QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES

DIVISION OF PLANT INDUSTRY BULLETIN No. 814

BANANA RIPENING—EFFECT OF TEMPERATURE ON FRUIT QUALITY

By B. C. Peacock, B.Sc., J.S.S.C.

SUMMARY

Banana ripening temperatures ranging from 13·9 to 32·2°C (57 to 90°F) were examined for their effects on eating quality, rate of colour development, quality of external colour, shelf-life, pulp firmness and weight loss. Over this range eating quality was not affected by the ripening temperature employed. Skin colour however, was altered at 26·7°C (80°F) and above. Shelf-life was found to decrease exponentially with increasing temperature. Pulp firmness was affected by temperature, lower ripening temperatures producing firmer fruit. Weight loss during ripening was found to be independent of temperature provided relative humidity was kept high (> 95%). A table is provided showing the temperatures and ripening times necessary to produce fruit of any desired degree of ripeness.

I. INTRODUCTION

Unlike most other fruits bananas are usually transported to markets in the preclimacteric state and then ripened under controlled conditions using ethylene gas. The quality of the product finally placed on the market is undoubtedly dependent on the ripening procedures employed. Hence a detailed knowledge of the effects of such factors as ripening temperature, relative humidity and ethylene levels on fruit quality is essential.

Conditions recommended in ripening manuals frequently vary. This variation may be partly due to industry being unable to achieve theoretical requirements due to commercial or economic limitations. It is also partly due to a lack of detailed theoretical studies with many recommendations being based solely on commercial observations. There is a distinct shortage of reports of detailed studies in the published literature.

Australian recommendations have been based mainly on studies conducted by Young *et al.* (1932). The studies provided a good indication of the ripening conditions that should be employed, but do not provide sufficient precise information to ensure optimum quality is always achieved. This paper reports the results of a more detailed study into the effects of ripening temperature on banana fruit quality.

II. MATERIALS AND METHODS

Fruit ripening was studied at eight ripening temperatures ranging from 13·9 to 32·2°C (57 to 90°F). Preliminary studies were undertaken to establish what periods of ripening were needed to produce eight distinct stages of ripeness at each of these temperatures. These ripening times × temperature combinations were then used in the present trial. In all instances, ethylene was applied continuously (200 ppm) and relative humidity was maintained as near as possible to 95%.

Fruit for the trial (*Musa acuminata* Colla cv. Giant Cavendish) were selected from four bunches from a local south Queensland grower and randomised into the 64 sample lots required, each sample consisting of six individual fingers. Samples were placed into the ripening chambers at staggered times so that all stages of ripeness for all temperatures were obtained within a 5-day time frame. To achieve this the ripening of some samples had to be delayed. Premature ripening of these samples was prevented by storing them at 20°C (68°F) sealed in polyethylene bags containing an ethylene absorbant. The trial was replicated three times.

Parameters measured

All fingers were weighed before ripening. On removal from a ripening temperature, the following parameters were measured on each sample.

Fruit weight

Each individual finger was weighed and the weight loss calculated as a percentage of initial weight. This was found to vary linearly with the time spent at the ripening temperature. Regression equations were calculated for percentage weight loss against time and used to determine the percentage weight loss at optimum eating quality (optimum EQ—see below) and the rate of weight loss.

Colour quality (CQ)

The quality of the skin colour was determined by a panel of 10 persons allocating a rating on a nine point hedonic scale (1 = dislike extremely; 9 = like extremely). At each temperature, a second order curve of best fit (convex upwards) for colour quality against time was used to calculate:

1. Optimum CQ: the highest rating obtained for colour quality.
2. Time to Optimum CQ: the time that elapses between the application of ethylene and the attainment of optimum CQ.
3. Earliest Acceptable CQ: the time that elapses from the application of ethylene to when the sample fruit first reaches a CQ rating of 5 (neither like nor dislike).
4. Latest Acceptable CQ: the time that elapses from the application of ethylene to when the sample reaches a CQ rating of 5 for the second time. At this time the fruit will be deteriorating from the optimum CQ.
5. Shelf-life (CQ): the length of time a sample remains at an acceptable CQ rating i.e. greater than 5 on the hedonic scale.

Eating quality (EQ)

The eating quality of the pulp was also determined by the same panel using the nine point hedonic scale. These data were treated in the same way as the colour quality data and the following equivalent parameters calculated:

1. Optimum EQ.
2. Time to Optimum EQ.
3. Earliest Acceptable EQ.
4. Latest Acceptable EQ.
5. Shelf-life (EQ).

Colour index

A standard colour index for bananas has been published in a local ripening manual (CSIRO 1971). This index illustrates the colour changes that take place in the peel of a ripening banana and ranges from 1 (green) to 8 (yellow with extensive brown areas) in whole numbers. Using this index, all samples were allotted a colour index score which was the average of the scores of a panel of three persons.

Panel ratings varied with duration of treatment in a curvilinear manner, approaching a maximum value of 8, the maximum value of the colour index. Results were found to fit the equation.

$$\log \frac{A-R}{A} = \log b - kt$$

where 'b' and 'k' are constants, 't' is the duration of treatment in days, 'A' is the maximum value of the colour index (namely 8) and 'R' is the panel rating at time 't'.

From the data of all three replicates, regression equations of this form were calculated for each temperature. These equations were then used to determine the time needed at each temperature, following the application of ethylene, to reach each particular value of the colour index.

Pulp firmness

Pulp firmness of each sample was determined using a modified gel penetrometer. Two half-inch-thick slices were removed from the centre of each of four fruit and three firmness readings made on each slice. Pulp firmness at optimum EQ was calculated using the pulp firmness data obtained on the day optimum EQ was reached and on the days before and after optimum EQ. Pulp firmness was assumed to vary linearly with time over such a short interval so pulp firmness at optimum EQ was calculated from a regression equation fitted to the selected firmness data.

III. RESULTS

Weight loss (table 1)

The percentage weight loss at optimum EQ was found to be approximately constant. However, the rate of weight loss varied logarithmically with temperature.

TABLE 1

Weight Loss at Optimum EQ (%) and Rate of Weight Loss (g day^{-1}) in Relation to Temperature. Data are the Means of All Replicates.

Temperature		Weight Loss at Optimum EQ	Rate of Weight Loss
°C	°F		
13·9	57	4·9	0·24
15·6	60	4·1	0·32
18·3	65	7·8	0·74
21·1	70	5·9	0·81
23·9	75	5·8	0·83
26·7	80	8·6	1·78
29·4	85	7·6	1·59
32·2	90	6·5	1·51

Colour quality (table 2)

Optimum CQ was not affected by the temperature of ripening below approximately 26·7°C (80°F). Above this temperature it showed a significant ($p < 0{\cdot}05$) decrease. Time to optimum CQ however, did vary with temperature in an approximately logarithmic manner.

Earliest Acceptable CQ, Latest Acceptable CQ and Shelf-life (CQ) all varied with temperature, also in a logarithmic manner. No values for these parameters were obtained for 26·7°C (80°F) and above as the optimum CQ scores were not above 5 hedonic units at these temperatures. The regression equation for log Shelf-life (CQ) against temperature, over the range 13·9 to 23·9°C (57 to 75°F), was:

$$\log \text{shelf-life (CQ)} = -0{\cdot}0326\,T + 1{\cdot}495$$

where T is temperature (°C). Above 23·9°C (75°F), shelf-life CQ tends to depart from this logarithmic relationship probably due to the effect of temperature on optimum CQ.

Eating quality (table 2)

Optimum EQ was not affected by temperature within the temperature range studied. Judging from the data however, there may be some reduction in quality at 29·4°C (85°F) and above even though statistically significant differences were not obtained. Time to Optimum EQ did vary with temperature in a logarithmic manner similarly to Optimum CQ.

Earliest Acceptable EQ, Latest Acceptable EQ and Shelf-life (EQ) also varied logarithmically with temperature. The regression equation for log Shelf-life (EQ) against temperature was:

$$\log \text{Shelf-life (EQ)} = -0{\cdot}0371\,T + 1{\cdot}642$$

where T is in degrees centigrade.

Shelf-life (EQ) was significantly longer ($p < 0{\cdot}01$) than Shelf-life (CQ) mainly due to eating quality becoming acceptable before colour quality. However Time to Optimum EQ was slightly shorter ($p < 0{\cdot}01$) than Time to Optimum CQ. This latter difference increased with temperature ($p < 0{\cdot}05$) from approximately 0·04 days at 13·9°C (57°F) to 0·9 days at 32·2°C (90°F)—calculated from the regression of mean difference with temperature.

Pulp firmness (table 3)

Pulp firmness at Optimum CQ and at Optimum EQ varied significantly with temperature ($p < 0{\cdot}01$), the pulp becoming softer as the temperature of ripening was increased. Pulp firmness at Optimum CQ was slightly less than at Optimum EQ ($p < 0{\cdot}05$) undoubtedly due to time to Optimum CQ being longer and thus allowing the pulp to soften more.

Colour index

The times needed to reach the various values of the CSIRO standard colour index following the application of ethylene have been calculated for each ripening temperature and are shown in table 4. By comparing table 2 and table 4, it can be seen that Optimum EQ and Optimum CQ both occur between colour index scores of 6 and 7.

TABLE 2

COLOUR QUALITY AND EATING QUALITY PARAMETERS IN RELATION TO RIPENING TEMPERATURE. DATA SHOWN ARE MEANS OF ALL REPLICATES.

Ripening Temperature (°C)	Ripening Temperature (°F)	Colour Quality Parameters					Eating Quality Parameters				
		Optimum CQ (Hedonic Units)	Time to Optimum CQ (Days)	Earliest Acceptable CQ (Days)	Latest Acceptable CQ (Days)	Shelf-life (CQ) (Days)	Optimum EQ (Hedonic Units)	Time to Optimum EQ (Days)	Earliest Acceptable EQ (Days)	Latest Acceptable EQ (Days)	Shelf-life (EQ) (Days)
13·9	57	7·06	17·67	11·19	24·15	12·96	7·06	17·49	9·91	25·08	15·17
15·6	60	7·58	11·61	7·30	15·93	8·63	7·08	11·71	6·64	16·78	10·13
18·3	65	7·00	9·19	5·36	13·03	7·67	7·15	8·85	4·32	13·38	9·06
21·1	70	7·16	7·25	4·43	10·07	5·65	7·34	7·10	3·53	10·68	7·15
23·9	75	7·55	6·74	3·75	9·73	5·99	7·50	5·83	2·89	8·78	5·89
26·7	80	4·97	5·02	..	..	..	7·33	4·44	2·36	6·52	4·16
29·4	85	4·51	4·83	..	..	..	6·75	3·98	2·12	5·84	3·72
32·2	90	3·55	3·58	..	..	..	6·40	2·79	1·95	3·63	1·68

TABLE 3

PULP FIRMNESS (PENETROMETER UNITS) AT OPTIMUM EQ AND OPTIMUM CQ IN RELATION TO TEMPERATURE. DATA ARE MEANS OF ALL REPLICATES.

Temperature		Pulp Firmness*	
°C	°F	Optimum EQ	Optimum CQ
13·9	57	11·2	11·3
15·6	60	11·2	11·2
18·3	65	10·5	10·8
21·1	70	10·0	10·2
23·9	75	8·6	9·7
26·7	80	8·0	8·6
29·4	85	7·1	7·8
32·2	90	..	..

* Decreasing Penetrometer Units = Decreasing Firmness.

TABLE 4

TIME (DAYS) REQUIRED TO REACH VARIOUS CSIRO STANDARD COLOUR INDEX SCORES IN RELATION TO TEMPERATURE

Temperature		CSIRO Standard Colour Index Scores						
°C	°F	2	3	4	5	6	7	8
13·9	57	8·9	9·9	11·2	13·0	15·3	19·4	28·9
15·6	60	6·0	6·6	7·5	8·6	10·1	12·7	18·8
18·3	65	3·6	4·2	5·0	6·1	7·6	10·1	16·0
21·1	70	3·1	3·5	4·1	4·8	5·7	7·4	11·3
23·9	75	2·6	3·1	3·8	4·6	5·8	7·8	12·4
26·7	80	2·4	2·8	3·2	3·9	4·6	6·0	9·3

IV. DISCUSSION

The results demonstrate that bananas may be ripened at any temperature ranging from 13·9°C (57°F) to 23·9°C (75°F) without major effects on quality. Over this range temperature does not alter either eating quality or the quality of the skin colour. Temperature alters the rate of ripening only, and hence ripening temperatures may be varied to produce the degree of ripeness required within a desired time frame. Above this range the quality of the skin colour will be markedly reduced even though eating quality is not severely affected.

The rate of weight loss during ripening varies with temperature while the amount of weight lost in reaching a particular degree of ripeness appears to be fairly independent of temperature. The data (table 1) indicate there may be some reduction in weight loss at the lower ripening temperatures. However, this may be due to slight differences in the relative humidities maintained in the ripening chambers.

The variation of pulp firmness at Optimum EQ and Optimum CQ with temperature simply reflects how the various enzymatic processes involved in these changes vary in their sensitivity to temperature. The results show that fruit ripened at 13·9°C (57°F) are 16% firmer at Optimum EQ than fruit ripened at 23·9°C (75°F) and agree with the findings of Charles and Tung (1973). As firmer fruit would be better able to withstand rough handling during marketing, it appears that low ripening temperatures should be used whenever practicable.

The data of table 4 can be used as a guide in deciding the ripening temperature needed to achieve fruit of a particular colour rating in a given time. A similar guide has been published in the local CSIRO ripening manual (CSIRO 1971). The latter guide shows only the temperatures and times necessary to obtain what is described as 'ripe fruit'. Judging from present results, what is meant by 'ripe fruit' in the manual is fruit having a colour index score of 2 (having a trace of yellow in the peel). For this stage of ripeness the data shown in the manual and those presented here agree very well. The present data (table 2) however, allow the choice of temperatures and times to achieve all other stages of ripeness depicted by the standard colour index.

The data of table 2 demonstrate that shelf-life (both CQ and EQ) decreases exponentially with increasing temperature. It is therefore essential for fruit to be kept cool once they are removed from the ripening room to ensure maximum shelf-life in the market chain. It is axiomatic (cf. table 2) that fruit ripened at 23·9°C (75°F) would have the same shelf-life as fruit ripened at 13·9°C (57°F) provided both were brought to a common temperature once they had reached the same stage of ripeness (Earliest Acceptable CQ or Earliest Acceptable EQ) in the ripening room. Rapid cooling of fruit ripened at high temperatures would be an extra burden on commercial operations. Hence, where possible, ripening temperatures should be chosen not only to achieve the speed of ripening required but also to allow removal of fruit at a temperature suited to the marketing chain (for example, 14°C).

The results demonstrate that theoretically, ripening temperatures anywhere in the range of 14 to 24°C can be employed without affecting fruit quality. However, the choice of temperatures will be greatly affected by various practical considerations and limitations of the marketing chain.

REFERENCES

ANON. (1971).—Banana Ripening Guide. Banana Research Advisory Committee, Technical Bulletin No. 3, CSIRO Melbourne.

CHARLES, R. J., and TUNG, M. A. (1973).—Physical, rheological and chemical properties of bananas during ripening. *Journal of Food Science* 38:456.

YOUNG, W. J., BAGSTER, L. S., HICKS, E. W., and HUELIN, F. E. (1932).—The Ripening and Transport of Bananas in Australia. CSIRO Bulletin No. 64.

(Received for publication 20 June 1978)

The author is an officer of the Sandy Trout Food Preservation Research Laboratory, Horticulture Branch, Queensland Department of Primary Industries, and is stationed at Hamilton, Q.