CHANGES PRODUCED IN APPLES BY THE USE OF CLEANING AND OIL-COATING PROCESSES[1]

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INTRODUCTION

In the past two years it has become necessary in several of the Rocky Mountain and Pacific Coast States to employ cleaning methods for the purpose of removing excessive spray residue from apples after harvest. These methods are of two general types—dry brushing or wiping the fruit and washing it in chemical solutions. The latter method is the more effective and is coming into general use. The cleansing liquids employed are usually dilute solutions of either an acid or a base. Hydrochloric has been found to be the best acid at strengths varying from ⅓ to 3 per cent by weight of the acid, depending upon conditions. Of the basic solutions, sodium hydroxide or sodium carbonate are generally used in strengths similar to those given for hydrochloric acid. Disinfectants are sometimes added to the washing solutions. A discussion of these processes has been reported by Heald, Neller, and Overley,[2] and it suffices here to state that the hydrochloric-acid treatment is conducted in tanks with varying degrees of agitation, or under spray pipes from which the liquid, under moderate pressure, is directed upon the fruit. Alkaline solutions are similarly used, except that the liquid is generally heated to about 43° C. In both cases the fruit is washed in water before it is dried and packed. Fruit that has been treated with an alkali, such as sodium hydroxide, is given a light coating of a mineral oil-paraffin mixture to retard shriveling of the skin. The oil is generally applied by means of revolving brushes.

It is probable that these cleaning processes affect the physiological activities of the fruit, particularly when they are followed by the addition of a protective coating of oil. The purpose of the present paper is, by presenting a comparison of treated and untreated fruit, to show some of the effects produced by these treatments. The fruit used in the experiments was commercially harvested, cleaned, and treated in an irrigated section of central Washington.

EXPERIMENTAL METHODS

Special attention was given to the effects of the treatments upon the respiratory rates of the fruit. These were determined by measuring the evolution of carbon dioxide from duplicate or triplicate samples of from six to eight apples each. The maximum variation

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[2] HEALD, F. D., NELLER, J. R., OVERLEY, F. L., and DANA, H. J. ARSENICAL SPRAY RESIDUE AND ITS REMOVAL FROM APPLES. Wash. Agr. Expt. Sta. Bul. 213, 56 p., illus. 1927.

between duplicate determinations was 9.68, the minimum 1.71, and the average 5.25 per cent.

By the method used, air was drawn through soda-lime towers to remove CO_2. It was next bubbled through a half-inch column of 10 per cent H_2SO_4, and then into desiccators containing the weighed fruits. The air was drawn out from the bottoms of the containers and through a series of CO_2 absorption towers containing 0.3 normal NaOH. Carbon dioxide was determined by precipitating the carbonate with $BaCl_2$ and titrating the excess of NaOH.

The air currents were drawn through the units at a fairly rapid rate for four hours each day. The determinations were made at laboratory temperatures, these being recorded on a thermograph. Although these temperatures fluctuated to a considerable extent, they do not introduce a variable factor into the comparative data obtained, since all the determinations of any given comparison were obtained at the same time and at the same temperature.

During the period in which respiration determinations were being made, duplicate samples of the same lots of apples were held in the same room to determine the loss in weight and moisture. These were stored unwrapped in open-top paper bags.

EFFECT OF BRUSHING AND WASHING ON RESPIRATION RATES AND LOSS IN WEIGHT

The first experiments were made to determine the effect of dry brushing upon the respiratory rate of the fruit. A rotating spiral-brush type of machine was used on Winesap apples that had been in cellar storage for about three and a half months. The rate of carbon dioxide evolution during the first six days after brushing was somewhat increased by this treatment, as is shown in Table 1. Where the dry brushing was preceded by an acid-spray treatment the respiration rate was 22 per cent greater than that of the untreated fruit.

TABLE 1.—*Respiration rates and loss in weight of dry-brushed and of acid-washed dry-brushed Winesap apples taken from cellar storage; experiments begun January 10, 1927* [a]

Treatment	Carbon dioxide per 100 gm. of fruit				Increase over untreated fruit	Loss in weight in 14 days
	Jan. 12	Jan. 14	Jan. 16	Total		
	Mgm.	*Mgm.*	*Mgm.*	*Mgm.*	*Per cent*	*Per cent*
Dry brushed	4.75	4.79	6.20	15.74	12.10	5.04
Sprayed with hydrochloric acid and dry brushed	5.49	5.45	6.19	17.13	22.00	5.83
Untreated	4.51	4.31	5.22	14.04	----------	2.93

[a] The data are the average of duplicate determinations.

Two months after the first group of experiments was begun some of the same lots of fruit were treated with 2 per cent solutions of hydrochloric acid and sodium hydroxide at 25° C. for 10 minutes with constant mild agitation but without brushing or wiping. The respiratory rate for the first six days after treatment was slightly less than that of the untreated fruit. (Table 2.)

TABLE 2.—*Respiration rates and loss in weight of Winesap apples taken from cellar storage and treated with sodium hydroxide or with hydrochloric acid; experiments begun March 11, 1926* [a]

Treatment	Carbon dioxide per 100 gm. of fruit				Decrease over untreated fruit	Loss in weight, Mar. 11 to 18
	Mar. 13	Mar. 15	Mar. 17	Total		
	Mgm.	*Mgm.*	*Mgm.*	*Mgm.*	*Per cent*	*Per cent*
2 per cent sodium hydroxide	10.55	7.02	6.60	24.17	2.18	4.12
2 per cent hydrochloric acid by weight	10.23	6.89	5.99	23.11	6.52	3.07
Untreated	10.82	7.21	6.68	24.71		3.31

[a] The data are the average of duplicate determinations.

During the first seven days after treatment the loss in weight of fruit treated with hydrochloric acid was practically the same as that of the untreated fruit (Table 2), but there was a considerably increased loss where sodium hydroxide was used. In the previous work with fruit from this lot it may be noted (Table 1) that dry brushing caused weight to be lost at a much increased rate and that an additional treatment with an acid spray caused but little further loss. An acid treatment without brushing or wiping likewise failed to produce an appreciable effect on the rate of loss. (Table 2.) Robinson and Hartman [3] also found that an acid-bath treatment had little effect on loss of weight as compared with the loss from wiping or brushing, which apparently disturbs and removes some of the protective wax coating. Heald, Neller, and Overley have shown, however,[4] that a brushing treatment which causes a rapidly increased loss of weight at laboratory or room storage has practically no effect on loss of weight when the fruit is held in cold storage at 32° to 33° C.

EFFECT OF OILING ON RESPIRATION RATES, LOSS IN WEIGHT, AND MOISTURE CONTENT

A considerable portion of the northwestern apple crop is prepared for storage and marketing by being coated with a thin film of oil after it has been cleaned by dry brushing or with a solution containing sodium hydroxide. In the process followed in these experiments the oil used was a highly refined, highly viscous mineral grade and was mixed with paraffin wax. It was warmed sufficiently to dissolve the paraffin and was spread over the surface of the apples by means of revolving brushes.

On November 1 some newly harvested Winesap apples that had been dry brushed and oiled were put in cold storage, together with some of the same lot that had been dry brushed but not oiled. At the same time untreated fruit was also stored. Four months later samples were brought to the laboratory for respiration determinations. The results show that whereas the respiratory rates of the brushed and untreated fruits were practically the same, they were both over 40 per cent higher than that of the oiled fruit. (Table 3.) In 1924 Magness and Diehl reported [5] data on the respiration of Winesap

[3] ROBINSON, R. H., and HARTMAN, H. A PROGRESS REPORT ON THE REMOVAL OF SPRAY RESIDUE FROM APPLES AND PEARS. Oreg. Agr. Expt. Sta. Bul. 226, 46 p., illus. 1927.
[4] HEALD, F. D., NELLER, J. R., OVERLEY, F. L., and DANA, H. J. Op. cit.
[5] MAGNESS, J. R., and DIEHL, H. C. PHYSIOLOGICAL STUDIES ON APPLES IN STORAGE. Jour. Agr. Research 27: 1–38, illus. 1924.

apples which showed that when they were coated with mineral oil and with paraffin the evolution of carbon dioxide was reduced by about 40 per cent. Their results were similar to those of Table 3 and were obtained at approximately the same temperature as the present writer used. Magness and Diehl also made a study of the CO_2–O_2 respiratory ratio and found that there was little anaerobic respiration in apples thinly coated with oil and stored at a temperature of 18° C. or lower. At 26°, however, there was considerable anaerobic respiration, with a consequent development of poor flavor. It was pointed out that this tendency became more pronounced as the thickness of the oil coating was increased.

TABLE 3.—*Respiration rates, water content, and loss in weight of brushed and of oil-coated Winesap apples after four months in cold storage; experiments begun February 28, 1927* [a]

Treatment	Carbon dioxide per 100 grams of fruit				Increase over oiled fruit	Water content Mar. 22	Loss in weight Mar. 1–22
	Mar. 2	Mar. 4	Mar. 6	Total			
	Mgm.	*Mgm.*	*Mgm.*	*Mgm.*	*Per cent*	*Per cent*	*Per cent*
Brushed	11.61	9.60	7.00	28.21	44.8	84.23	4.83
Oil coated	7.52	6.42	5.54	19.48		84.05	4.51
Untreated	11.10	8.50	7.68	27.28	40.1	84.00	5.29

[a] The data are the average of duplicate determinations.

Loss-in-weight determinations showed that the unoiled fruits of Table 3 lost weight but little faster than the oiled fruits. The moisture content of the brushed, oiled, and untreated fruits was about the same. Figure 1 shows the air temperature and relative humidity that prevailed during the progress of the above experiment.

On June 22, or after nearly eight months of cold storage, other samples from the same lots of Winesap apples were subjected to respiratory measurements. The unoiled apples continued to respire at a faster rate than the oiled, although to a lesser extent. The increases amounted to 16.8 and 18.3 per cent, respectively, for the brushed and untreated lots. (Table 4.)

TABLE 4.—*Respiration rates of brushed and of oil-coated Winesap apples after eight months in cold storage; experiments begun June 20, 1927* [a]

Treatment	Carbon dioxide per 100 grams of fruit			Increase over oiled fruit
	June 22	June 24	Total	
	Mgm.	*Mgm.*	*Mgm.*	*Per cent*
Brushed	12.00	12.30	24.30	16.8
Oil coated	11.24	9.56	20.80	
Untreated	12.24	12.37	24.61	18.3

[a] The data are the average of duplicate determinations. Water content and loss in weight were not determined.

The process of brushing without oiling had little effect upon the respiration of these stored Winesap apples, as the brushed fruit respired slightly faster after four months and slightly slower after eight months of cold storage. (Tables 3 and 4.) Brushing had likewise little effect upon losses of moisture and of weight.

Samples of Delicious apples were prepared for storage in the same manner as were the Winesaps and they were kept in the same cold-storage room. As seen in Table 5, oil had a similar retarding effect upon respiration. This retardation amounted to 33.4 and 46.7 per cent, respectively, of the CO_2 evolution from the brushed and untreated lots. There was but little difference in the loss in weight of the different lots, but the moisture content of the oiled fruit was slightly higher.

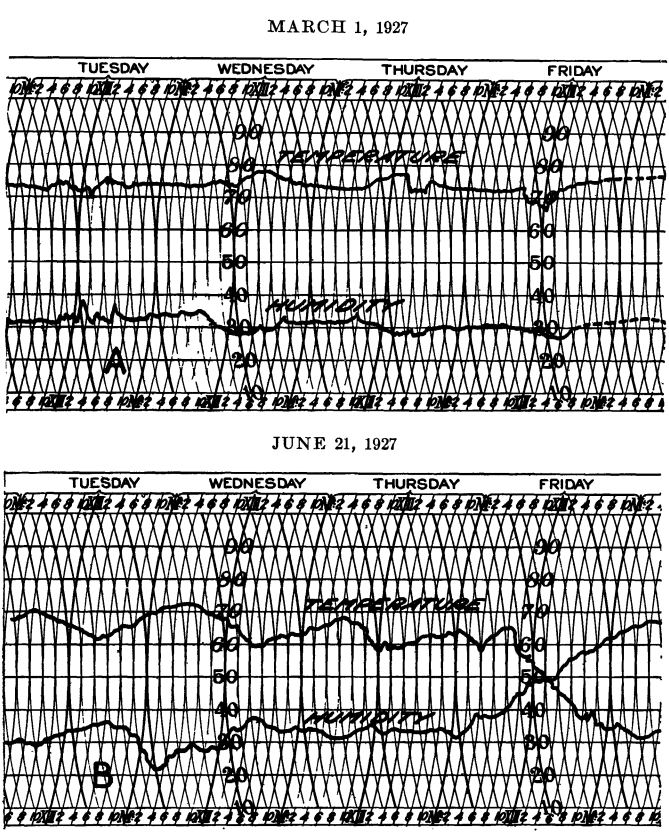

FIG. 1.—Temperature in degrees Fahrenheit and percentage of relative humidity that prevailed during respiration determinations of Winesap apples. A refers to the data in Table 3; B, to the data in Table 6

TABLE 5.—*Respiration rates, moisture content, and loss in weight of brushed and of oil-coated Delicious apples after four months in cold storage; experiments begun February 21, 1927* [a]

Treatment	Carbon dioxide per 100 grams of fruit				Increase over oiled fruit	Loss in weight, Feb. 21–Mar. 15	Moisture content, Mar. 15
	Feb. 23	Feb. 25	Feb. 27	Total			
	Mgm.	*Mgm.*	*Mgm.*	*Mgm.*	*Per cent*	*Per cent*	*Per cent*
Brushed	15.1	19.2	17.2	51.5	33.4	5.04	83.59
Oil coated	12.2	14.4	12.0	38.6		4.87	84.54
Untreated	17.0	20.1	19.5	56.6	46.7	4.75	83.77

[a] The data are the average of duplicate determinations.

The respiratory rates of the Delicious apples were again determined after a period of eight months in cold storage. At that time (Table 6) the untreated fruit respired 43.28 per cent more carbon dioxide than the oil-coated fruit. Figure 2 gives the air-temperature and relative humidity record for the time during which the respiration and loss of weight determinations with Delicious apples were in progress. Although the fluctuations in temperature and humidity were considerable, they were the same for the compared treatments as given in the above discussion.

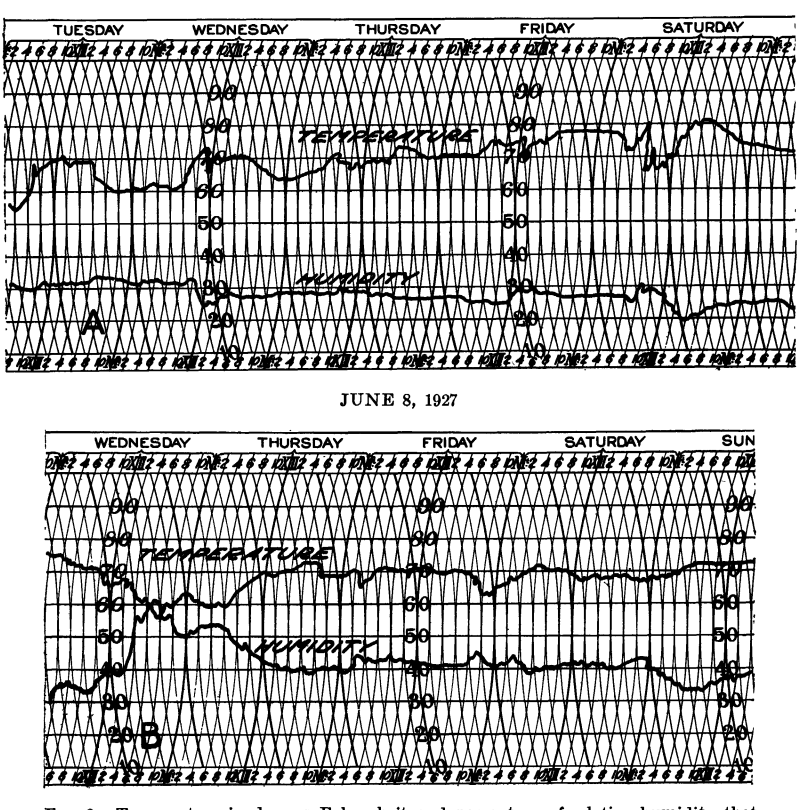

FIG. 2.—Temperature in degrees Fahrenheit and percentage of relative humidity that prevailed during respiration determinations of Delicious apples. A refers to the data in Table 5; B, to the data in Table 6

TABLE 6.—*Respiration rates and loss in weight of oil-coated Delicious apples after eight months in cold storage; experiments begun June 7, 1927* [a]

Treatment	Carbon dioxide per 100 grams of fruit			Increase over oiled fruit	Loss in weight, June 6–21
	June 9	June 12	Total		
	Mgm.	*Mgm.*	*Mgm.*	*Per cent*	*Per cent*
Oil coated	9.95	12.46	22.41		4.73
Untreated	14.23	17.87	32.10	43.28	5.54

[a] The data are the average of triplicate determinations. Water content not determined.

Dry brushing without oil coating slowed up the respiratory rate of Delicious apples as measured after four months of cold storage. (Table 5.) The data of Table 1 show a slight increase in the rate of respiration of Winesap apples as measured immediately after brushing. It is possible that the brushing process accelerated the respiration rate of the Delicious apples at first, resulting in less metabolic reserve when the respiration rates were determined four months later.

As shown in Tables 3 and 4, the effect of oiling was less apparent on the Winesap apples held eight months in cold storage than on those held four months. After eight months in storage the Winesap apples appeared very waxy, especially after warming up to room temperatures. This wax may have served to check respiration in much the same way as did the oil. The respiratory rate of the unoiled Delicious apples after eight months continued to be as much in excess of the oiled fruit as it was after four months of cold storage. The Delicious apples, of course, did not become nearly so waxy as the Winesap apples.

EFFECT OF OILING ON QUALITY OF FRUIT

It has been shown that coating apples with a film of oil causes a marked reduction in the respiratory rate of the fruit even after eight months of cold storage. The practice of oiling is employed when the fruit has been brushed or cleaned in an alkaline solution, the object being to give the fruit an oil-film protection equal or superior to the natural waxy protective coating of the untreated fruit. Since the experiments show that this cleaning and oil-coating process causes the respiration rate of the fruit to be considerably lowered, the question arises as to the effect of this practice upon the keeping and dessert quality of the fruit.

A comparison of apples by tasting or eating did not reveal any significant difference in dessert quality between treated and untreated fruit kept in storage for different lengths of time. When waxy apples like the Winesap variety, are brought to room temperature after a long period in cold storage, the excessive development of wax often makes it difficult to differentiate between the oiled and unoiled fruit even by visual examination. In most cases, however, the oil-coated fruit is easily recognized by its decreased luster and increased waxiness.

The oil-coated Delicious fruits could easily be distinguished from the unoiled, and the flavor was also slightly different. This change in flavor could not be declared either beneficial or detrimental.

DISCUSSION

In general, the experiments here reported have shown that the oil-coated fruit loses weight and shrinks somewhat less rapidly than the unoiled when brought into room or marketing temperature after long periods of cold storage. Since the oil-coated fruit also has a greater reserve of metabolic activity, as shown by respiration measurements, it is quite apparent that the practice of oil coating has a tendency to prolong the keeping quality of the fruit. In the fruit under test the dessert quality was neither noticeably benefited nor harmed. This fact indicates that the coating of oil as applied in these experiments was not sufficiently heavy to induce anaerobic respiration with its accompanying unpleasant flavors.

SUMMARY

Winesap and Delicious apples grown in an irrigated section of eastern Washington were placed in cold storage immediately after harvesting and cleaning. The cleaning methods used were (1) dry brushing, (2) dry brushing and oil coating, and (3) mild agitation in dilute hydrochloric acid without brushing or wiping. When the fruit to be tested had remained in cold storage for a certain time the rates of respiration and losses of moisture and of weight were determined at room or marketing temperature.

After four months in cold storage untreated Winesap apples respired CO_2 at a rate over 40 per cent faster than dry-brushed, oil-coated fruit. After eight months in cold storage the unoiled Winesap apples respired about 17 per cent faster.

Untreated Delicious apples respired about 46 per cent faster than the brushed, oil-coated lot after four months, and about 43 per cent faster after eight months in cold storage.

When exposed to room or marketing temperatures of about 20° C. and relative humidities of about 30 per cent of the maximum, the unoiled Delicious and Winesap apples lost weight at a moderately faster rate than the oil-coated fruit. The moisture content of the untreated was only slightly lower than that of the oil-treated apples.

A film of oil of the character and thickness used in the process employed in these experiments caused no significant difference in the dessert quality of the fruit after as much as eight months of cold storage. The oil coating tended to reduce the rate of shriveling and softening when the fruit was exposed to room or marketing temperatures.

Dipping in 2 per cent by weight of hydrochloric acid at 20° C. with mild agitation for 10 minutes had little effect upon the subsequent rates of either CO_2 respiration or loss in weight of Winesap apples. Dipping in 2 per cent sodium hydroxide under the same conditions affected respiration slightly and increased the rate of loss in weight.

The use of hydrochloric acid under the above conditions, except that contact was made with the fruit by means of jet sprays, resulted in unchanged rates of respiration and in no change in rate of loss in weight.

Brushing the fruit in either the dry or the wet cleaning process caused the respiration rate to be greater, and markedly increased the rate of loss in weight when the fruit was exposed to marketing temperatures immediately after the brushing treatments. When the fruit was held in cold storage for several weeks, beginning immediately after a brushing treatment, this effect of brushing became less marked.