QUANTITATIVE STUDY OF ETHYLENE PRODUCTION IN APPLE VARIETIES[1]

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(WITH THREE FIGURES)

The capacity for ethylene formation is present in many kinds of fruits but appears to be entirely absent in others. In apples and pears the amounts of ethylene produced vary greatly between varieties; according to the available data, the intensity of production is correlated with the longevity of the fruit in storage. In six varieties of apples, NELSON (**5**) found that those with the longest storage life were characterized by the least capacity to produce ethylene. Similarly in pears, the short-lived variety, Bartlett, was observed to have a maximum rate of ethylene production six to seven times greater than the long-lived variety, Anjou (**2**). The formation and accumulation of ethylene in the fruit tissues is a vital factor in the natural ripening processes of pears (**3**) and probably of apples (**4**). In the present study, the production of ethylene by apple varieties in relation to season of maturation, rate of ripening, length of storage, respiration, and temperature are considered.

Materials and methods

Five varieties of apples differing in time of maturity from mid-summer to late fall were obtained from the Experiment Station orchard located near Corvallis. The samples were carefully selected for uniformity in size, maturity, and freedom from blemishes. The summer-maturing apples (Astrachan, Red June, and Gravenstein) were picked when firm but partially colored and placed immediately in the respiration chambers maintained at 20° C. (68° F.). The fall-maturing varieties (Delicious and Newtown) were harvested on September 23 and October 1, respectively, packed in oiled paper wraps, and stored at 0° C. (32° F.). Samples were withdrawn from storage at various intervals for ethylene and respiration measurements at 20° C. and similar determinations were made at 0° C. Due to the development of bitter pit in the Newtown apples, investigations on this variety were discontinued after February 12.

The rates of ethylene and CO_2 production were determined simultaneously on the same samples of fruit, according to the methods described previously (**2**).

Results

EARLY-MATURING VARIETIES

Astrachan, Red June, and Gravenstein apples mature and ripen consecutively during the summer in the order listed. According to the data (fig. 1)

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there is an inverse correlation between the length of the maturation period of a variety and the amount of ethylene produced during ripening. Thus, the rate of ethylene production (ml. per kgm./24 hrs.) was highest in Astrachan (11.39 ml.), intermediate in Red June (9.27 ml.), and lowest in Gravenstein (5.15 ml.). With the exception of Astrachan, the amounts of ethylene produced on the first day following picking were below the chemically-determinable minimum (0.001 ml.) but increased rapidly to maximum values during an 8–10-day period. The peak in ethylene production was reached 4–5 days later than that for CO_2 production. NELSON (6) reported similar results for McIntosh apples; in pears, however, the maxima for

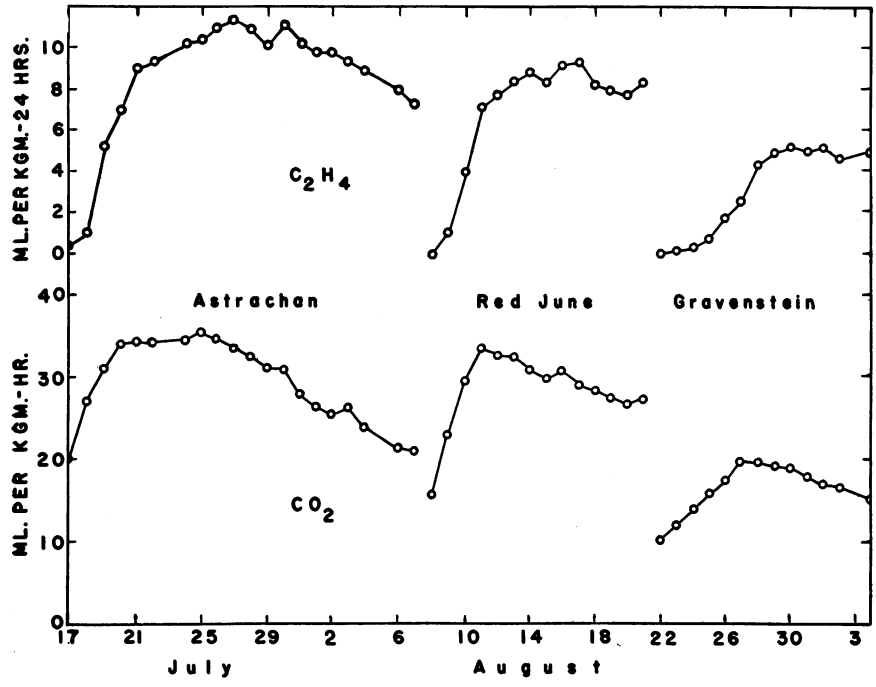

FIG. 1. Production of ethylene and respiration in three varieties of apples which mature and ripen at intervals during the summer season.

ethylene and CO_2 production were found to coincide (2). The relative increase in production during the climacteric was much greater for ethylene than for carbon dioxide. In Astrachan apples, ethylene production rose from 0.040 ml. to 11.38 ml. per kgm./24 hrs., approximately a 30-fold increase; while CO_2 production rose from 20.09 to 35.32 ml. per kgm./hr., less than a 2-fold increase. In Red June and Gravenstein, the comparative differences were even greater. This lack of correlation between ethylene and CO_2 production would appear to indicate that several oxidation-reduction systems function in the respiration of apples; probably only one of these is associated with the formation of ethylene. If the total CO_2 of respiration as well as ethylene were formed by the activity of a single respiratory enzyme

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system, then a more definite quantitative relationship should exist between these two products than has been observed in these and former experiments (**2**).

Late-maturing varieties

The Delicious and Newtown apples (Figs. 2, 3) maintained a much lower rate of ethylene production during ripening than the early-maturing varieties. There was very little difference between the amounts of ethylene produced by Delicious and Newtown, but the rate of production increased much slower in the latter variety. In the Delicious apples ripened after 4 weeks of storage, the rise in ethylene production was completed in 14 days but in

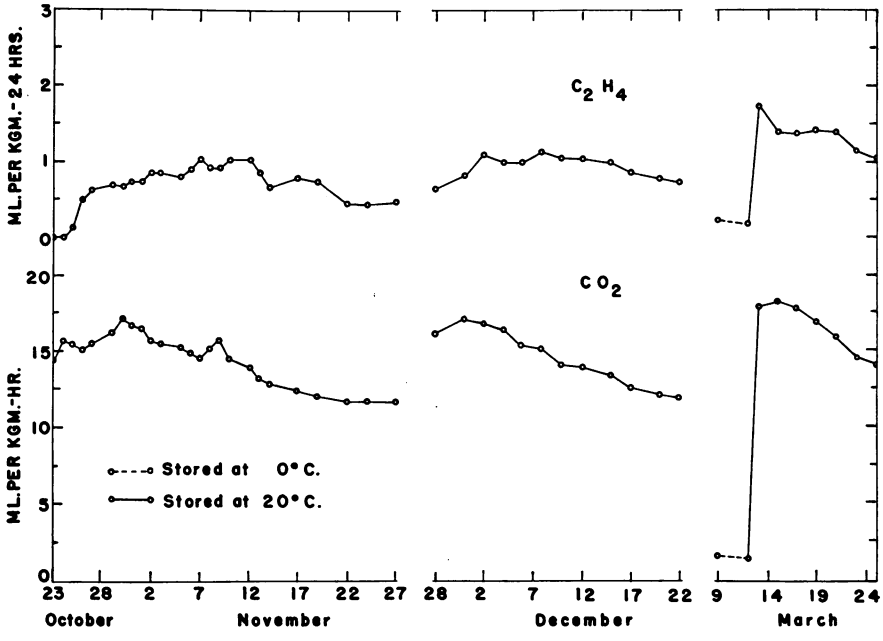

FIG. 2. Production of ethylene and respiration in Delicious apples after various storage intervals.

Newtown extended over a period of 40 days. The intensity of ethylene production evidently increases at cold temperatures, since lots of fruit withdrawn at later dates showed increasingly higher initial rates of ethylene production. This increase is undoubtedly associated with a steady progress in ripening of the fruit during the storage period.

The rates of ethylene production by Delicious, Newtown, and Jonathan apples during storage at 0° C. are shown in table I. These three varieties were not at the same stage of ripeness when the determinations were made; hence the results are not comparable on a varietal basis. According to these data, apples at 0° produce ethylene at approximately one-eighth to one-eleventh the rate at 20° C. Under commercial conditions, it would be possible for considerable ethylene to accumulate in the cold storage rooms, since

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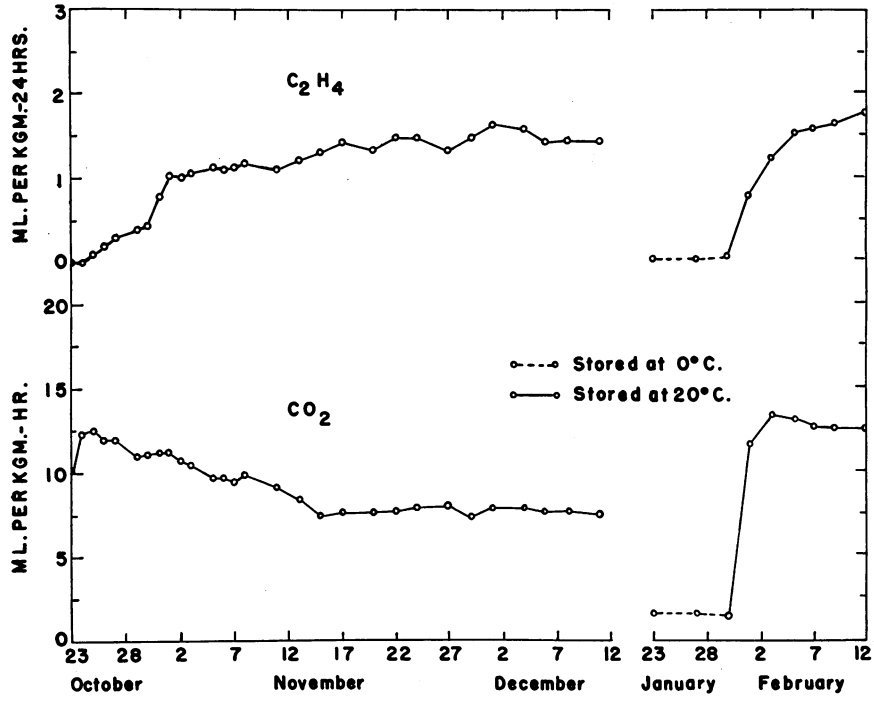

FIG. 3. Production of ethylene and respiration in Newtown apples after various storage intervals.

according to these data one bushel of apples produces approximately 1–4 ml. of ethylene per day, depending upon the variety and length of time in storage.

Neither Delicious nor Newtown apples showed a distinct climacteric rise in CO_2 production, such as occurred in the early-ripening varieties. Respi-

TABLE I

CARBON DIOXIDE AND ETHYLENE PRODUCTION IN APPLES AT 0° AND 20° C.

DATE, 1944	TEMPERATURE	ML. C_2H_4/KGM.-24 HR.	ML. CO_2/KGM.-HR.
	°C.	*ml.*	*ml.*
Delicious			
March 6– 9	0	0.223	1.78
March 9–12	0	0.198	1.46
March 12–13	20	1.770	18.03
Newtown			
Jan. 23–27	0	0.061	1.69
Jan. 27–30	0	0.082	1.54
Jan. 30–Feb. 1	20	1.770	11.85
Jonathan			
Feb. 2– 5	0	0.185	2.20
Feb. 5– 8	0	0.184	2.27
Feb. 8–10	20	1.590	18.15

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ratory activity in the first samples ripened increased slightly during the first few days then declined during the remainder of the period. This behavior is especially apparent in the Newtown apples and is opposite to the trend in ethylene production. A more distinct climacteric rise in respiration may have been observed at time of harvest, although this is questionable in view of the results reported by EZELL and GERHARDT (1).

Summary

The production of ethylene and the respiration in five varieties of apples ranging in season of maturity from midsummer to late fall have been studied. Early-maturing summer apples were found to produce more ethylene during ripening than late-maturing fall varieties. The maximum rates of ethylene production at 20° C., expressed as ml. per kgm./24 hrs., were as follows: Astrachan, 11.38; Red June, 9.27; Gravenstein, 5.16; Delicious, 1.77; and Newtown, 1.78 ml. With the exception of Astrachan, the amounts of ethylene produced by mature but unripened fruit were below the sensitivity of the analytical method used (0.001 ml.). The rates of ethylene production increased rapidly after picking in the summer-maturing apples but slowly in Delicious and Newtown.

Apples stored at 0° C. produced ethylene at approximately one-eighth to one-eleventh the rate at 20° C. The rates of production at 0° C. for Delicious, Newtown, and Jonathan were 0.211, 0.071, and 0.185 ml. per kgm./24 hrs., respectively. The data obtained indicate that the intensity of ethylene production increases during the storage period.

Early-maturing varieties of apples showed a distinct climacteric rise in respiration, but this was not apparent in either the Delicious or Newtown apples. The increase in ethylene production during ripening does not appear to be correlated with total CO_2 production.

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