sample attained the color since color was checked only periodically.

The data in the table show that it is not possible to relate the color of the dried scallions with the moisture content and the temperature of the storage. In order to draw a relationship between these factors, more exact and more frequent observations would be required to find out the exact day at which the color changed into any particular shade.

TABLE IX

The Degree of Browning of the Samples grouped into four different Shades

Storage Temp. (°C)	Moisture (%) Content	Period of Storage (months)
NO BROWNING		
20	2.3	0.66
20	2.7	12.5
20	2.9	0.66
20	11.7	0.66
37	2.3	0.66
37	2.9	0.66
57	2.3	0.66
57	2.9	0.66
TRACE OF BROWNING		
20	3.3	22
20	4.1	19.5
20	4.1	21
20	5.7	20.5
20	6.8	14.5
20	7.0	14.5
37	2.7	12.5
37	6.8	14.5
37	11.7	0.66
57	11.7	0.17
CONSIDERABLE BROWNING		
20	8.4	20.5
20	10.4	14.5
37	3.6	22
37	4.1	21
37	7.0	14.5
37	7.3	20.5
37	10.4	14.5
57	11.7	0.17
MAXIMUM BROWNING		
57	11.7	0.66
57	2.7	12.5
57	5.7	20.5

Note: Storage Temp. denotes storage temperature.

DISCUSSION OF RESULTS

I. Dehydration of Scallions

1. Conditions Required to Produce Better Quality Scallions

Raw Material. When scallions, refrigerated for three days after purchase, were dried, the end product showed detectable amount of browning.

Scallions were also stored at -40°F for three weeks, then dried. The resulted product was not acceptable and inferior to the sample which was refrigerated before drying.

This indicates that the absolutely fresh raw material is necessary to obtain a superior quality end product.

Preparation. Scallions dried without cutting required a longer drying time. When the scallions were out to two to three inches in length the required drying time was somewhat shortened. The scallions were cut to two to three inches in length then sliced as thin as one sixteenth of an inch in width. Then the drying time was appreciably shortened and the quality of the end product was excellent. Since slicing by hand takes considerable time, some mechanical means of slicing would be essential to obtain best quality in commercial production.

Chopping in a food chopper before drying is not suitable because of the fact that product commented in this manner is very difficult to spread on the drying trays in a thin layer.

Temperature. The scallions dried at 100°F to 120°F in a cabinet dryer were quite satisfactory in both color and flavor. The drying temperature of 100°F to 120°F is considerably lower than that of 180°F to 190°F, 160°F, 165°F, 120°F to 165°F, 145°F, 140°F to 165°F, 110°F to 200°F, 115°F to 145°F used for apples appricot, figs, grapes, logenberries, onions and cabbage respectively(Cruess, 1958). The necessity of using lower temperature for drying scallions is due to high perishability of this product.

Sorting during Dehydration. The green part of the scallions seemed to dry faster than that of white part. Sorting out of already dried green part during drying, turning around and shifting the position of scallions was advantageous in obtaining a uniform moisture in the product and preventing over-drying of the green part. Actually the green parts of the scallions were more stable than the white parts and a higher moisture content in these portions than in white parts did not cause deterioration but was helpful in improving the good appearance of the product.

Moisture. The scallions dried to a 4 percent moisture content was similar to the only commercial dried scallions available(produced by McCormick & Co., Inc.). The scallions dried to a moisture content of less than

4 percent were in inferior quality at the start but had a longer shelf life.

The scallions dried to more than 7 percent moisture were excellent in both appearence and flavor before storage, and rehydration was faster and more complete. However this product had a short shelf life.

Packaging. The transparent glass jars used to hold the dried scallions would be ideal for attracting the consumers attention. However, when the dried scallions in the glass jars were placed under light, rather than in the dark, the green part of the scallions were bleached, thus showing up the browned white part more and turning yellow in itself. Technically packaging other than by means of glass jars would prolong the storage life of the dried scallions. Probably plastic bags impervious to light and leaving only a small transparent portion to show the product may be the solution. These plastic bags would not only reduce the bleaching of the sample but also solve the problems of breakage, disposal, and transportation.

II. Browning of Dried Scallions

1. Observation of Color

The samples with moisture contents of 2.7percent were quite stable at 20°C and retained their wholesome appearance even after one year of storage. The samples with moisture contents of 3.6 percent showed detectable browning but were not objectionable in this respect after 22 months of storage at 20°C. Samples with 3.6 percent moisture stored 22 months at 37°C or 57°C showed considerable to excessive browning and would not be suitable as commercial products.

The samples consisting 7.0 percent moisture, stored at 20°C, showed considerable browning after 14.5 months and the same degree of browning as the 5.7 percent moisture sample stored at 20°C for 20.5 months.

At the end of one week, 11.7 percent moisture samples stored at 57°C showed considerable browning. These samples in 20 days, became were as brown as the 3.6 percent moisture sample stored at 57°C for 22 months. The 11.8 percent moisture samples stored at 57°C for 20.5 months were indistinguishable from the 11.7 percent moisture samples stored at 57°C for 20 days. This indicated that the brown color was at a maximum and that 11.7 percent moisture content samples reached a maximum browning at 57°C in 20 days.

After 20 days of storage, 2.9 percent moisture samples placed at 20°C, 37°C, and 57°C were all of very good color.

The samples with 11.8 percent moisture content were very brown even at 20°C after 22.5 months of storage and darker in color than the 11.7 percent moisture samples stored at 37°C for 20 days.

II. Determination of the Percent Transmission of Extracts

From the data and graphs, it is apparent that the percent transmission decreased with increased browning, moisture content, storage temperature and storage time.

After 20 days of storage, the percent transmission of the sample extract decreased rapidly with increased moisture content of samples when stored at 57°C but the decrease was not significant at storage temperatures of 37°C and 20°C.

After 14.5 months of storage the percent transmission decreased more rapidly as samples stored at the lower temperatures(20°C and 37°C), and in samples with lower moisture content(below 8 percent).

After 20.5 months of storage the percent transmission fell rapidly in extracts from lower moisture content samples (below 6 percent) stored at lower temperatures(20°C and 30°C) and the curve became straight, having a slope of approximately one-tenth.

The curves (percent transmission versus percent moisture) obtained for 14.5 and 20.5 months of storage were somewhat similar. All curves obtained showed the expected trend of decreasing transmissions with increasing moisture content and storage temperature with the exception of the curve, for the 57°C storage temperature for 20 days, which showed increase in the percent transmission in extracts between

2.3 and 2.9 percent moisture. The reason for this is not clear. However, it may due to the experimental errors or inhomogeneity of the sample.

In 3 percent moisture content samples, the change in transmission of extracts occurred only slowly during 7.5 months at temperatures of 20°C and 37°C and the rate of change increased from then on. At storage temperature of 57°C reverse is true. The rate of change in transmission in extracts from 4 percent moisture samples was very slow or almost constant up to about 10 months of storage then the rate increased at all three storage temperature levels. The 11 percent moisture samples showed little change in transmission of extracts until nearly 8 months at 20°C but showed a moderate decreasing rate of change up to 14 months. The rate of change then decreased to nearly zero.

The decreases in transmission of the extract of the samples stored at 37°C and 57°C were not proportional to that from samples stored at 20°C but rather the rate of change increased at all moisture content and storage times. This change was accentuated in samples with higher moisture content and in samples stored for the longer periods.

The brown color produced in the samples stored at 57°C was not obtained at 37°C and 20°C regardless of the length of storage time. A definite distinction existed between the shade of brown obtained in the samples stored at 37°C and 20°C. From this result it is indicated that the type of browning taking place in dried scallions at 57°C may not be the same type as that taking place at 37°C and 20°C. Or the Maillard reaction, caramelization and ascorbic acid type browning all may take place at different rates at higher temperature than at lower temperatures.

It is quite reasonable that browning at 20°C and 37°C is either Maillard-type reaction or the oxidation of ascorbic acid-type or a combination of the two. The data from the analysis of scallions show that the all the known necessary reactant for this reactions are present abundantly in the scallions. It is possible that the browning taking place at higher temperature is due to a caramelization-type decomposition of sugars.

III. Determination of Off-Flavor by Organoleptic Tests

Although the numbers of individual testers employed was not large, the degree of agreement between them was high.

The color of dried scallions seem to greately affect the acceptability characteristics of the flavor. No one liked the flavor of the heavely browned product stored at 57°C for 20 days when they were allowed to see the product but the majority of them liked the odor of the browned product when they were asked to close their eyes, when evaluating samples in dry form. In the browned product, the off-flavor was more easily detectable but more scallion odor appeared to be present. The panel complained that the sample with the best appearance (stored at 20°C) had little scallion odors and had a hay-like odor when the sample was not suspended in water but was presented in the dry forms.

When the sample was suspended in water for presentation most of the panel liked the odor of the sample with the best appearence and disliked that of the browned sample even with their eyes closed. The sample with best appearance did not have an off-odor when presented in the wetted state. This indicates that upon rehydration a regeneration of the flavor of the dried scallions takes place. It is also interesting to notice that the odor of the dried scallions was not effected as much as the color, by moisture content, storage temperature or storage time.

IV. Determination of Color by using the "Dictionary of Color"

This determination was carried out to make it possible to find colors of samples in this experiment in easily visible form. The investigator can decide whether the color is acceptible, or how much color change took the place objectively with the aid of color plates found in the dictionary. The method can not be ignored because the consumer when choosing the product will rely entirely on the visual characteristics of commercial products of this type.

SUMMARY AND CONCLUSIONS

The present study was concerned with following topics,

1. The effect of moisture content upon the storage characteristics of dried scallions.

2. The effect of storage temperature changes occuring during the storage of dried scallions.

3. The effect of storage time on the extent of deterioration of dried scallions.

The scallions were dried to different moisture content(2.3 percent to 11.8 percent) and each sample was stored at 20° C, 37° C, and 57° C. After periods of storage (from 20 days to 22 months) the dried scallions were tested by the following methods:

1. Determination of color and flavor by olganoleptic tests.

2. Determination of browning by measurement of the percent transmission of aqueaus extracts.

The color of dried scallions was also determined by comparison with color plates in the "Dictionary of Color" according to this method of evaluating color classes.

The results obtained in the studies outlined above led to the following conclusions:

1. Browning in dried scallions increased with increased moisture content of the samples.

2. Browning in dried scallions increased with increased storage temperature.

3. Browning in dried scallions increased with increasing storage times.

4. Regarding factors accelerating the rate of browning in dried scallions the moisture content was most important, storage temperature was next and the number of days of storage was the least important factor.

5. The mechanism of browning in the slightly browned dried scallions may be different from that occuring in highly browned products held at higher temperatures.

6. The odor of dried scallions was not as much affected as the color by high moisture content, elevated storage temperatures and long storage periods.

SUGGESTIONS FOR FUTURE RESEARCH

In the studies of the dried scallions, it is essential to obtain the required amount of sample from one batch in order to obtain raw material with the same composition and the same freshness.

An investigation of the groups of samples with definite intervals of moisture content, such as moisture content of 2%, 4%, 6%, 8%.... for regular intervals of time, for instance every 14 days, until definite change takes place would be most helpful in finding and evaluating changes.

During this study, it was found that the browning in the dried scallions were accompanied and increased by the bleaching of the green part of the scallions when samples were stored in light. Investigation of this effect with relation to the other storage conditions and the mechanism of this effect may be very interesting and rewarding.

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