

Maturity Indices for Harvesting of Beans (*Phaseolous vulgaris* L.) Variety Kentucky Wonder Green in Dry Zone Cultivations in Sri Lanka

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ABSTRACT. Beans (*Phaseolous vulgaris* L.) are an economically important vegetable grown in nearly all parts of the world for fresh and processed markets. There are no locally developed maturity indices for the crop; therefore, this study was conducted to determine maturity indices for harvesting of bean variety Kentucky Wonder Green grown under dry zone conditions in Sri Lanka to ensure acceptable produce quality for local fresh produce and processing markets in Sri Lanka as well as potential export markets.

Pods were harvested at four different maturity stages namely 9, 12, 15 and 18 days after fruit set (DAFS), and analysed for physico-chemical and physiological parameters such as pod weight, length, diameter, firmness, percentage seed weight, moisture, dry matter, fiber, total soluble solids (TSS), pH, titratable acidity, respiration and ethylene emission. They were also analysed for disease frequency (DF), visual quality rating (VQR), snapping quality (SQ) and weight loss under ambient storage. A sensory evaluation test was also conducted.

The results revealed that commercial maturity of beans was achieved at 12 to 15 DAFS under dry zone conditions (temperature of 28 ± 2 °C and relative humidity of 69-78%) in Sri Lanka. For local fresh produce markets, pods can be harvested at their maximum length, before seeds become prominent. Objective indices such as weight to length ratio of ≤ 0.7 , diameter of 1cm and firmness < 6 kg, percentage seed weight of 8–10%, pod weight to seed weight ratio of 7 and moisture content of 90% (w/b) can be used to determine the correct harvesting stage for potential export markets. Pods harvested at this stage can also be used for processing as they contained high TSS and dry matter.

INTRODUCTION

Beans (*Phaseolous vulgaris*), belong to the family Fabaceae and are popular vegetable crops grown in nearly all parts of the world. They are the major suppliers of vegetable proteins in developing countries as the pods and seeds are rich in protein and are also excellent sources of vitamins and minerals.

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Sri Lanka produced 31,690 t from an annual cultivated area of 6,461 ha at an average yield of 4.3 t/ha of beans (FAOSTAT, 2007). Badulla, Nuwara Eliya, Matale, Kandy and Ratnapura districts are the major growing areas in the country. In the recent past, beans are popularly grown in the Mahaweli system “H” areas such as Eppawala and Thambuttegama. The crop can be cultivated during both *Yala* and *Maha* seasons. There are many cultivars of beans grown commercially and new cultivars appear each year. Kentucky Wonder Green (KWG) and Kentucky Wonder Wax (KWW) are two imported varieties of pole beans. Keppetipola Nil, Balangoda Nil, Lanka Butter, Peas Butter, Lanka Nil, Chiddu Murunga, Bowaththa Selection and Mathurata Selection are domestic pole bean varieties popularly grown in Sri Lanka. In addition to these, private companies have imported several other varieties of bean, namely Provider, Liana, Royalnel, Septhy, Garonel, Mount Out *etc.* for research and export purposes (Hettiarachchi *et al.*, 2000).

Gains in yields are often offset by postharvest losses from stage of harvesting until the produce reaches the final consumer or processor. Postharvest losses of beans totaled 30% which occurred at the producer (4%), collector (6%), wholesaler (13%) and the retailer (7%) levels (Sarananda, 2000). The major causes of these losses are harvesting at an over-mature stage, mechanical damages caused by poor packaging in polyethylene sacks and rough handling during packing and transportation, exposure of the produce to high temperature, ethylene gas *etc.*

The experience of many countries showed that, the postharvest losses of agricultural produce could be reduced by using appropriate technology during harvesting, handling, packaging, transportation, processing and marketing. The most critical stage in the postharvest system that leads to serious quantitative and qualitative losses is harvesting at proper stage of maturity (Gast, 1992). According to Salunkhe and Desai (1984), beans should be harvested before the pods are fully grown and when the seeds are still small. Most cultivars become tough and stringy if left on the plant until the seed develops to a considerable size. Over-matured beans with bulging seeds are tough and fibrous while immature pods are more susceptible to wilting. The pod shape must be fairly straight, the colour bright and the appearance fresh, turgid and without blemishes. However, the majority of the beans that are sold in the domestic market is over-matured with bulging out seeds and are tough and fibrous.

Therefore, this study was conducted to determine subjective and objective indices for harvesting of beans (*P. vulgaris*) in Sri Lanka at correct stage of maturity in order to ensure acceptable produce quality for local fresh produce and processing markets as well as potential export markets.

MATERIALS AND METHODS

Field establishment and crop management

The field experiments were conducted during *Maha* season 2005/2006, at the Institute of Post Harvest Technology (IPHT), Anuradhapura situated in low country dry zone. Beans variety “Kentucky Wonder Green” (KWG) was selected for the study, as it is widely cultivated in the area. A land area of 200 m² was selected and ploughed to a depth of 30-40 cm. Then the land was divided into nine subplots, each 2 x 9.4 m in size. Each plot was separated by a 30 cm wide drain for easy irrigation. Planting holes of 30 x 30 x 30 cm

were made by maintaining an inter row spacing of 45 cm and an intra row spacing of 30 cm. One week before sowing, each hole was filled with 3 kg of organic manure. Basal dressing was applied two days prior to sowing of seeds according to recommendations made by the Department of Agriculture (Anon, 2003), and all the crop management practices were carried out based on their recommendations. Seeds were sown at the rate of three per hole and thinned, leaving two vigorous ones at three weeks after planting coinciding with trellising practices. Each plot consisted of 124 plants and 58 plants were selected from the middle two rows of the bed for data collection. The experimental design was Complete Randomized Design (CRD) with three replicates, each consisting 43 plants.

Flowers were tagged with the date soon after fruit set during peak flowering season consecutively for ten days. Pods were harvested at four different maturity stages namely 9, 12, 15 and 18 days after fruit set (DAFS) and brought to the laboratory.

Measurement of physico-chemical parameters

Individual pods at different maturity stages were weighed using a top loading balance (OHAUS; model ARA 520) to record the initial pod weight. Then the seeds were removed from the pod and weighed to record the percentage seeds with reference to pod weight. Pod length was measured by using a measuring tape and the diameter (perpendicular to the mid rib) was measured by using the vernier calliper (Mitutoyo, Japan). The firmness of pods was measured by using a digital fruit firmness tester (TURONI, model: 53205, Italy). Moisture content and dry matter were determined gravimetrically by oven dry method (Mammert, Model: ULE 500)

Physico-chemical parameters such as total soluble solids (TSS), pH and titratable acidity (TA) were determined as shown below. A representative sample of finely cut pieces of bean pods was obtained and chopped using mortar and pestle. TSS content of the juice was directly measured using a hand-held refractometer (ATAGO, model: HR-5) by squeezing the juice with a clean piece of cloth on to the cleaned sensor and the reading was reported as °Brix. To measure the pH and TA, 10 g of finely cut pod sample was weighed using a top loading balance (OHAUS; model: ARA 520). It was chopped by adding 5 ml of distilled water. Chopped samples were placed in centrifuge tubes with 15 ml of distilled water and centrifuged (Himac CR 21 E, Hitachi) at 13000 x g for 20 min. Aqueous extract was separated into a beaker and pH was measured using a pH meter (Thermoorion; model: 230A+). To measure the TA, 10 ml of the aliquot was transferred into a conical flask and titrated against 0.1N NaOH, using phenolphthalein as the indicator. The titration was repeated three times and the average was calculated. The percentage of TA was calculated based on NaOH volume used in the titration (AOAC, 2000).

To measure the fiber content a 10 g of sample was weighed accurately using a top loading balance (OHAUS; model ARA 520). Fat was extracted by using soxhlet apparatus and fiber content of each sample was measured according to Horwitz (2000).

Measurement of physiological parameters

The rate of respiration was measured in triplicate as given below. One kilogram (1 kg) of pods from each maturity stage was weighed using a top loading balance (OHAUS; model ARA 520) and placed in air-tight containers with constant volumes (24.39 L) at temperature of 29 °C for one hour before taking gas samples for assessment. A 3 ml of gas sample from

head space (95%) was collected and injected to a Gas Chromatograph (GC) (VARIAN, CP-3800, Australia). Carbon dioxide and ethylene emission were measured using flame-ionization detector (FID). Helium was used as the carrier gas at a flow rate of 60 ml/min. Column oven and FID temperatures were of 70 and 300 °C, respectively.

Evaluation of storability

Rate of respiration during storage was measured in triplicate in three day intervals using Gas Chromatography (Varian CP-3800, Australia) as described above. Weight loss during storage under ambient conditions (28±2 °C and RH of 69–78%) was measured using the top loading balance at three day intervals. The difference in weight compared to the original weight was recorded as percentage weight loss. External appearance of the pods was recorded using the following ranking system. *i.e.*: 9 = excellent (fresh, turgid and without blemishes), 7 = good (fresh, slightly turgid with some blemishes), 5 = fair (poor turgidity with moderate blemishes), 3 = edible, cannot be sold, 1 = inedible. The pods were examined for any visible incidence of disease. The number of pods infected was expressed as disease frequency (%) with reference to the total number of pods stored. Snapping quality of pods harvested at different maturity stages was evaluated using a scale, 4 = very good (snaps readily), 3 = good, 2 = fair, 1 = poor (tough).

Sensory evaluation

A sensory evaluation was conducted to test the sensory attributes of beans harvested at four different maturity stages. Thirty (30) pods from each maturity stage were taken and two ends of each pod were cut by a knife. The same amount of salt (1.5% w/w) was added to each of the samples and was steamed for 2 min. Steamed samples were presented in identical dishes, coded with 3-digit random numbers to 15-un-trained panelists. The panelists were given a ballot and advised to rank coded samples for acceptance in the order of most acceptable (rank value 4) to least acceptable (rank value 1).

Experimental design and analysis

The laboratory experiments were carried out as complete randomized design (CRD) with three replicates. Each replicate consisted of 04 kg of pods. Data obtained from the study were analyzed for variance by using the SAS (V 6.12, 1996) package. Mean separation was done by using Duncan Multiple Range Test (DMRT) and Least Significant Difference (LSD) (at $\alpha = 0.05$). Non-parametric data were analyzed by MINITAB computer package and were followed the Kruskal- Wallis test and the Friedman test.

RESULTS AND DISCUSSION

Changes in physico-chemical properties during development

The variations of physico-chemical properties of beans variety Kentucky Wonder Green (KWG) with maturity are shown in Table 1.

Pod weight, length, diameter and weight to length ratio

The pod weight, length and diameter were significantly different according to stage of maturity ($\alpha=0.05$). Initially the weight increased rapidly up to 15 days after fruit set (DAFS)

and after that it increased slowly up to a point at which 18 DAFS where the highest pod weight was found. The pod length and diameter showed a similar pattern of variation. Both the length and diameter increased to a point at which 12 DAFS and then grew slowly, before becoming constant at 15 DAFS.

Gast (1992), reported that pod weight to length ratio provides a better maturity index for beans. Pods harvested at maturity stages of 9 and 12 DAFS are still in the growing phase so that cell division and enlargement take place resulting rapid increase in weight, length and diameter. At 12 to 15 DAFS the pod is at maturation phase, showing slow rate of growth. Clearly, the physiological maturity of beans is achieved on or after 15 DAFS so that harvesting should be done before the physiological maturity to gain a high quality yield. Therefore bean pods should be harvested at weight to length ratio of 0.5 - 0.7 and at a diameter of 1cm.

Percentage seed weight and pod weight to seed weight ratio

Significant differences were observed among maturity stages with respect to both percentage seed weight and pod weight to seed weight ratio at $\alpha=0.05$ probability level. A higher percentage of seed weight was recorded when pods harvested at 18 and 15 DAFS while the highest pod weight to seed weight ratio was recorded when pods harvested at 9 DAFS. This is because at 9 DAFS seeds are very small yet growing and developing while at 12 DAFS onwards seeds are fully developed and achieved the maximum size. Percentage seeds can be used as an index for the maturity of snap beans (Board and Coote, 1959). According to Board and Coote (1959) the United States standards for canned snap beans are as follows. Grade A, not more than 8 percent seeds and Grade B not more than 16 percent seeds. Based on results of this study, it can be suggested that beans should be harvested at percentage seed weight in between 8–10% and the pod weight to seed weight ratio of not less than 7.

Table 1. Physico-chemical properties of beans variety KWG harvested at different maturity stages.

Physico-chemical property	Stage of maturity (days after fruit set)			
	9	12	15	18
Pod weight (g)	5.56 ^d	8.82 ^c	11.84 ^b	13.03 ^a
Pod length (cm)	14.5 ^c	16.21 ^b	17.05 ^a	17.15 ^a
Weight :Length	0.38 ^c	0.54 ^b	0.70 ^a	0.76 ^a
Pod diameter (cm)	0.92 ^c	1.19 ^b	1.26 ^{ab}	1.27 ^a
Seed weight (%)	3.82 ^c	9.74 ^b	18.23 ^a	20.57 ^a
Pod weight to seed weight ratio	24.45 ^a	7.43 ^b	5.13 ^b	4.95 ^b
Moisture content (% wet basis)	92.01 ^b	90.73 ^a	90.14 ^a	90.58 ^a
Dry matter (%)	7.9 ^b	9.3 ^a	9.8 ^a	9.4 ^a
Firmness (N)	54.50 ^c	54.59 ^c	61.64 ^b	74.87 ^a
Fiber content (g/100g)	0.09 ^c	0.12 ^c	1.3 ^b	1.65 ^a
Total soluble solids (Brix °)	4.17 ^b	5.23 ^a	5.73 ^a	4.67 ^a
Titrate acidity (g/100g)	0.042 ^b	0.052 ^a	0.057 ^a	0.047 ^b
pH	5.84 ^b	6.07 ^b	6.61 ^a	6.07 ^b

Note: Means in a row with the same letter are not significantly different ($\alpha = 0.05$).

Dry matter and moisture content

The dry matter and moisture contents were significantly different among the pods harvested at 9 DAFS compared to other three harvesting stages. Pods harvested at 9 DAFS are immature so that it has a low dry matter and high moisture contents, contrasting to other three stages. Lorenz and Maynard (1980) reported that moisture content of bean is 90%. The same results were obtained from the present study too when harvested at 12 DAFS and onwards. Harvesting early, results in both quantitative and qualitative losses due to excessive water loss through under developed cuticle of the peel and the high rate of respiration of immature tissues.

Firmness and fiber content

Pod firmness and fiber content were significantly different with stage of maturity. With increasing maturity, the firmness as well as the fiber content increased. Bourne (1983) reported that the changes in the chemical nature of pectic materials are the primary cause of changes that occur in textural properties of horticultural products. Unlike fruits, in pod vegetables like beans, the pod firmness increases with increasing maturity. Therefore, other substances such as lignin could be playing a prominent role. He reported that, the stone cells and fiber cells in fruits and vegetables are highly lignified, and contrasting to pectin, lignin is not depolymerized, solubilized or removed by naturally occurring enzymes or by heating. Hence, lignification may be considered as irreversible toughening. The only practical means of controlling lignification is by prevention. Thus, harvesting of lignin prone commodities when they are young (before extensive lignification of the cells) appeared to be the most appropriate approach. Therefore, beans should be harvested before 15 DAFS to avoid excessive pod toughening.

According to Board and Coote (1959) the United States standards for canned snap beans with reference to the fiber content are as follows, Grade A not more than 0.05 percent fiber and Grade B not more than 0.1 percent fiber. He also reported that the fiber content increased with increasing maturity but the rate of fiber development was different in different varieties of beans and was also affected by the weather. Similarly in this study, fiber content increased with maturity. However, difference in values observed may be due to the difference in the variety and the weather.

Total soluble solids, titratable acidity and juice pH

There were slight differences in the pattern of variation in total soluble solids (TSS) content, titratable acidity (TA) and juice pH (table 1) of beans harvested at different maturity stages and as a result, a clear relationship could not be established.

Changes in physiological parameters

Rate of respiration

The mean rate of respiration of beans harvested at different maturity stages is shown in Figure 1. The rate of respiration of beans varied within 6.3-10.5 mg of CO₂/kg/h at 29 °C. The highest respiration rate was recorded at 9 DAFS and decreased with a slight fluctuation on day 15. There was no significant difference observed among the different maturity stages at 5% probability level by DMRT. According to Kader (1992), beans have been classified in

very high respiration rate category of, 40-60 mg of CO₂/kg/h at temperature of 5 °C. The deviation found in the test results may be due to difference in variety, climate, weather and difference in the stages of maturity.

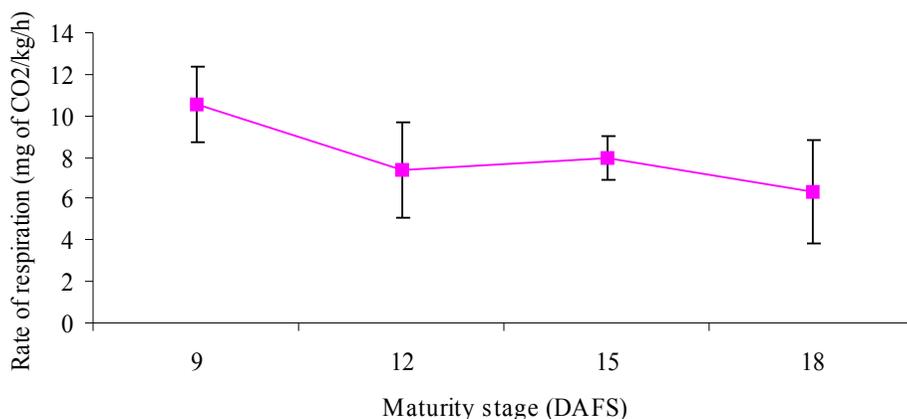


Figure 1. Rate of respiration of beans variety KWG harvested at different stage of maturities and at temperature of 29 ±2 °C.

(DAFS – days after fruit set) data are means ± S.E.

Evaluation of keeping quality

Rate of respiration during storage

The variation in rate of respiration for a period of 6 days in storage under ambient conditions (28 ±2°C and RH of 70-80%) is shown in Figure 2. The highest respiration rate was observed at the date of harvest and it may be due to field heat. Peleg (1985) reported that field-warm produce naturally has a much higher initial respiration rate than cooled down fruits and vegetables. The respiration rate of pods harvested at 9 DAFS was consistently higher than that of other three stages. Apparently, pods harvested at 9 DAFS were still in the growing phase where the rate of cell division and enlargement could have been higher, requiring a higher rate of respiration. The normal rate of respiration of a produce is usually inversely proportional to its storage life. So that high respiration rates are generally attributed to a short shelf life (Peleg, 1985). Therefore, it can be suggested that based on rate of respiration during storage, beans should be harvested during 12-15 DAFS.

Rate of ethylene emission during storage

On the day of harvest no ethylene production was detected in pods harvested at the four different maturity stages. However ethylene was detected during 03rd day in storage (Figure 3). A higher amount of ethylene was produced by the pods harvested at 15 and 18 DAFS whereas the lowest amount was detected in pods harvested at 12 DAFS. A relatively higher amount of ethylene was produced by pods harvested at 9 DAFS and it may be due to water stress. Kader (1992) reported that generally ethylene production rates increases with

maturity at harvest, physical injuries, disease incidence, high temperatures (>30°C) and water stress. Ethylene production rates of cucumber, okra, eggplant and pumpkin were 0.1-1.0 $\mu\text{L C}_2\text{H}_2/\text{kg/h}$ at the temperature of about 20°C and based on this they were categorized under low ethylene producing crops (Kader, 1992). In this study the ethylene production rate of beans was 0.1-0.6 $\mu\text{L C}_2\text{H}_2/\text{kg/h}$ at temperature of about $28 \pm 2^\circ\text{C}$. Therefore, beans can also be categorized under the same group.

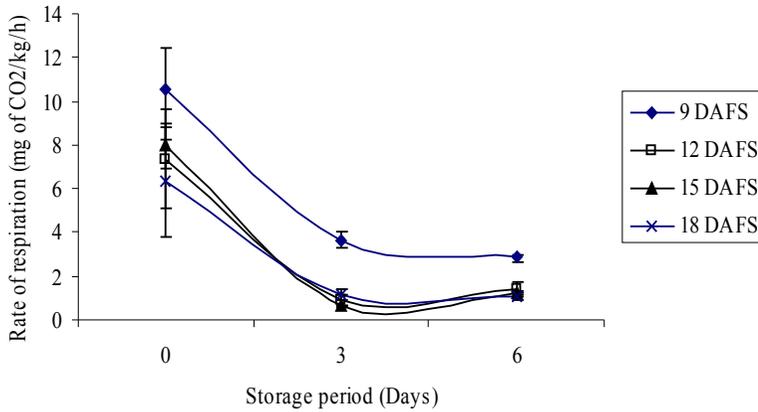


Figure 2. Rate of respiration of beans variety KWG for a period of six days in storage under ambient conditions (temperature $28 \pm 2^\circ\text{C}$, RH 70 – 80%)

(DAFS – days after fruit set) data are means \pm S.E.

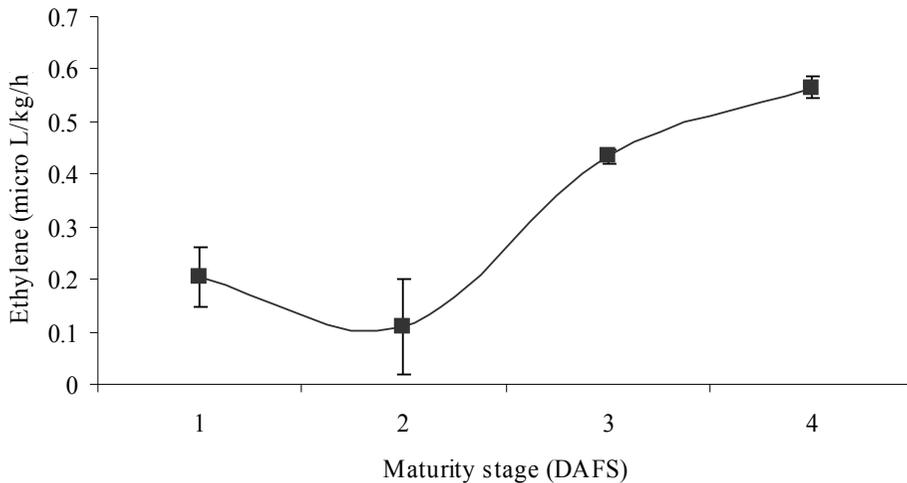


Figure 3. Rate of ethylene emission of beans variety KWG at 03rd day in storage under ambient conditions (temperature of $28 \pm 2^\circ\text{C}$ and RH of 70 -80%).

(DAFS – days after fruit set) data are means \pm S.E.

Weight loss

Variation in cumulative weight loss, disease frequency (DF), visual quality rating (VQR) and snapping quality at 9th day under ambient storage conditions is shown in the Table 2. A higher rate of weight loss was observed in pods harvested at 9 DAFS and it may be due to high metabolic activities of the growing tissues, active stomata and underdeveloped cuticle in the peel which enhance water loss through transpiration and evaporation. Peleg (1985) reported that every percentage point of water loss through transpiration may add to the weight loss. Pods harvested at 18 DAFS also had a higher rate of weight loss during storage. This may be due to the pods at this stage emitting more ethylene which enhances yellowing and disease development creating stress conditions and thereby increases respiration rate and consequently weight loss. Pods harvested at 12 DAFS had the lowest rate of water loss throughout the storage period. Based on the results observed, it can be suggested that beans should be harvested during 12-15 DAFS.

Disease frequency

During the first three days storage, no disease symptoms were observed in pods harvested at 9, 12 and 15 DAFS whereas the pods harvested at 18 DAFS showed a disease frequency of 5% (data not shown). These symptoms appeared as dark brown sunken patches and the disease was identified as anthracnose which is caused by *Colletotrichum lindemuthianum* (Anon, 1994). During the last three days the disease development in pods harvested at 18 DAFS increased significantly. This may be due to higher rate of respiration and ethylene emission. The disease incidence was low when beans were harvested at 12-15 DAFS compared to other two stages.

Table 2. Cumulative weight loss, disease frequency, visual quality rating and snapping quality of beans variety KWG at 9th day under ambient storage.

Stage of maturity (days after fruit set)	Cumulative weight loss (%)	Disease frequency (%)	Visual quality rating (VQR)	Snapping quality (SQ)
9	28.47 ^b	39.43 ^b	1	1
12	15.02 ^c	29.97 ^b	3	2
15	20.12 ^{bc}	31.48 ^b	3	1
18	55.09 ^a	59.32 ^a	1	1
	LSD _{0.05} 6.54	LSD _{0.05} 7.44	P=0.01	P=0.03

Note: Means in a column with the same letter are not significantly different ($\alpha = 0.05$).
VQR (1-9), i.e. 9 = excellent (fresh, turgid and without blemishes), 7 = good (fresh, tightly turgid with some blemishes), 5 = fair (poor turgidity with moderate blemishes), 3 = edible, cannot be sold, 1 = inedible.
SQ (1-4), i.e. 4 = very good, snaps easily, 3 = good, 2 = fair, 1 = poor

Visual quality rating

On the day of harvesting, the pods harvested at maturity stages of 9, 12 and 15 DAFS showed a better visual quality (data not shown) whereas, the pods harvested at 18 DAFS were wrinkled due to bulge seeds. During the following three days, pods harvested at 9

DAFS showed a lower visual quality as a result of shriveling caused by excessive water loss through immature peel (Table 2). As a result it showed poor turgidity. Pods harvested at 18 DAFS also had lower visual quality as it showed yellowing, toughening and high disease incidences. Kader (1992) reported that exposure of most commodities to ethylene accelerates their senescence, and in many plant tissues, ethylene results in rapid loss of chlorophyll. Pods harvested at this stage produced a high amount of ethylene thereby it has accelerated pod deterioration. Pods harvested at 12-15 DAFS maintained freshness and turgidity throughout the storage period tested.

Snapping quality

Initially, the snapping quality of pods harvested at 9, 12 and 15 DAFS was higher than those of pods harvested at 18 DAFS (data not shown). Then the snapping quality of pods harvested at 9 DAFS decreased as a result of losses in turgidity. Pod toughening caused by excessive lignification and suberisation was the reason for poor snapping quality of pods harvested at 18 DAFS. Rohana and Jayasekera (2002) reported that harvesting of bushsitao (*Vigna unguiculata*) at early stages of maturity gives higher snapping quality than the pods harvested at later stages. Similarly in this study beans harvested at 12 DAFS had higher snapping quality than that of pods harvested at 15 and 18 DAFS.

Sensory evaluation

There was a significant difference in acceptability of texture among the stages of maturity according to critical absolute rank sum differences for all treatments comparisons at 5% level of probability (data not shown). The pods harvested at 9 DAFS had the highest acceptability. This may be due to pods at this stage being immature and therefore more tender and less fiber and also because the seeds were still developing. Tender pods with low fiber were accepted by the panelists for the highest quality.

CONCLUSIONS

The results revealed that commercial maturity of bean was achieved at 12 to 15 DAFS under dry zone conditions (temperature of 28 ± 2 °C and relative humidity of 69% - 78%) in Sri Lanka. For local fresh produce markets pods can be harvested at their maximum length and before seeds become prominent. For potential export markets objective indices such as weight to length ratio of ≤ 0.7 , diameter of 1cm and firmness < 6 kg, percentage seed weight of 8 – 10%, pod weight to seed weight ratio of 7 and moisture content of 90% (w/b) can be used to identify the correct harvesting stage. Pods harvested at this stage can also be used for processing markets as they contained higher TSS and dry matter.

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REFERENCES

- Anon. (2003). Beans. pp. 31. *In*: Mankotte K.N. (Ed.). Vegetable Cultivation, Department of Agriculture, P.O.Box 18, Peradeniya, Sri Lanka.
- Anon. (1994). Beans, Brassicas, pp. 19-35. *In*: Perseley, D. (Ed.). Diseases of Vegetables. Queensland Department of Primary Industries, GPO Box 46, Brisbane Q 40001.
- Board, P.W. and Coote, G.G. (1959). The Maturation of Green Stringless Bush Beans. Technical Paper No.12, Commonwealth Scientific and Industrial Research Organization, C.S.I.R.O., Melbourne, Australia : 1-11.
- Bourne, M.C. (1983). Physical properties and structure of horticultural crops, pp. 207-228. *In*: Peleg, K. and Bagley, B.E. (Eds). Physical Properties of Foods, The AVI Publishing Co. Inc. Connecticut.
- FAOSTAT (2007). FAO statistical database. Food And Agricultural Organization of the United Nations. <http://w3.fao.org/site/340/> (Access on 12.02.2007).
- Gast, K.L.B. (1992). Harvesting maturity indicators for fruits and vegetables. *Postharvest Management of Commercial Horticultural Crops*, Kensas State University Agricultural Experiment Station and Cooperative Extension Service. (<http://w3aces.uiuc.edu/NRES/extension/factsheets/vc-11/vc-11.html>) (Accessed on 05.07.2005).
- Hettiarrachchi, M.P., Costa, W.A.J.M.D. and Jayasekara, S.J.B.A. (2000). Common bean (*Phaseolus vulgaris L*). Evaluation of the Success of Varietal Improvements Programmes of Selected Food Legumes in Sri Lanka. National Library & Documentation Center, Sri Lanka.
- Horwitz, W. (2000). Official Method of Analysis of AOAC International (Vol. II). Suite 500 481, North Frederick Avenue, Gaithersburg, Maryland 20877-2417. USA.
- Kader, A.A. (1992). Postharvest Technology of Horticultural Crops. Publication 3311, Division of Agriculture and Natural Resources, University of California, 6701, California.
- Lorenz, O.A. and Maynard, D.A. (1980). Knott's Handbook for Vegetable Growers. John Willey and Sons, New York.
- Peleg, K. (1985). Receiving Produce From Field. pp.17-34. *In*: Produce Handling, Packaging and Distribution, The AVI Publishing Co. INC., Connecticut.
- Rohana, T.J. and Jayasekera, S.J.B.A. (2002). Development of maturity indices for harvesting of bushitao (*Vigna unguiculata*). pp.137-143. Proc. Second Agric. Research Sym., Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Makandura, Gonawila.
- Salunkhe, D.K. and Desai, B.B. (1984). Postharvest Biotechnology of Vegetables, CRC Press. Inc., Florida.
- Sarananda, K.H. (2000). Report of the APO Seminar on Appropriate Postharvest

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Technologies for Horticultural Crops in Asia. Held in Bangkok from 5 to 9 July, 1999, Asian Productivity Organization. Tokyo : 230-236.