QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES
DIVISION OF PLANT INDUSTRY BULLETIN No. 340

SOME EFFECTS OF PARAFFIN WAX EMULSIONS ON BANANAS

By J. R. BLAKE, B.SC.*

SUMMARY

Green bananas (cv. Mons Mari, a mutant of Cavendish) were dipped in water-base emulsions containing 2–10% paraffin. The effects of wax concentration and fruit size on the time to ripen in the presence of ethylene, shelf life, weight loss and respiration rate were observed.

Treatment with wax emulsions delayed the development of full colour, increased shelf life, reduced weight loss, and at some periods reduced rate of respiration. The magnitude of each effect was generally related to the concentration of wax in the dipping treatment.

Recommended concentrations to meet the requirements of commercial ripeners are 2% wax for fruit harvested in October and November; 6% wax for fruit harvested in late January, February and March; and 4% wax for fruit harvested at other times.

I. INTRODUCTION

The reduction of carbon dioxide production and of moisture loss by the application of wax coatings to the skins of fruit has been reported by many workers (e.g. Platenius 1939; Trout 1953, 1954, 1955, 1956; Trout, Hall, and Sykes 1953; Hardenburg 1953; Mathur and Subramanyan 1956; Long and Leggo 1959; and Hartman and Isenberg 1956). Although several methods of applying wax coatings have been tried, the most commonly used is dipping in a water-base wax emulsion.

Few references are available on the use of wax coatings for bananas. Trout (1953, p. 23; 1954, p. 47; 1955, pp. 44-5; 1956, p. 56) reported briefly on the results obtained by officers of the Queensland Department of Agriculture and Stock. Results indicated that an extension of ripe shelf life of 3-5 days was obtained when either green or ripe bananas were treated with a mixture of two commercial emulsions diluted to contain 10% of wax. This result was confirmed by results obtained in Western Australia (Lawson 1960). Hall and Kapur (private communication) investigated the effect of concentrations of various wax emulsions on respiration, ripening and storage life of bananas. The effects produced depended on the storage temperatures and the type and concentration of the wax in the emulsion. Respiration rates were retarded 20–40% at ripening

* Food Preservation Research Laboratory, Queensland Department of Primary Industries.

temperatures and ripening was greatly retarded, but waxed fruit did not ripen uniformly. Waxing did not retard the development of latent infections, so waxed fruit was often lost by skin-rotting before it ripened. Excessive development of latent infections prevented storage life being extended at 53°F.

The waxing process was not used to any great extent in Queensland until the advent of the fibreboard container, when an attempt was made to improve the appearance and keeping quality of bananas packed in hands by treating them prior to ripening with an emulsion containing 10% wax. It was found that ripening was delayed so much that economic use of ripening space was not possible.

A series of experiments was therefore carried out to observe the effects of waxing on the behaviour of fruit of Mons Mari banana (a giant mutant of Cavendish banana) during ripening and subsequent senescence at different times of the year.

II. MATERIALS AND METHODS

A commercial paraffin wax emulsion was used at concentrations of 2, 4, 6, 8 and 10% wax. All fruit was treated with 0·15% sodium salicylanilide to decrease stem-end infections, the fungicide being included in the emulsion in the waxing treatments. Fruit was selected on August 9 and November 8, 1961; February 2 and February 28, 1962; and January 9 and May 22, 1963. It was harvested from a commercial plantation as being mature for market. At each harvesting period, two bunches of as even a size as possible were selected. Twenty-four fruit from one bunch were selected for treatment and subsequent determinations of respiration rate. The remainder of the fruit was cut from the bunches in hands and divided into four groups according to size of fingers (Table 1). Hands of fruit from each group were divided into single fruit and distributed at random into six groups of 10 fruit each for treatment. All fruit was hard and green when treated.

TABLE 1

CATEGORIES OF FRUIT SIZE*

Size	9.viii.61	8.xi.61	14.ii.62	9.i.63	22.v.63
1	8s and 9s	9s	9s	9s	8s and 9s
2	mainly 8s	8s and 9s	8s and 9s	8s and 9s	mainly 8s
3	7s and 8s	7s and 8s	8s and 9s	mainly 8s	7s and 8s
4	6s and 7s	6s and 7s	7s and 8s	7s and 8s	mainly 7s

* 6s, 7s, etc., are abbreviations of "sixes", "sevens", etc., and refer to length of fruit in inches (6s = 6 in.)

Individual fruits were labelled, treated, weighed and placed in a 44-gal drum at 64°F in the presence of ethylene at a concentration of 1 part in 1,000 for ripening. After ripening, the fruit was removed from the drum and placed on open shelves at 64°F and approximately 90% R.H. until judged to be softer than a normal firm-ripe banana. Respiration rates were measured, using calibrated manometric-type flowmeters and an infra-red gas analyser.

III. RESULTS AND DISCUSSION

The mean values for time to reach full colour, time from full colour to final breakdown, weight loss from green to full colour, and weight loss from green to final breakdown, are shown for wax concentration and fruit size in Tables 2-5. Time to climacteric peak is shown in Table 6 and respiration rate at climacteric peak in Table 7.

(a) Effects of Wax Concentration

Time to full colour.—Increase in wax concentration delayed the time to reach full colour (Table 2). This occurred generally for all harvest times except August (for which no data were obtained), though there was some variation in magnitude according to time of harvest.

TABLE 2

MEAN NUMBER OF DAYS TO REACH FULL COLOUR

Treatment/Size	Date of Harvest					
	9.viii.61	8.xi.61	14.ii.62	28.ii.62	9.i.63	22.v.63
(1) Control	..	6·65	7·15	7·30	6·85	6·18
(2) 2% wax	..	8·35	7·28	8·68	7·38	7·05
(3) 4% wax	..	9·83	7·63	8·90	7·75	8·00
(4) 6% wax	..	10·43	8·23	9·78	8·93	9·35
(5) 8% wax	..	11·60	8·93	10·40	9·88	11·23
(6) 10% wax	..	12·83	9·03	10·55	11·18	12·38
		1≪2,3,4,5,6	1≪3,4,5,6	1≪2,3,4,5,6	1≪3,4,5,6	1≪2,3,4,5,6
		2≪3,4,5,6	2≪4,5,6	2≪4,5,6	2≪4,5,6	2≪3,4,5,6
		3≪5,6	3<4	3<4	3≪4,5,6	3≪4,5,6
		4<5	3≪5,6	3≪5,6	4≪5,6	4≪5,6
		4≪6	4≪5,6	4<6	5≪6	5≪6
		5<6				
Size 1 ..	..	10·3	8·7	..	9·2	9·6
Size 2 ..	..	10·0	7·9	..	8·7	8·9
Size 3 ..	..	9·8	7·8	..	8·75	9·3
Size 4 ..	..	9·6	7·9	..	8·0	8·3
			1≫2,3,4	..	1>2,3	1≫2,4
		N.S.D.			1≫4	2>4
					2≫4	3≫4
					3≫4	

From the marketing aspect, it is important that time to reach the stage of ripeness desirable from a sale point of view should not be unduly delayed, because this could cause an accumulation of fruit in the commercial ripening rooms. Ripeners of fruit are prepared to tolerate a delay of 1 day in the time taken by waxed fruit to reach a desirable level of ripeness compared with the time taken by unwaxed fruit. As fruit is sold to retailers at a stage of ripeness of half to three-quarters colour and not full colour, as was recorded in this experiment, it is not possible to use the data obtained (Table 2) to determine

what concentrations of wax should be used to ensure that the ripening of fruit is not unduly delayed. However, estimates have been prepared based on the data obtained; acceptable concentrations should be 2% for fruit harvested in October and November; 6% for fruit harvested in January, February and March; and 4% for fruit harvested at other times of the year.

Time from full colour to final breakdown (shelf life).—The effect of wax concentration on the shelf life of fruit as measured from full colour to final breakdown (Table 3) varied considerably with time of marketing. During the period when anthracnose was a problem (January and February) increasing wax concentration decreased shelf life because of an increase in mould wastage. At these times the use of a wax emulsion is not recommended. However, if waxing is necessary, only a weak concentration should be used. At other times, the addition of small amounts of wax increased shelf life.

TABLE 3

MEAN NUMBER OF DAYS FROM FULL COLOUR TO FINAL BREAKDOWN

Treatment/Size	Date of Harvest					
	9.viii.61	8.xi.61	14.ii.62	28.ii.62	9.i.63	22.v.63
(1) Control	9·18	9·35	6·10	8·88	10·90	11·43
(2) 2% wax	10·70	11·98	5·98	8·85	10·48	12·73
(3) 4% wax	10·73	11·78	5·63	9·40	9·50	12·60
(4) 6% wax	11·38	11·38	5·03	9·28	9·03	12·60
(5) 8% wax	11·13	10·88	4·58	8·63	8·00	12·58
(6) 10% wax	11·48	11·25	4·48	8·60	7·23	11·83
	1 < 2,3	1 < 4,6	1 ⩾ 4,5,6	N.S.D.	1 ⩾ 3,4,5,6	1 ⩽ 2,3,4,5
	1 ⩽ 4,5,6	1 ⩽ 2,3	2 ⩾ 4,5,6		2 > 3	
			3 > 4		2 ⩾ 4,5,6	2 ⩾ 6
			3 ⩾ 5,6		3 ⩾ 5,6	3,4,5 > 6
					4 > 5	
					4 ⩾ 6	
Size 1 ..	9·7	11·0	4·4	..	7·8	11·8
Size 2 ..	10·6	10·9	5·1	..	9·0	12·2
Size 3 ..	11·2	10·6	5·6	..	9·4	12·5
Size 4 ..	11·6	11·9	6·1	..	10·5	12·7
	1 ⩽ 3,4	N.S.D.	1 ⩽ 2,3,4		1 ⩽ 2,3,4	1 ⩽ 3,4
	2 < 4		2 < 3		2,3 ⩽ 4	2 < 4
			2 ⩽ 4			
			3 < 4			

When a fruit is held from the time of harvesting until the time of final breakdown and a time to reach a stage of ripeness (which depends on prevailing commercial conditions) is determined, the shelf life is the time from this point until breakdown occurs. Any alteration in the stage of ripeness changes the shelf life. In the present experiment, full colour was taken as being indicative of a constant stage of ripeness and the data obtained for shelf life are based on this criterion. In commercial practice fruit is sold to the retailer at an earlier stage of ripeness —usually half to three-quarter colour. If this latter stage of ripeness had been

used to determine both time to ripen and shelf life, different figures would have been obtained. Thus the shelf life would have been increased by useful amounts proportionally greater than those shown in Table 3 as concentrations of wax were increased.

Weight loss.—With the exception of the August and January picks, the addition of even 2% wax caused a marked reduction in mean weight loss from green to full colour (Table 4). While this effect was obvious, further reductions in weight loss with further increases in wax concentration were not so apparent. This was probably due to the fact that with the higher concentrations of wax it was difficult to determine the time to full colour, as small blotches of green colour frequently remained even when the remainder of the skin was full yellow colour. This effect varied with time of year.

TABLE 4

MEAN PERCENTAGE WEIGHT LOSS FROM GREEN TO FULL COLOUR

Treatment/Size	Date of Harvest					
	9.viii.61	8.xi.61	14.ii.62	28.ii.62	9.i.63	22.v.63
(1) Control	1·80	2·07	2·91	2·23	1·83	2·52
(2) 2% wax	1·93	1·40	2·33	1·84	1·77	2·04
(3) 4% wax	1·91	1·28	2·15	1·86	1·86	1·91
(4) 6% wax	1·47	1·11	2·00	1·93	1·82	2·00
(5) 8% wax	1·49	1·15	1·72	1·86	1·88	2·10
(6) 10% wax	1·46	1·12	1·96	1·74	1·95	2·31
	1 > 4,5,6	1 ⩾ 2,3,4,5,6	1 ⩾ 2,3,4,5,6	1 > 3,4,5	N.S.D.	1 ⩾ 2,3,4,5
	2,3 ⩾ 4,5,6	2 > 4,6	2 > 6	1 ⩾ 2,6		2 < 6
			2 ⩾ 5			3 ⩽ 6
			3 > 5			
Size 1 ..	1·56	1·49	2·39	..	1·80	2·33
Size 2 ..	1·61	1·12	2·12	..	1·78	2·31
Size 3 ..	1·65	1·26	2·11	..	1·90	2·24
Size 4 ..	1·89	1·56	2·09	..	1·94	1·72
	1 ⩽ 4	1 ⩾ 2	1 > 3,4		N.S.D.	1,2,3 ⩾ 4
	2,3 < 4	1 > 3				
		2,3 ⩽ 4				

The mean percentage weight loss from the green colour stage to final breakdown (Table 5) showed no trend. This result is undoubtedly due to the fact that although increasing wax concentration decreased the rate of water loss it also delayed the onset of breakdown. The total amount of moisture lost therefore depended on a combination of these two factors. The effect of waxing treatments on fruit harvested on February 14, 1962, was undoubtedly associated with anthracnose infection, and increasing the wax concentration shortened shelf life because of the increase in anthracnose incidence. Similar results were obtained with fruit harvested on January 9, 1963, which became affected by anthracnose.

TABLE 5

MEAN PERCENTAGE WEIGHT LOSS FROM GREEN TO FINAL BREAKDOWN

Treatment/Size	Date of Harvest					
	9.viii.61	8.xi.61	14.ii.62	28.ii.62	9.i.63	22.v.63
(1) Control	7·27	3·94	7·23	5·47	5·29	13·44
(2) 2% wax	7·79	4·86	5·79	5·83	5·48	11·18
(3) 4% wax	7·72	4·34	5·29	6·10	4·96	11·35
(4) 6% wax	7·18	4·24	4·88	5·90	4·52	11·20
(5) 8% wax	7·29	4·01	4·15	5·52	4·79	11·72
(6) 10% wax	6·88	3·66	4·33	5·64	4·59	11·94
	2,3 > 6	1 < 2	1 ⩾ 2,3,4,5,6	1 < 3	1 > 4,6	1 > 5,6
		2 > 5	2 > 4	3 > 5		1 ⩾ 2,3,4
		2 ⩾ 6	2 ⩾ 5,6			
			3 > 5,6			
Size 1 ..	6·47	3·67	5·61	..	4·96	11·74
Size 2 ..	6·87	3·74	5·03	..	4·47	11·79
Size 3 ..	7·41	4·38	5·27	..	4·81	12·28
Size 4 ..	8·67	4·91	5·20	..	5·22	11·41
	1 ≪ 3,4	1 < 3	N.S.D.		1 > 2	N.S.D.
	2 ≪ 4	1 ≪ 4			2 ≪ 4	
	3 ≪ 4	2 < 3				
		2 ≪ 4				

Respiration.—The results shown in Table 6 indicate that for the May and August harvests, increasing wax concentration significantly increased the time taken for respiration rate to reach the peak of the climacteric rise. The erratic results produced for fruit picked in January are unexplained, but may be due to the influence of the anthracnose infected fingers, which severely affected other results obtained with this pick. Control fruit took different times to reach a climacteric peak at different periods but the reason for this is not clear.

TABLE 6

MEAN NUMBER OF DAYS TO CLIMACTERIC PEAK

Treatment	Date of Harvest		
	9.viii.61	9.i.63	22.v.63
(1) Control ..	4·00	5·63	7·25
(2) 2% wax ..	5·50	6·00	7·25
(3) 4% wax ..	8·25	5·88	7·25
(4) 6% wax ..	8·50	6·25	8·00
(5) 8% wax ..	8·25	5·81	8·88
(6) 10% wax ..	9·75	5·81	9·75
	1 < 3,4,5,6	N.S.D.	1,2,3 ≪ 5,6
	2 < 3,4,5		4 ≪ 6
	2 ≪ 6		

It will also be seen (Table 7) that for the January and August harvests, increasing wax concentration depressed the rate of respiration at the peak of the climacteric rise.

TABLE 7

MEAN RESPIRATION RATE (mg/kg/hr) AT THE PEAK OF THE CLIMACTERIC RISE

Treatment	Date of Harvest	
	9.viii.61	9.i.63
(1) Control ..	127·0	115·1
(2) 2% wax ..	99·9	106·6
(3) 4% wax ..	81·7	114·1
(4) 6% wax ..	66·5	102·4
(5) 8% wax ..	70·0	89·3
(6) 10% wax ..	63·2	91·3
	1≫2,3,4,5,6	1,3>5,6
	2≫3,4,5,6	
	3≫4,6	
	3>5	

(b) Effect of Size

There is considerable taper from the top to the bottom of a normal bunch of bananas due to the decreasing size of individual fingers. Within a particular bunch the large sizes are more mature than the small sizes. Because of the sampling method used in this trial, the data obtained for size are probably due at least in part to maturity differences.

Number of days to reach full colour.—The results given in Table 2 indicate a trend in which decreasing size of fruit was related to decreasing time to reach full colour. This trend occurred for all harvests from November to May, but the statistical significance of differences varied. The results suggest that when ripening is initiated with ethylene the ripening process is more rapid in small fruit than in large.

Number of days from full colour to final breakdown.—Generally, the results shown in Table 3 indicate that decrease in size brought about an increase in the time to final breakdown. The process of senescence occurs more slowly, apparently, in immature than in mature fruits.

Weight loss.—The results shown in Tables 4 and 5 suggest that weight losses were greater in small than in large fruit. This appears to depend to some extent on time of year and the situation is probably confused by the different times taken by different sized fruit to reach full colour and breakdown.

IV. ACKNOWLEDGEMENTS

The assistance of the Biometrics Branch in the planning of the trial and analysis of results is gratefully acknowledged.

REFERENCES

HARDENBURG, R. E. (1953).—Waxing horticultural products (a bibliography). *Pamph. U.S. Dep. Agric. Bur. Pl. Ind. Soils Agric. Engng.*

HARTMAN, J. D., and ISENBERG, F. M. (1956).—Waxing vegetables. *Cornell Ext. Bull.* No. 965.

LAWSON, J. A. (1960).—Banana packing and waxing. *J. Agric. West. Aust.* 1:41–5.

LONG, J. K., and LEGGO, D. (1959).—Waxing citrus fruits. *Fd Pres. Q.* 19:32–7.

MATHUR, P. B., and SUBRAMANYAN, H. (1956).—Effect of a fungicidal wax coating on the storage behaviour of mangoes. *J. Sci. Fd Agric.* 7:673–6.

PLATENIUS, H. (1939).—Wax emulsions for vegetables. *Bull. Cornell Univ. Agric. Exp. Stn* No. 723.

TROUT, S. A. (1953).—In *Rep. Dep. Agric. Qd* 1952–53.

TROUT, S. A. (1954).—In *Rep. Dep. Agric. Qd* 1953–54.

TROUT, S. A. (1955).—In *Rep. Dep. Agric. Qd* 1954–55.

TROUT, S. A. (1956).—In *Rep. Dep. Agric. Qd* 1955–56.

TROUT, S. A., HALL, E. G., and SYKES, S. M. (1953).—Effects of skin coatings on the behaviour of apples in storage. I. Physiological and general investigations. *Aust. J. Agric. Res.* 57–81.

(Received for publication October 13, 1965)