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Appropriate Technology of Post-Harvest Broccoli Quality Produced in Indonesia

Nurpilihan Bafdal[#,1], Carmencita Tjahjadi[#], Debby Sumanti Moodi[#], Totok Pujianto[#], Seok-In Hong[*], Dongman Kim[*]

[#] *Faculty of Agricultural Industrial Technology, Universitas Padjadjaran, Sumedang, 43563, Indonesia*
E-mail:[1]nurpilihanbafdal@yahoo.com

[*] *The Korean Food Research Institute (KFRI), Korea*

***Abstract*— Broccoli is a highly economic crop in Indonesia, it is rich in vitamin and mineral and is a good source of vitamin A; Potassium; Folic acid; Iron and Fiber. The best grows of broccoli in area with a cool climate or high land; in West Java cultivated of broccoli were at Lembang and Pangalengan. Broccoli is cultivated for its curd, which should be dark green in color. The curd has diameter of 5-25 cm depending on soil conditions and variety. Head of broccoli must be entirely green and all flower buds must be completely closed to be desirable. Quality factors for broccoli consist of curd density, greenness, and absence of blemishes. The problem of broccoli is post-harvest handling without appropriate technology and handling is still carried out by traditional method without hardly any starting or grading prior. The quality of the product cannot be improved by post-harvest handling a lone, but is necessary for extending shelf life. Post-harvest handling covers the time span from product harvesting in the farm field until it reaches the urban consumer through the market. The two main objectives of applying appropriate technology of post-harvest of broccoli are to maintain quality and reduce losses between harvest and consumption A descriptive experiment method was done and regression analysis consisting of two variables (dependent and independent) were employed with five treatments. The results showed were all treatment gave various results depend of packaging in a sealed and temperature. Low storage temperature in broccoli more important than type of packaging in maintaining sensory characteristics of the curd and reducing weight loss as well as decay scores. LPDE bag was best cold storage of broccoli curds.**

***Keywords*— broccoli; packaging; post-harvest; storage; appropriate technology.**

I. INTRODUCTION

Broccoli is a member part of the cabbage family; and can grow in a wide variety of soils type. To get a better yield from broccoli crop; sandy and silt loam soils are better. The main physical problems with quality of broccoli are stores are yellow discoloration or mold development of the flowers. Chemical problems quality was odor, weight loss and colors chlorophyll and carotenoid pigments and vitamin C.

Broccoli grows best in areas with a cool climate; in Indonesia especially in West Java were farmers grown broccoli in upland or high land area such are Lembang and Pangalengan. Broccoli is cultivated for its curd, which should be dark green in color[1]–[3]. The curd has a diameter of 5- 25 cm depending on soil conditions and variety.

Nutritionally of most cruciferous vegetable such as broccoli are low in calories, fat and carbohydrates but are rich source of protein[4]–[6]. Broccoli is known as the crown of Jewel Nutrition because it is rich in vitamin and mineral and is a good source of vitamin A; Potassium, Folic acid; Iron and Fiber [7]–[10]. Appropriate technology of broccoli grading and criteria can minimize moisture loss, slow down respiration rate, and inhibit development of decay causing pathogens. In other words, wilting, re-growth, ripening, senescence, and decay can be postponed.

Minimum quality requirements of broccoli in all classes must be fresh[11]; compact; well-trimmed; maximum stem length of 10 cm; free of bloom or free of opening flower; free of pests and damage caused by them affecting the general appearance of the produce and free of abnormal external moisture, excluding condensation following removal from cold storage[12]–[14].

In Indonesia quality and criteria of broccoli, handling is still carried out by traditional methods without hardly any starting or grading prior to marketing. Therefore quality and criteria of broccoli must begin in the farm level it is necessary for extending technology and criteria of broccoli. [15]–[17]. Reasons why quality of broccoli should carried

out of the farm level, respectively i) vegetable farmers are mostly small-land holders (0,2-0,5 ha); ii) limited investment abilities; (iii) all farm work is done manually with simple tools; (iv) sanitary and food-safety condition at packaging stations are poor[4], [18], [19] and (v) produce management is also poor. Introducing appropriate technology for post-harvest broccoli require research on (a) storage stability at ambient and low temperature (b) packaging methods of produce[9]. The research were carried out on broccoli since the broccoli is the most highly price cole-crop in Indonesia although it is not extensively grown[7], [13], [20].

II. Material and Methods

A. Quality Criteria

Head of broccoli must be entirely green and all flower buds must be completely closed to be desirable [21]. That purplish cast to the surface is not all objectionable. Size is determined by the weight or maximum diameter of the equatorial section of the inflorescence in accordance with the following Table 1 and Table 2.

TABLE I
SIZE CLASSIFICATION OF BROCCOLI BASED ON WEIGHT

Size Code	Weight (gram)
1	>400
2	>300-400
3	>200-300
4	100-200

TABLE II
SIZE CLASSIFICATION OF BROCCOLI BASED ON DIAMETER

Size Code	Weight (gram)
1	>14
2	>12-14
3	>10-12
4	>8-10
5	6-8

After harvest of broccoli, they subjected to physiological pathological deterioration. The quality of broccoli can be improved by extending shelf- life.; it is the fresh produce is defined as the period from harvest to consumption that food product remains safe and wholesome[22], [23]. Appropriate technology for post-harvest can only minimize moisture loss; slow down respiration rate and inhibit development of decay causing pathogens. Initial appropriate technology for broccoli require of the following treatments trimming; cleaning; curing; disease or insect control, waxing and ripening [15], [24], [25].

B. Appropriate Technology For Post-Harvest Handling of Broccoli

Broccoli should be harvested when the curd is firm/compact, has attained maximum size and the flowers has not opened. Indonesian farmer's actually they harvest the broccoli is 50-60 days after planting but also depending on cultivar. The famers should be done harvest in the morning or in the afternoon; and then consists of sorting; packaging and storage. Curd are wrapped in polyethylene fill and packed in wooden crates or field boz of 25- 30 kg. Storage condition should be dark; 4,4^{o}C, RH 83 – 90%; in such condition broccoli can be stored for 14-23 days. The appropriate technology after harvested of broccoli is packaging. Broccoli must be properly packed in such a way as to protect the produce. The material used inside the package must be clean and of good quality such as to avoid causing any external damage to the produce. Broccoli shall packed in material used filter paper and water; the use of material particularly of paper or specifications is allowed. After packed broccoli shall be put in the containers to meet the quality, hygiene, ventilation and resistance characteristics to ensure suitable preserving[26]–[29]. Packages must be free of all foreign matter and smell.

The experiment was carried out in the Technology Laboratories of the Faculty of Agriculture Industrial Technology of the Universitas Padjadjaran. Broccoli harvest from the farmers in Lembang with harvested 2 months after planting and possessing curds of 15 cm diameter, dark green in color and compact was used for the experiment. A descriptive experimental method and regression analyses consisting of 2 variables (dependent and independent) were employed. The treatments were:

A = without packaging, stored at ambient temperature ($27^{o}C \pm 2^{o}C$)
B = without packaging, stored in cold storage ($5^{o}C \pm 10^{o}C$)
C = packed in LPDPE bag, stored at ambient temperature ($27^{o}C \pm 2^{o}C$)
D = packed in LPDPE bag, stored in cold stored ($5^{o}C \pm 10^{o}C$)
E = packed in polypropylene net bag, stored at ambient temperature ($27^{o}C \pm 2^{o}C$)
F = packed in polypropylene net bag, stored in cold storage ($5^{o}C \pm 10^{o}C$)
G = packed in carton box, stored at ambient temperature ($27^{o}C \pm 2^{o}C$)
H = packed in carton box, stored in cold storage ($5^{o}C \pm 10^{o}C$)

The variable observed was sensory description using a sensory scoring standard; degree of decay (percentage of decay); weight loss for two weeks. The sensory scoring was prepared by storing sound curds at ambient temperature ($27^{o}C \pm 2^{o}C$) for 48 hours. Observation and photographs of the samples were made every 4 hours until yellowing of the curds. Variable measured were curd color, percentage of discoloration of curd surface either due to yellowing or due to disease (gray or black discoloration). Five pictures were chosen and assigned sensory score ranging from 1 (excellent) to 5 (not fit for sale). The packaging and storage temperature experiment were done as follow: samples were sorted, trimmed, and weighted. Each type of container was filled with 3 samples. Broccoli was observed every 3 days for 2 weeks.

III. Result and Discussion

A. Sensory Scoring Standard for Broccoli

The sensory scoring standard for broccoli stored at ambient temperature (27-0C ± 2 0C) for 56 hours is presented in Figure 1.

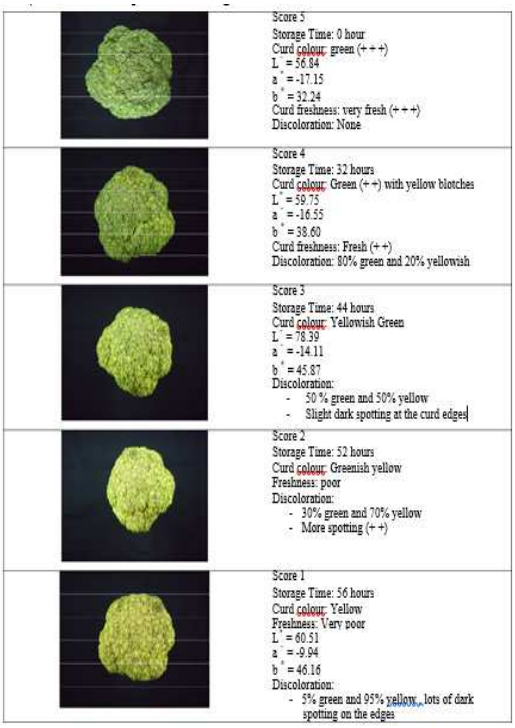


Fig. 1 Sensory Scoring Standard and Description of Scores for Broccoli

B. Changes in Sensory Scores of Broccoli during Storage at Ambient Temperature and Cold Storage

Regression Curves between sensory scores and storage time for the packing and storage temperature treatments are shown in Figure 2. The regression equations coefficients of determination and coefficients of correlation are presented in Table 3.

TABLE III
Regression Equations of Sensory Scores of Broccoli against Storage Time and Their Coefficients of Determination and Coefficients of Correlation

Treatment	Regression Equation	R^2	r
A	$Y_i = 5\text{-}0.93X_i - 0.041X_i^2$	0.975	0.987
B	$Y_i = 4.96+0.15X_i - 0.003\ X_i^2 + 0.001\ X_i^3$	0.967	0.983
C	$Y_i = 4.583 - 0.583$	0.855	0.925
D	$Y_i = 5 - 0.048\ X_i - 0.014X_i^2 + 0.0008\ X_i3$	0.951	0.975
E	$Y_i = 4.583 - 0.583$	0.855	0.925
F	$Y_i = 5.02 + 0.008X_i - 0.005X_i^2$	0.929	0.964
G	$Y_i = 5\text{-}0.87X_i + 0.037X_i^2$	0.929	0.963
H	$Y_i = 4.99 + 0.0009\ X_i + 0.003X_i^2 - 0.0005\ X_i^3$	0.979	0.990

Table 3 shows that all linear regression equations possess R^2 values larger than 0.855, showing equations fit very well.

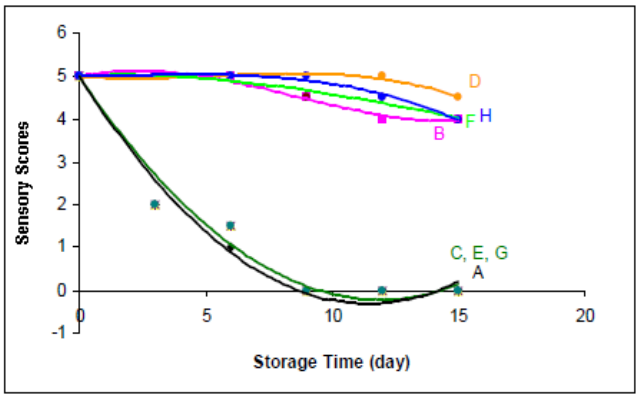


Fig. 2 Regression Curves of Sensory Scores of Broccoli and Storage Time

Regression Curve for treatment D showed that after 15 days storage the sensory score of the broccoli sample was still excellent, i.e. no decline of sensory score occurred during storage. Sample D was packed in a sealed LDPE bag and stored at 5 0C ± 1 0C, so that besides the low storage temperature, inside the sealed bag a modified atmosphere (high CO2, low O2) might have developed.

Treatment A C E G, which were stored at ambient temperature, reached a sensory score of 2 after 3 days i.e. not acceptable anymore to be displayed for sale. Tan (2005) reported that shelf life of broccoli at 20 0C and 60 – 70% RH is only 1 – 2 days while at 4 0C shelf life is 2 – 6 weeks. In conclusion, packaging treatments respectively without packaging, LDPE bag, propylene-net-bag and carton box, without refrigeration, cannot prolong shelf life of broccoli if not stored at low temperature.

Treatment B, D, F and H, which were stored at 5 0C, still attained sensory scores ranging from 4 to 5 after 15 days, showing low temperature storage irrespective of packaging, was able to keep the broccoli samples in excellent condition. Treatment D as previously discussed gave the best results, probably due to the modified atmosphere generated within the sealed LDPE bag. Up to 6 days storage hardly any difference in sensory scores was observed, showing all 4 packaging treatments were equally good.

TABLE IV
Regression Equations of Weight Loss of Broccoli against Storage Time and Their Coefficients of Determination and Coefficients of Correlation

Treatment	Regression Equation	R^2	r
A	$Y_i = 0.003+9.099X_i - 0.311\ X_i^2 + 0.003\ X_i^3$	0.999	0.999
B	$Y_i = 0.27+2.059X_i - 0.77\ X_i^2 + 0.003\ X_i^3$	0.992	0.996
C	$Y_i = -2.084 + 3.22X$	0.878	0.937
D	$Y_i = 0.103+1.038X_i - 0.12\ X_i^2 + 0.004\ X_i^3$	0.957	0.978
E	$Y_i = 0.507 + 3.99X$	0.995	0.997
F	$Y_i = 0.04+2.07X_i - 0.03X_i^2 + 5.94\ X_i^3$	0.999	0.999
G	$Y_i = -0.56 + 3.77X$	0.993	0.996
H	$Y_i = 0.14 + 1.43\ X_i - 0.07X_i^2 - 0.002\ X_i^3$	0.996	0.997

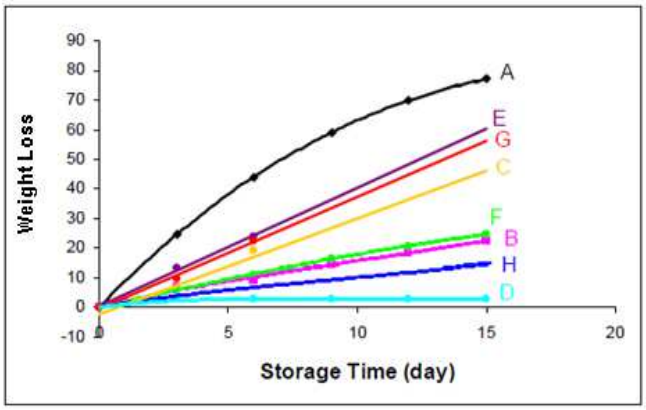


Fig. 3 Regression Curves of Weight Loss of Broccoli against Storage Tim

C. Weight Loss of Broccoli

Results of regression analyses showed there is a very close relationship between weight loss and storage time in all treatments. Regression curves are presented in Figure 4. Regression and equations, coefficients of determination and coefficients of correlation for all treatments are presented in Figure 3 and Table 4. Coefficients of determination ranged between 0.878 – 0,999, showing a very close fit of the relationship between weight loss and storage time. Storage at ambient temperature showed larger weight losses (55 – 70%) than those stored at 5 ^{o}C (2 – 20%). This may be caused by the larger vapor pressure difference between the samples and the surrounding air at ambient temperature as compared to cold storage at 5 ^{o}C.

The ambient temperature weight loss was highest in treatment A, i.e. without packaging, followed by treatment E (packed in propylene net bag), G (packed in carton box), and C (packed in LDPE bag). Weight loss after 15 days storage was about 75 % in treatment A and 45% in treatment C. At 5 ^{o}C ± 1 0C weight loss of treatments F (PP-net bag) and B (without packaging) are highest and the curves near overlaps each other; percentage of weight loss after 15 days storage was about 20%. Samples packed in carton boxes (H) had a weight loss of about 10% after the 15-day storage, while those packed in LDPE (D) produced the lowest weight loss i.e. about 2% after the 15-day storage.

Protection of the packaging materials against weight loss was quit significant, PP net-bag equals no packaging, while the carton-box gave intermediate values of weight loss (10% weight loss in 2 weeks), while the LDPE bag gave the best protection (2% weight loss in 2 weeks). The no packaging and net-bag probably provides too much air movement during storage, causing larger losses. Mesh bags are now abandoned due to the minimal protection it provides against rough handling and the larger wilting losses. The carton box is light-weight and provides sufficient protection, while the LDPE bag provides good protection against moisture losses, is also light-weight but it does not give sufficient protection against rough handling.

D. Curd Color

Curd color was evaluated using the same sensory standard as presented in Figure 4. Regression curves between curd color sensory scores against storage time are presented in Figure 4 and Table 5. R^2 for the samples stored at ambient temperature and in cold storage ranged from 0.911 to 0.975 showing a very good fit.

TABLE V
REGRESSION EQUATIONS OF CURD COLOR SENSORY SCORES OF BROCCOLI AGAINST STORAGE TIME AND THEIR COEFFICIENTS OF DETERMINATION AND COEFFICIENTS OF CORRELATION

Treatment	Regression Equation	R^2	r
A	$Y_i = 5\text{-}0.93X_i - 0.041X_i^2$	0.975	0.987
B	$Y_i = 4.99\text{-}0.13X_i - 0.006\ X_i^2 + 0.0001\ X_i^3$	0.967	0.983
C	$Y_i = 5 - 0.93X_i - 0.041X_i^2$	0.975	0.987
D	$Y_i = 4.97 - 0.098X_i - 0.02X_i^2 + 0.0009\ X_i^3$	0.967	0.983
E	$Y_i = 5 - 0.93X_i - 0.041X_i^2$	0.975	0.987
F	$Y_i = 5.025 + 0.15X_i - 0.007X_i^2$	0.911	0.954
G	$Y_i = 5\text{-}0.93X_i + 0.041X_i^2$	0.975	0.987
H	$Y_i = 5.2 + 0.02\ X_i + 0.018X_i^2 - 0.0009\ X_i^3$	0.919	0.957

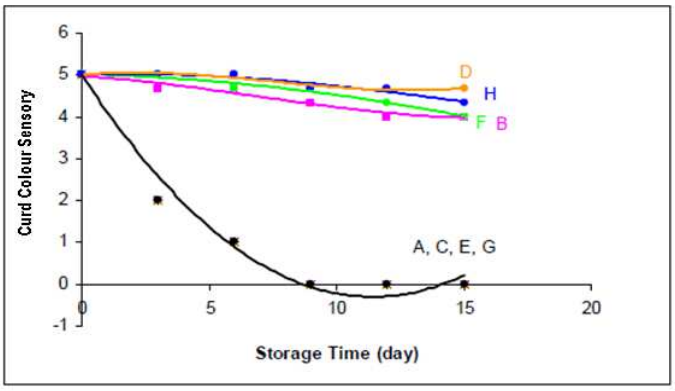


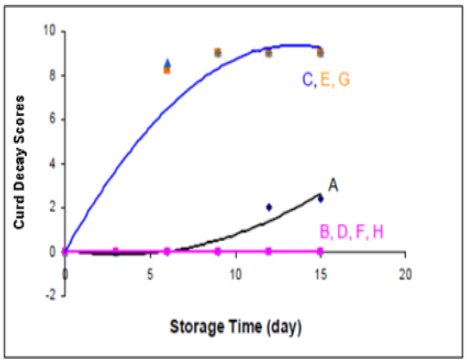
Fig. 4 Regression Curves of Curd Color Sensory Scores of Broccoli against Storage Time

Curds stored at 5 0C ± 2 0C still obtained color scores between 4 and 5 after the 15 day storage irrespective of the packaging material. Among the 4 packaging materials, during the course of the 15 day storage, LDPE bag (D) was best, followed by H (carton box), treatment B and F gave similar results up to day 12. Curds stored at ambient temperature reached a score of 2 within 3 days of storage perspective of type of packaging.

Thus, low temperature storage is more important in preserving color of curd than packaging as is also reported [8]. Color change starts when flowers begin to open and turn yellow [9], this occurs within 3 days at room temperature. Yellowing itself is related to ethylene production by the broccoli, although refrigeration could reduce ethylene production considerably. Treatment D was best, partly because of the modified atmosphere generation within the LDPE bag.

E. Curd Decay

Curd decay regression curves and regression equations at ambient temperature and cold storage are presented in Figure 5 and Table 6.



Score	Curd Decay Percentage
0	None = 0%
1	1% - 20%
3	21% - 40%
5	41% - 60%
7	61% - 80%
9	81% - 100%

Fig. 5 Regression Curves of Curd Decay Scores of Broccoli against Storage Time

TABLE VI
REGRESSION EQUATIONS OF CURD DECAY SCORES OF BROCCOLI AGAINST STORAGE TIME AND THEIR COEFFICIENTS OF DETERMINATION AND COEFFICIENTS OF CORRELATION

Treatment	Regression Equation	R^2	r
A	$Yi = 0.04\text{-}0.126X_i - 0.019X_i^2$	0.891	0.944
B	$Y = 0$	-	-
C	$Y_i = 1.34X_i - 0.051X_i^2$	0.828	0.910
D	$Y = 0$	-	-
E	$Y_i = 1.384X_i - 0.051X_i^2$	0.828	0.910
F	$Y = 0$	-	-
G	$Y_i = 1.384X_i - 0.051X_i^2$	0.828	0.910
H	$Y = 0$	-	-

Table 6 shows that samples stored at room temperature have R^2 values less than 0,80 except for treatment A, thus showing less suitable fit.Decay was highest in treatments C, G, E (11%) i.e. treatments packed in various types of packages and stored at ambient temperature. Treatment A (without packaging + ambient temperature storage) showed decay after day 5 and culminated at day 15 (about 2%). The warm ambient temperature was suitable for mold growth and was also aggravated by packaging, because packaging causes RH within the package to increase. Mold usually requires a temperature of 25 – 50 0C and RH of 70 – 75% for growth.

Cold storage (treatment B, D, F, H) did not show mold growth at all during the 15 day storage, either on curds stored without packaging or in the various types of packages. This shows that mold growth is more affected by storage temperature than packaging.

IV. CONCLUSIONS

Low storage temperature in broccoli storage is more important than type of packaging in maintaining sensory characteristics of the curd and reducing weight loss as well as decay scores. LPDE bag was best for cold storage of broccoli curds Political will of the Indonesia government to preparing of cold storage in the broccoli at farmers field is very important.

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