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EFFECT OF STAGE OF DEVELOPMENT OF BEAN PODS AT HARVEST ON POST-HARVEST CHANGES

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SUMMARY

Fibre weight, seed fresh and dry weights, percentage dry weight of seed, specific gravity and shear value all showed significant differences during storage.

Rates of change in the fresh and dry weights of the seed and in specific gravity of the pods were all significantly greater in more developed pods, but no significant differences were found between rates of change in fibre or shear values of pods at three stages of development.

I. INTRODUCTION

Quality characteristics of fresh beans are closely related to the physiological condition of the pods and the changes which occur in them after harvest.

Features which are considered most useful in quality assessment at harvest, as evidenced by their frequent experimental use, are various aspects of seed development and texture. Rowe and Bonney (1936) proposed percentage seed as a basis for assessment of quality, and seed size is prescribed in grade standards for fresh beans under the Queensland Fruit and Vegetable Grading Regulations. Texture of fresh fruit and vegetables is dependent on the qualities of cell aggregates and is divided by Matz (1962) into three components—intercellular forces which bind cells together, mechanical strength and rigidity due to structural elements, and cell turgidity. Numerous methods and instruments which have been evolved for the measurement of these, either singly or in combination, are reviewed by Matz (1962).

The work of Parker and Stuart (1935), Platenius and Jones (1944), Guyer, Kramer, and Ide (1950) and Groeschel, Nelson, and Steinberg (1966) on post-harvest changes was almost entirely restricted to changes in chemical composition. However, Guyer, Kramer, and Ide (1950) also studied seed and fibre content, but found little or no change during 10 days' storage. H. M. Groszmann (personal communication 1964) has shown post-harvest increases in seed size, and investigations at this laboratory have shown increases in seed size and fibre with time in store, both being dependent on temperature.

The purpose of this work was to examine further post-harvest physiological changes by observing the behaviour in store of pods harvested at different stages of development.

II. MATERIALS AND METHODS

General.—Beans used in the experiment were *Phaseolus vulgaris* L.cv.Redlands Autumn Crop, harvested during November 1966, from the property of a commercial grower in the Cleveland area, near Brisbane. Three harvests were made, each of six replications. Correspondingly the field layout was of six plots, each of three randomized sub-plots. The plots were laid out at first anthesis, and picks were made at intervals of 3 days over the period which would normally have been the first commercial harvest. At each harvest all the pods of each appropriate sub-plot were removed and subsampled in the laboratory. After various periods in store, measurements were made on fresh and dry weight of seeds, and the structural tissues of the pods were assessed by fibre determinations. No assessment was made of turgor, but loss of moisture, which is a major cause of post-harvest quality deterioration in beans, was measured as weight loss and also as specific gravity (SG). Forces needed to shear pods were also measured. These are affected by structural elements and the condition of the pectic substances of the middle lamella, and while shear readings have never been shown to be affected by turgor, they were taken as being representative of overall texture.

Procedure.—Each replication was dealt with in the laboratory in the following way:—All broken, misshapen and diseased pods and all those below a standard maximum thickness of 9·0 mm were rejected and all stalks and floral receptacles of the remainder were removed with sharp clippers. Pods were then counted and total weight was assessed, and from these figures the average pod weight and number of pods per 200 g were calculated. Samples of the average number of pods (to the nearest whole number) were taken and adjusted by replacement on a pod-for-pod basis to weigh 200 ± 0·5 g. From each replicate four samples were selected for seed size and four for fibre and shear determinations. From a number of the replicates an extra sample was taken for the measurement of changes in pod shape. The samples to be measured at zero days for seed size and for fibre and shear values were assessed for specific gravity, and then frozen rapidly at —20°F. The other samples, to be measured at 3, 6 and 9 days, were spread out in store at 70°F and 85% relative humidity for the required number of days, and on removal were weighed, then measured for specific gravity and frozen. On completion of all removals, samples were taken as required for seed and texture measurements.

Fibre.—The selection of weight of pods as a sample standard was dictated by requirements of the method of Rowe and Bonney (1936), which was used for determination of fibre, but was modified in a number of ways to improve and validate its use in post-harvest experiments. The method was originally designed to assess canned beans, and each sample of 100 g was composed of small pieces from a relatively large number of pods. However, 12-16 pods usually constitute 100 g of fresh pods, and this variability provides problems. Sample size and quantities of reagents were therefore doubled. Secondly, investigations have shown that percentage fibre increases with pod weight at harvest. In order to reduce variability further, the number of pods in each sample of any one replicate was held constant. Thirdly, compensation for moisture loss in store is required or the caustic soda becomes relatively diluted when boiled with fresher pods. To compensate for this, all samples after pulping were made up to a constant volume with water (600 ml).

Floral receptacles were removed because they are resistant to caustic soda, independent of pod quality, and their weight forms a considerable part of the total weight of fibre.

Moisture loss.—Useful critera for measurement of loss of moisture are weight loss and specific gravity. Weight loss was measured directly, and specific gravity by passing pods through graded series of alcohol/water solutions. Specific gravity values of 0·95, 0·90, 0·85, and 0·80 were rated 4, 3, 2 and 1 respectively, and each pod was rated with the value of the solution of greatest specific gravity in which it sank. Pods with a specific gravity less than 0·80 were rated zero. Ratings were adopted to avoid giving the pods a value in terms of specific gravity, which would be unreal because the value given would be at an extreme of the specific gravity range to which they belonged.

Resistance to shear.—The forces required to shear individual pods were measured with an instrument specificially designed and constructed for this purpose. It consists essentially of a level horizontal brass platform through which is drilled a 14-mm diam. hole and over the top of which slides a 6-mm thick square-edged blade. Overlapping rails are finely machined to maintain the blade flush with the platform while allowing movement with negligible friction.

Forces were applied to the blade with a modified Magness penetrometer as described by Haller (1941), and thence to a pod passed through the hole. The force needed to shear the pod is registered on the instrument.

Averages were calculated from five readings taken on each pod.

Seed weight.—Both fresh and dry weight of seeds were measured on the heaviest three seeds of each pod. Averages of fresh weight, dry weight and percentage dry weight were calculated.

Freezing.—Samples were frozen on removal from storage to prevent further changes and were assessed as time permitted. This allowed the performance of an experiment of more suitable proportions than was possible if all measurements were to be taken on the day of removal. Moisture loss and specific gravity were the features most likely to suffer change through freezing, so determinations of these were performed first, immediately on removal from storage. Pods were rapidly frozen at —20°F, and each sample was rapidly thawed in a stream of water just prior to measurement.

III. RESULTS

General.—Data on the effects of maturity at harvest on post-harvest changes are given in Table 1. All values are from six samples each weighing 200 g at harvest, the number of pods being constant for all samples within any one replicate. The number of pods in each replicate is shown in Table 2, together with average pod weight at harvest.

Fibre weight values in Table 1 are means of six single weighings. Because samples of 200 g were used, percentage fibre based on original fresh weight may be found by taking one-half the values given. Mean seed fresh weights are averages obtained for the largest three seeds from each pod, the number of pods per sample being dependent on the replication (Table 2). Average seed dry weights were similarly found, and from these two sets of values percentage dry weight of seeds was calculated. Shear values are averages of five readings taken on each pod of the sample and are expressed in pounds weight. Values of specific gravity are averages of the values obtained for each pod.

Data on pod characters at each harvest are presented in Table 3, and are the values given for zero storage in Table 1. Table 4 is also extracted from Table 1, and because it is composed of data on pods of the same age irrespective of harvest, it is suitable for comparing pod development on and off the plant.

Linear daily rates of increase of each character were calculated over the whole storage range and are presented in Table 5.

TABLE 1

MEAN VALUES OF CHARACTERS DURING STORAGE OF PODS FROM THREE HARVESTS*

Measurement	Harvest	Days in Store				Necessary Differences for Significance		Significance
		0	3	6	9	5%	1%	
Fibre weight (g)	A	0·130	0·181	0·250	0·235	0·0402	0·0537	A9, A6 ⩾ A0, A3; A3 > A0
	B	0·138	0·200	0·221	0·249	0·0402	0·0537	B3, B6, B9 ⩾ B0; B9 > B3
	C	0·226	0·290	0·333	0·337	0·0402	0·0537	C9, C6 > C3 ⩾ C0.
Seed fresh weight (g)	A	0·022	0·037	0·052	0·072	0·010	0·013	A9 ⩾ A6 ⩾ A3 ⩾ A0.
	B	0·044	0·055	0·074	0·090	0·010	0·013	B9 ⩾ B6 ⩾ B3 > B0.
	C	0·104	0·109	0·137	0·163	0·010	0·013	C9 ⩾ C6 ⩾ C3, C0.
Seed dry weight (g)	A	0·0031	0·0066	0·0106	0·0161	0·0031	0·0042	A9 ⩾ A6 > A3 > A0.
	B	0·0064	0·0096	0·0145	0·0186	0·0031	0·0042	B9 > B6 ⩾ B3 > B0.
	C	0·0177	0·0215	0·0316	0·0407	0·0031	0·0042	C9 ⩾ C6 ⩾ C3 > C0.
Percentage dry weight seed ..	A	13·81	17·60	20·33	22·54	0·99	1·33	A9 ⩾ A6 ⩾ A3 ⩾ A0.
	B	14·49	17·41	19·46	20·36	0·99	1·33	B9, B6 ⩾ B3 ⩾ B0.
	C	17·03	19·58	22·65	24·95	0·99	1·33	C9 ⩾ C6 ⩾ C3 ⩾ C0.
Specific gravity	A	3·803	3·417	2·268	1·992	0·168	0·224	A0 ⩾ A3 ⩾ A6 ⩾ A9.
	B	3·447	2·623	2·367	1·533	0·168	0·224	B0 ⩾ B3 ⩾ B6 ⩾ B9.
	C	3·845	3·095	1·703	0·492	0·168	0·224	C0 ⩾ C3 ⩾ C6 ⩾ C9.
Shear value (lb)	A	4·200	3·732	3·903	3·720	0·256	0·342	A0 ⩾ A3, A9; A0 > A6.
	B	4·925	4·672	4·633	4·435	0·256	0·342	B0 ⩾ B9; B0 > B3, B6.
	C	5·720	5·840	5·457	5·263	0·256	0·342	C3 ⩾ C6, C9; C0 ⩾ C9; C0 > C6.

* In all tables, A, B and C refer to first, second and third harvests, and 0, 3, 6 and 9 refer to the number of days in storage at 70°F and 85% relative humidity.

TABLE 2

MEAN POD WEIGHT AND NUMBER OF PODS PER REPLICATE AT EACH HARVEST

Harvest	Measurement	Plot Replicates						Harvest Mean Pod Weight
		1	2	3	4	5	6	
A	(1) Pods/200 g	42	40	42	40	41	40	..
	(2) Replicate mean pod weight (g)	4·76	4·96	4·72	5·06	4·90	5·01	4·90
B	(1) Pods/200 g	32	30	30	29	29	29	..
	(2) Replicate mean pod weight (g)	6·20	6·72	6·62	6·92	6·87	6·87	6·70
C	(1) Pods/200 g	26	25	26	26	27	26	..
	(2) Replicate mean pod weight (g)	7·74	8·13	7·71	7·56	7·39	7·74	7·71

TABLE 3

STAGE OF DEVELOPMENT AT HARVEST

Measurement	Harvest			Necessary Differences for Significance		Significances
	AO	BO	CO	5%	1%	
Fibre weight (g)	0·130	0·138	0·226	0·0477	0·0656	C0 $\gg$ B0, A0.
Seed fresh weight (g)	0·022	0·044	0·104	0·0153	0·0213	C0 $\gg$ B0 $\gg$ A0.
Seed dry weight (g)	0·0031	0·0064	0·0177	0·0031	0·0042	C0 $\gg$ B0 $>$ A0.
Percentage dry weight seed	13·81	14·49	17·03	1·47	2·04	C0 $\gg$ B0, A0.
Specific gravity rating	3·803	3·447	3·845	0·189	0·259	C0, A0 $\gg$ B0.
Shear values (lb)	4·200	4·925	5·720	0·332	0·458	C0 $\gg$ B0 $\gg$ A0.

TABLE 4

Changes in Pod Characteristics off and on the Plant

Measurement	Treatment			Necessary Differences for Significance		Significances
	A6	B3	C0	5%	1%	
Fibre weight (g)	0·250	0·200	0·226	0·0477	0·0656	A6 > B3.
Seed fresh weight (g)	0·052	0·055	0·104	0·0153	0·0213	C0 $\gg$ A6, B3.
Seed dry weight (g)	0·0106	0·0096	0·0177	0·0047	0·0066	C0 $\gg$ A6, B3.
Percentage dry weight seed	20·33	17·41	17·03	1·47	2·04	A6 $\gg$ B3, C0.
Specific gravity rating	2·268	2·623	3·845	0·189	0·259	C0 $\gg$ B3 $\gg$ A6.
Shear value (lb)	3·903	4·672	5·720	0·332	0·458	C0 $\gg$ B3 $\gg$ A6.

TABLE 5

Mean Linear Rates of Increase per Day

Measurement	Harvest			Necessary Differences for Significance		Significances
	A	B	C	5%	1%	
Fibre weight (g)	0·013	0·012	0·013	0·006	0·008	NSD.
Seed fresh weight (g)	0·0054	0·0052	0·0069	0·0016	0·0022	C > B.
Seed dry weight (g)	0·0014	0·0014	0·0026	0·0005	0·0007	C $\gg$ B, A.
Percentage dry weight seed	0·964	0·656	0·895	0·149	0·213	A, C $\gg$ B.
Specific gravity rating	−0·219	−0·200	−0·382	0·026	0·037	C $\gg$ A, B.
Shear value (lb)	−0·042	−0·050	−0·058	0·047	0·066	NSD.

Fibre.—Fibre increased significantly in storage at all stages of pod maturation. No differences in linear rate of fibre development were found between harvests taken over the whole storage period, values being from 0·012 to 0·013 g fibre per day. Also, absolute differences between fibre contents of the three harvests at 9 days' storage were essentially the same as occurred at harvest. However, it appears that fibre development at early stages of maturation was more rapid after harvest than on the plant. As maturation proceeded, this trend reversed due to a rate increase on the plant and a tapering off in rate as the storage period increased. The result of this was that for fibres of pods of the same age (Table 4), the first harvest at 6 days' storage was significantly greater than 3 days' storage of the second harvest. The third harvest, without storage, fell between these.

A microscopic examination made of the fibrous material weighed in the experiment showed it to consist mainly of xylem vessels and tracheids, but large quantities of epidermal tissue were also present.

Weight.—Fresh and dry seed weights increased both in the field and in store for all harvests. Daily rate of increase in fresh weight for the first two picks (Table 5) was 0·0054 and 0·0052 g, of which 0·0014 g of each was dry matter. For both picks the rate of increase in dry material was significantly less than at the third harvest, where daily fresh and dry weight increases were 0·0069 and 0·0026 g respectively. A comparison of seed development on and off the plant (Table 4) shows significantly greater seed weights at the third harvest than in the first and second harvests at storage periods of 6 and 3 days respectively. The relative differences by which these factors were altered resulted in the changes in percentage dry weight of seeds shown in Table 1. Highly significant differences were found during storage of all harvests, and a significantly lower rate of increase was found in pods of the second harvest.

Shear value.—From Tables 1 and 3 it can be seen that shear values increased significantly in pods kept on the plant but fell when the pods were removed and placed in store. No differences were demonstrated between the linear rates of change per day at each harvest, so the differences found between pods of the same age (Table 4) may be expected. It appears that the effects on shear forces of change in turgor and/or the pectic substances of the middle lamella far outweigh the effects due to the increases in fibre.

Specific gravity.—The rate of change in specific gravity of pods of harvest 3 was shown to be significantly greater than the rates from harvests 1 and 2. However, no significant differences were found in rate of moisture loss, and the behaviour of specific gravity is attributed to differences in pod wall rigidity. The more immature pods became partly shrivelled, and this loss in volume prevented the larger changes in specific gravity that occurred with tougher pods.

IV. DISCUSSION

It may be seen from Table 1 that significant changes occurred in all pod features during the storage period.

Comparisons between harvests (Table 3) show that in all measurements except specific gravity, pod characters at the third harvest showed highly significant differences from those of the second. Differences between the second and first harvest were not so marked, and it appears that changes generally occurred more rapidly as maturation increased. However, this is not found in the values for mean pod weights taken over each harvest (Table 2). Comparisons drawn between harvests are not performed on the different stages of maturation of originally equivalent samples but of samples selected from all pods down to a standard thickness. Later picks therefore contained pods which were previously sub-standard, a situation which is more closely allied to commercial practice and more likely to mask physiological differences at harvest, which are therefore probably greater than shown in Table 3.

As the characteristics measured are closely related to various features of pod quality, some observations on changes after harvest are pertinent to post-harvest quality deterioration. The validity of these observations is enhanced since the selection of samples was based on commercial practice, and the harvests were taken to overlap a normal commercial harvest.

Changes on the plant were found to occur more rapidly in fibre, seed fresh and dry weights, and percentage dry weight of seed in the more developed pods. These pods also had greater rates of change of various characters after harvest, particularly in fresh and dry seed weights and in specific gravity.

It is concluded, therefore, that pods which are harvested too mature commercially not only start off as a product of lower quality, but also, in some quality aspects, deteriorate at a more rapid rate.

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