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Maturity Indices for Harvesting of Cabbage (*Brassica oleraceae L.*) Variety Green Coronet

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ABSTRACT. *Cabbage (Brassica oleraceae L.) is one of the most economically important vegetable grown for fresh and processed markets. There are no properly developed maturity indices for the crop and therefore, the present study was conducted to determine maturity indices for harvesting of cabbage to ensure optimum field yield, processed yield and acceptable product quality for local fresh produce and processing markets as well as potential export markets.*

The experiment was executed for the variety "Green Coronet". The heads were harvested at eight different maturity stages namely 60, 75, 80, 85, 90, 95, 100, 105 and 110 days after planting (DAP). Then they were analysed for physico-chemical and physiological parameters such as head weight, diameter, firmness, specific gravity, moisture, dry matter, total soluble solids (TSS), pH, ascorbic acids and rate of respiration. They were also analysed for disease index (DI), visual quality rating (VQR) and weight loss under ambient storage. A sensory evaluation test was also conducted.

The results revealed that commercial maturity of cabbage achieved at 75-80 DAP under dry zone conditions (temperature of 28±2^{o}C *and relative humidity (RH) of 69% - 78%) in Sri Lanka. So that, for fresh market, cabbage can be harvested when the weights of the heads were 1.2 - 1.5 kg, diameter of 11 cm, firmness of 8 kg, specific gravity of 0.78 - 0.86 and at the moisture content of 91% (weight basis). Heads harvested at this stage can also be used for processing markets as they contained high amount of TSS and dry matter while low in pH. For long-term storage, harvesting of heads at 75 - 80 DAP is the best maturity stage since the rate of weight loss was minimum while good VQR and low disease incidences could be achieved.*

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INTRODUCTION

Cabbage (*Brassica oleracea* sub sp. *capitata* L.) is the most important member of the group "cole crops" and is one of the important vegetable crops in the world. Cabbage ranks high among vegetables for nutritive value. It is rich in minerals such as phosphorus, potassium, calcium and, ion and vitamins such as A and C (Ryder, 1979).

Sri Lanka produced an annual average cabbage yield of 52,220 t from a cultivated area of 2,891 ha at an average yield of 18.2 t/ha in 2003 (FAOSAT, 2007). Cabbage thrives best in a relatively cool and moist climate. The major growing areas in the country are Badulla, Marassana, Mahaweli H zone, Naula and Nuwara Eliya. There are several cultivars recommended by the Department of Agriculture (DOA) for cultivation. Among these, Exotic and Herculis are recommended for the up-country wet zone where as Exotic, AS cross and KY cross are recommended for mid-country areas (Anon, 2003). However, there are many hybrids available in the market as they develop a good crop stand and have higher heading, early maturity and uniform sized compact heads. They are namely Royal Sluis, Green 123, Green Coronet, Golden Cross, GS Cabbage and Tropicana.

Gains in yields are often offset by postharvest losses from the stage of harvesting until the produce reaches the final consumer or processor. The postharvest losses of durables range between 10 - 20% and 30 - 40% for perishables (Anon, 2001) which could have been used in reducing poverty and hunger, malnutrition and loss of export earnings. The value of those losses has been estimated to be 12 - 13 billion rupees, and fruits and vegetables contribute more than eight billion rupees (Anon, 2001). Postharvest losses of cabbage are totalled to 25% which, occurred at the producer (4%), collector (7%), wholesaler (9%) and at the retailer (5%) levels, (Sarananda, 2000). The major causes for these losses are harvesting at an over mature stage that indicated by cracks in heads and due to mechanical damages caused by rough handling during harvesting and poor packing in polyethylene sacks. Mechanical damage that take place in poly stacks during distribution resulted in cracks and cuts through which the cabbage lost moisture and became susceptible to microbial attack.

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 (Gast, 1992). This is the starting point for the postharvest management process. After harvesting, the quality of fruits and vegetables usually cannot be improved, only can be maintained (Gast, 1992). The most basic factor affecting good quality is harvesting at proper stage of maturity. However, maturity variations among varieties of fruits and vegetables, as well as differences in maturation of produce on the same tree or vine make it difficult to identify the correct stage to harvest.

According to Salunkhe and Desai (1984) cabbage cultivars generally mature within 62 to 110 days from field setting at low elevations and from 81 to 125 days at high elevations. The important quality characteristics of fresh market cabbage are colour, firmness, crispness and freedom from decay and rot (Ryder, 1979). Cabbage approaching maturity does not exhibit readily detectable changes, as such harvesting too early will results in loose unfilled heads while late harvesting may result in cracked or rotted heads. Research

by Isenberg *et al.* (1975) suggests that most cabbage cultivars are ready for harvest when they reach a specific gravity of 0.72 - 0.80 and a weight of 2.2 -3.0 kg. However, these may vary according to climatic conditions in the area and cultural practices that are adopted. Hence, it is very beneficial to develop maturity indices for cabbages that are grown in Sri Lanka as there are no such indices developed yet.

Therefore, this study was conducted to determine subjective and objective indices for harvesting of cabbage (*B. oleraceae*) at correct stages of maturity in order to ensure optimum field yield, processed yield and acceptable product quality in terms of storage life and palatability characteristics targeting 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 2004/2005, at the Institute of Postharvest Technology (IPHT), Anuradhapura situated in the dry zone. Cabbage variety Green Coronet was selected for the study**,** as it is widely cultivated in the area. Cabbage seeds were sown in containerized plant nurseries and one month old healthy vigorous seedlings were selected for field planting. A land area of 200 m^2 was selected and it was ploughed to a depth of 30 - 40 cm. Then six raised beds were prepared each in size of 3 x 9.4 m. Each plot was separated by a 30 cm wide drain. Planting holes of 30 x 30 x 30 cm were made by maintaining an inter row spacing of 50 cm and intra row spacing of 40 cm. Each hole was added 3 kg of cow dung, one week before the establishment of seedlings. The basal dressing was applied according to recommendations made by the DOA (Anon, 2003) prior to establishment of seedlings and cultural practices were carried out according to their recommendations. Each plot was consisted of 138 plants and 84 plants were selected from the middle four rows of the bed for data collection. So that, total of 504 plants was used for the experiment. Measures were taken to maintain homogeneity of all the field operations. The experimental design was Completely Randomized Design (CRD) with three replicates and each replicate was consisted of 21 plants**.**

Cabbage heads were harvested randomly from the field at eight different maturity stages, starting from 60 days after planting (DAP) and at 75, 80, 85, 90, 95, 100, 105 and 110 DAP. Heads were harvested in the morning at 8.00 - 10.30 a.m, put into plastic crates and transported to the laboratory.

Measurement of physico chemical parameters

Head weight was recorded using a top loading balance (OHAUS, model ARA520). And the diameter was calculated after measuring the perimeters of heads. The firmness of heads was measured by using a digital fruit firmness tester (TURONI, model 53205). Specific gravity was measured by water displacement method (Szczesniak, 1983). Moisture content and dry matter were determined gravimetrically by the oven dry method (Mammert, model ULE 500).

Chemical parameters such as total soluble solids (TSS), pH and ascorbic acids were determined as given below. A representative sample of finely cut pieces of cabbage heads were obtained and chopped using motar and pestle. TSS content of the juice was directly measured using a hand refractrometer (ATAGO, model: HR-5) by squeezing the juice with a clean piece of cloth on to the cleaned sensor and reading was reported as Brix. To measure the pH, chopped samples were put into centrifuge tubes with 15 ml of distilled water and were centrifuged for 20 min. Aqueous extract was separated to a beaker and pH was measured using a pH meter (Thermoorion, model 230A+).

To measure the ascorbic acids, 10 g of chopped cabbage sample from each maturity stage were put into centrifuge tubes and 15 mL of 0.25% oxalic acid were added. The samples were centrifuged for 20 min. Aqueous extract was separated into 100 mL volumetric flasks and volumrized up to the mark with 0.25% oxalic acid solution. Ten (10) ml of sample solution was pipetted into a conical flask and was titrated with 2, 6 dichloro-phenol indophenol, as described by Askar and Treptow (1993).

Measurement of physiological parameters

The rate of respiration was measured as described below. Cabbage heads were weighed and were placed in air-tight containers with constant volumes (28.32 l) at temperature of 29^{o}C and kept for one hr. A 3 mL of gas sample from the head space was collected and injected to Gas Chromatography (GC) (VARIAN, CP-3800). Carbon dioxide was measured using flame-ionized detector (FID). Helium was used as the carrier gas at a flow rate of 60 mL/min. Column oven and FID temperatures were of 140^{o}C and 300^{o}C, respectively.

Evaluation of storability

Weight loss during storage under ambient conditions (28±2^{o}C and Relative humidity (RH) of 69 - 78%) was measured using the top loading balance at three day intervals and weight difference to the original weight was recorded as the percentage weight loss. The heads were tested for diseases using a disease index (0-4), *i.e.*:0 = no disease symptoms, 1 = minimal, 1- 5% of heads having disease symptoms, 2 = moderate, 6 - 10% of heads having disease symptoms, 3 = less severe, 11 - 25% of heads having disease symptoms, 4 = severe, more than 26% of heads having disease symptoms. External appearances of the heads were recorded by using the following ranking system. *i.e.*: 5 = excellent fresh appearance, 4 = better, slight freshness, 3 = moderate freshness, 2 = Severe, more than 10% of outer leaves wilted but marketable after removing those outer leaves, 1 = not marketable.

Sensory evaluation

Sensory evaluation test was conducted for six maturity stages *i.e.* 60, 75, 85, 90, 100 and 105 DAP. Cabbage heads were shredded into approximately 2.5 cm pieces and representative samples from each maturity stage were steamed for 2 min by adding the same amount of salt. And those were presented in identical dishes, coded with 3-digit random numbers to 15-non-trained panelists. The panelists were given a ballot and advised to rank coded samples for acceptance in the order of most acceptable (rank value 6) to least acceptable (rank value 1).

Experimental design and analysis

The laboratory experiments were carried out as completely randomized design (CRD) with four replicates. Each replicate consisted of six heads. Data obtained from the study was analyzed for variance by using the SAS package. Mean separation was done by using Duncan Multiple Range Test (DMRT) and Least Significant Difference (LSD) (at α=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 physical properties during development

The variations of physical properties such as head weight, diameter, firmness, specific gravity, moisture content and dry matter content of cabbage variety Green Coronet with maturity are shown in Table 1.

Table 1. Physical properties of cabbage variety Green Coronet harvested at different maturity stages.

Stage of maturity (DAP)	Physical properties of heads					
	Weight (kg)	Diameter (cm)	Firmness (kg)	Specific gravity	Moisture content (%)	Dry matter (%)
60	0.88^{d}	9.46^{c}	10.49^{a}	0.868 ^{a}	94 ^{a}	6 ^{d}
75	1.33^{ab}	11.00^{a}	8.12^{bc}	0.789 ^{a}	91.4 ^{d}	8.6 ^{a}
80	1.33^{ab}	10.12^{b}	7.74^{bc}	0.869^{a}	91.5^{d}	8.5^{a}
85	1.26^{b}	9.95^{b}	8.1^{bc}	0.867^{a}	93.2^{b}	6.8^{c}
90	1.37^{ab}	11.25^{a}	8.61^{b}	0.928^{a}	93.5^{ab}	6.5^{cd}
95	1.38^{ab}	11.00^{a}	8.52^{b}	0.999^{a}	92.4^{c}	7.6^{b}
100	1.46^{a}	11.09^{a}	6.42^{d}	1.047^{a}	91.7^{d}	8.3^{a}
105	1.39 ^{ab}	11.14 ^{a}	6.96^{cd}	0.962^{a}	91.6^{d}	8.4^{a}
110	1.06 ^{c}	10.04 ^{b}	3.67^{e}	0.872^{a}	91.8^{d}	8.2^{a}

Note: Means in a column with the same letter are not significantly different (at P = 0.05).

Head weight and diameter

The lowest head weight and diameter were recorded at 60 days after planting (DAP) while the maximum head weight and diameter were attained at 90 - 105 DAP. Then both weight and diameter were decreased. Removal of more and more wrapper leaves,

which were curled backward and became pale with blemishes and cracks, appeared to be the reason for the reduction in both head weight and diameter with maturity. Isenberg *et al.* (1975) reported that cabbage is ready for harvesting when they reach a weight of 2.2 - 3.0 kg. He also reported that this could vary according to climatic conditions in the area and cultural practices that are adopted. In this trial cabbage variety Green Coronet was ready for harvesting when the weights of the heads were 1.3 - 1.5 kg and at a diameter of 11 cm.

Firmness

The firmness of cabbage heads decreased with maturity and there was a significant difference among different maturity stages. Firmness is an indirect indication of the texture, and increase in crispness of heads might have caused to reduce the head firmness with maturation. Firmness and crispness are important quality parameters for fresh market cabbages (Ryder, 1979). Therefore, based on firmness cabbage variety, Green Coronet is ready for harvesting when the head firmness reached to 8 kg which achieved during 75 - 95 DAP.

Specific gravity

The specific gravity of cabbage variety Green Coronet was not significantly variable with respect to different stages of maturity. However, with the increase of diameter, volume of heads increased while specific gravity decreased. Isenberg *et al*. (1975) suggested that most cabbage cultivars are ready for harvesting when they reach a specific gravity of 0.72 - 0.80. A high specific gravity of 0.78 - 1.04 observed in this study could be due to the low volume of heads under variable climatic conditions and cultural practices.

Moisture content and dry matter

There was a significant difference in moisture content and percentage dry matter with different stages of maturity. The moisture content was high and percentage dry matter was low when heads were harvested at early mature stages (*i.e*. 60 DAP). Increasing maturity, the moisture content decreased while percentage dry matter increased. As far as processing markets are concerned having low moisture and high dry matter are advantageous. Therefore, based on moisture and dry matter, harvesting of cabbage variety Green Coronet after 75 DAP can be suggested.

Changes in chemical properties during development

The variability of chemical properties namely, total soluble solid content (TSS), pH and ascorbic acid content of cabbage variety Green Coronet with the maturity of heads are given in Table 2.

Total soluble solids and pH

The TSS of cabbage variety Green Coronet varied within 3.17 - 5.33% while the juice pH varied in the range of 5.65 - 6.54 with the stage of maturity at harvesting. However, there were slight irregularities in the pattern of variation and it might be due to the inherent variability and also the influence of climatic factors.

Table 2. Total soluble solids (TSS), pH and ascorbic acid content of cabbage variety Green Coronet harvested at different maturity stages.

Stage of maturity (days after planting)	TSS (^{0}Brix)	pH	Ascorbic acids (mg/100 g)
60	5.10^{a}	6.37^{abc}	18.6^{g}
75	3.27^{d}	6.5^{ab}	22.47^{f}
80	5.33^{a}	6.54^{a}	25.67^{e}
85	3.23^{d}	6.27^{abc}	66.37^{d}
90	3.17^{d}	6.12^{c}	81.47^{c}
95	3.67^{cd}	6.06^{c}	85.23^{b}
100	4.17^{cb}	6.13^{c}	85.57^{b}
105	4.33^{b}	6.2^{bc}	86.33^{a}
110	4.42^{b}	5.65^{d}	86.00^{a}

Note: Means with the same letter are not significantly different (at P = 0.05).

Ascorbic acids

Heads harvested at 60 DAP had the lowest ascorbic acid content, and then it increased significantly during 80 - 90 DAP reaching the maximum values at the end of the maturation stages (90 - 110 DAP). According to Lorenz and Maynard (1980) ascorbic acid content of cabbage was 42 mg/100 g of edible portion, and Salunkhe and Desai (1984) reported that ascorbic acid content of cabbage is 47 mg/100 g of edible portion. In this study ascorbic acid content of cabbage variety Green Coronet was varied within 18-86 mg/100 g of edible portion. The reason for this wide range might be due to different maturity stages, variety, climate and management practices.

Changes in physiological properties

Rate of respiration

Rate of respiration was high at early stages of growth (60 - 75 DAP) and it decreased with increasing maturity stage (Figure 1). Heads harvested during early stages of maturity were at actively growing phase where the rapid cell division and enlargement take place resulting high rate of respiration. Peleg (1985) reported that high rate of respiration is characteristic of young tissues. Plant organs harvested when it is no longer actively growing have a lower rate of respiration (Burton, 1982). The similar observations made at the present study too. The respiration rate of heads harvested at 60, 75, and 80 DAP were significantly different and rate was high than those of the heads harvested at other stages of maturity. In any given material rate of respiration may be influenced by several factors such

as temperature, concentration of respiratory substrate and different stages of development of the plant organ (Burton, 1982). The difference of rate of respiration observed may be due to difference in concentration of respiratory substrate as a result of harvesting at different maturity stages.

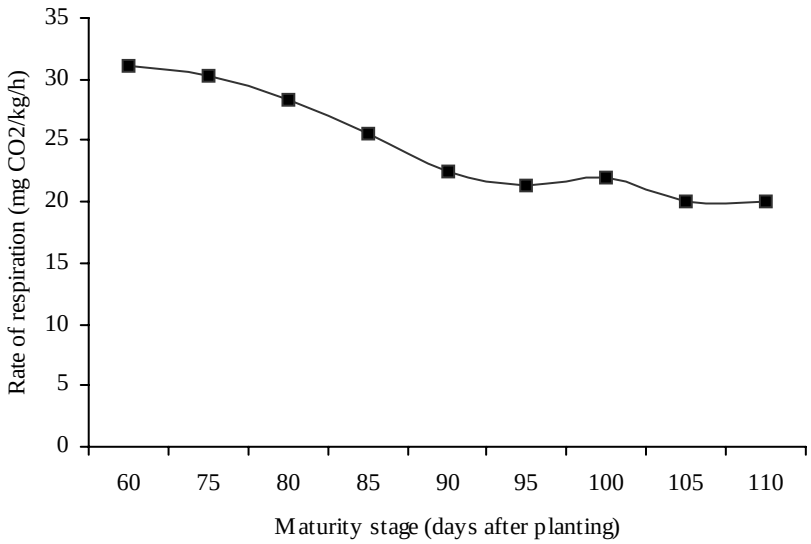

Figure 1. Variation in rate of respiration of cabbage variety, "Green Coronet" with maturity at temperature of 29 ± 2.

Evaluation of keeping quality

Weight loss

Variation in cumulative weight loss, disease index (DI) and visual quality rating (VQR) at 12th day under ambient storage is shown in Table 3. Cabbage heads harvested at 75 DAP had the lowest rate of weight loss compared to other harvesting stages. Most of the tissues of heads harvested at 60 DAP were at growing stage while having active stomata and high surface area:volume, resulting high rate of water loss, finally contributing to a huge weight loss. The reason for having high rate of weight loss of heads harvested at 90 DAP and thereafter may be due to presence of cracks and blemishes predispose heads to high water loss. Burton (1982) reported that compactness of cabbage heads are affect on rate of water loss. Heads that are harvested at firm and compact stage resistant to water loss than that of heads harvested too early (*i.e.* loose and unfilled heads) and too late (*i.e.* cracked or rotted heads) (Ryder, 1979). Therefore, harvesting of cabbage variety Green Coronet at 75 DAP which showed the lowest rate of weight loss can be recommended to have a high keeping quality.

Visual quality rating

The visual quality (VQR) of cabbage heads decreased with increasing storage period. However, the rate of quality reduction varied among different maturity stages. Evidently, the rate of quality reduction was minimum from 75 to 85 DAP whereas after 85 DAP a higher rate of reduction in visual quality was observed. Presence of cracks and blemishes in heads harvested at late stages of maturity (*i.e.* From 85 DAP onward) enhance loss of moisture and susceptibility to microbial attack. As a result, wilting and yellowing of outermost leaves and disease development caused to reduce visual quality when stored under ambient conditions (temperature 28 ±2°C, RH 70 - 80%).

Table 3. Cumulative weight loss, disease index and visual quality rating of cabbage variety Green Coronet at 12th day under ambient storage.

Stage of maturity (days after planting)	Cumulative weight loss (%)	Visual quality rating (VQR)	Disease index (DI)
60	31.98[b]	1	4
75	16.79[g]	3	1
80	21.37[f]	3.75	1
85	25.18[e]	3	2.75
90	32.68[a]	2	3
95	25.49[e]	2	3
100	28.36[d]	2	3
105	31.39[bc]	1	3
110	30.82[c]	1	3
	$LSD_{0.05}$ 0.62	P= 0.002	P= 0.002

Note: Means in a column with the same letter are not significantly different (at =0.05).
VQR (1-5), *i.e.*: 5 = excellent fresh appearance, 4 = better, slight freshness, 3 = moderate freshness, 2 = Severe, more than 10% of outer leaves wilted but marketable after removing those outer leaves, 1 = not marketable.
DI (0-4), *i.e.*:0 = no disease symptoms, 1 = minimal, 1- 5% of heads having disease symptoms, 2 = moderate, 6-10% of heads having disease symptoms, 3 = less severe, 11-25% of heads having disease symptoms, 4 = severe, more than 26% of heads having disease symptoms.

Disease index

Until six days in storage there was no sign of disease development (data not shown). From 85 - 100 DAP, signs of head rot disease caused by the several species of bacteria including *Erwinia spp*. and *Pseudomonas spp*. was appeared (Anon, 1994). Heads harvested at 75 - 100 DAP were less susceptible to diseases compared with other maturity

stages. Therefore, harvesting of heads either at immature (*i.e.* 60 DAP) or at over mature stages (*i.e*. beyond 100 DAP) should be avoided. Because, immature tissues are not hard enough to cope up with invasion by pathogens while cracks and blemishes appeared in over-mature tissues provide pathways for easy entrance of pathogens. It can be suggested that harvesting of cabbage variety Green Coronet at 75 - 80 DAP would produce the heads with less disease incidences.

Table 4. Acceptability ranks of the Friedman test for cabbage heads harvested at six different maturity stages.

Days after planting	Rank assigned (median)
60	1.92
75	3.92
85	4.75
90	2.75
100	5.08
105	3.08
P = 0.09	

Note: Each data point represent rank median of 15 non-trained panelists. Rank value 6 = most acceptable, 1 = least acceptable

Sensory evaluation

The rank median of the Friedman test is shown in the Table 4. There was no significant difference (at P = 0.05) in acceptability among cabbage heads harvested at different maturity stages. Most of the panellists stated that heads harvested at 100 DAP were better in mouth feel than those of the other five stages. This might be due to the low firmness and greater crispness of heads, giving a better mouth feel.

CONCLUSION

The results revealed that commercial maturity of cabbage achieved at 75 - 80 DAP under dry zone conditions (temperature of 28±2^{o}C and relative humidity of 69% - 78%) in Sri Lanka. So that, for fresh market, cabbage can be harvested when weights of the heads were 1.2 - 1.5 kg, diameter of 11 cm, firmness of 8 kg, specific gravity of 0.78 - 0.86 and at the moisture content of 91% (weight basis). For processing markets, heads can be harvested at 75 - 80 DAP as they contained high amount of TSS and dry matter while low in pH and moisture. For long-term storage, harvesting of heads at 75 - 80 DAP is the best maturity stage since the rate of weight loss was minimum while good VQR and low disease incidences could be achieved.

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