THE INFLUENCE OF THE BROCCOLI (*Brassica oleracea* var. *itálica*) FILL WEIGTH ON POSTHARVEST QUALITY[1]

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SUMMARY

Broccoli is a vegetable of important economic value as well as a source of vitamin C and anticarcinogenic property substances. Although it can be minimally processed, this vegetable presents fast senescence, characterized by yellowing, loss of turgescence, development of off-odors, increase in enzymatic activity and reduction of nutritional value. Among the frequently used techniques that can extend the shelf-life of minimally processed broccoli, we have the use of cool storage and modified atmosphere packaging (MAP). Several factors interfere in the efficiency of MAP, influencing the speed and intensity of the changes on atmosphere composition. This work aimed to study the influence of the amount packaged broccoli on its postharvest quality, when stored at 1°C. Results demonstrated strong influence of the use of MAP compared to control treatment. It was observed that for all packaged treatments there was better vitamin C retention, lower loss of weight, lower peroxidase activity and better turgidity score of broccoli. This study demonstrated that the treatments with higher amounts of product showed the worst performance on vitamin C and aroma evaluation. The peroxidase activity was also influenced, and the best results were found in the treatment with higher amounts, which presented lowest values. However there is a tendency of increase in the activity along the time, especially at the end of the experiment. It was not detected the influence of the fill weight about color evaluation.

Keywords: broccoli; postharvest quality; modified atmosphere packaging; amount of packed broccoli.

RESUMO

INFLUÊNCIA DA QUANTIDADE DE BRÓCOLIS (*Brassica oleracea* var. *itálica*) EMBALADO EM SUA QUALIDADE PÓS-COLHEITA. O brócolis é uma hortaliça de importante valor econômico, bem como uma fonte de vitamina C e de substâncias com propriedades anticarcinogênicas. Embora possa ser minimamente processada, essa hortaliça apresenta rápida senescência, caracterizada por amarelamento, perda de turgescência, desenvolvimento de odores indesejáveis, aumento na atividade enzimática e redução do valor nutricional. Dentre as técnicas que podem estender a vida pós-colheita do brócolis minimamente processado, temos o uso de refrigeração e de embalagem com atmosfera modificada. Vários fatores interferem na técnica de embalagem com atmosfera modificada, influenciando na velocidade de instalação da atmosfera e na intensidade da alteração. Este trabalho teve como objetivo avaliar a influência da quantidade de brócolis embalado em sua qualidade pós-colheita quando armazenado a 1°C. Foi observado um efeito marcante do uso de embalagem com atmosfera modificada em comparação ao tratamento controle, sendo que, para todos os tratamentos embalados foi observado melhor retenção de vitamina C, menor perda de massa, menor atividade da peroxidase e as melhores notas para textura. O trabalho demonstrou que os tratamentos com maiores quantidades de massa apresentaram a pior performance para vitamina C e avaliação de aroma. A atividade enzimática também foi influenciada e os melhores resultados foram encontrados para os tratamentos com maiores quantidades de brócolis. Entretanto, há uma tendência de aumento da atividade com o decorrer do tempo. Não foi detectada influência da quantidade de brócolis sobre a cor.

Palavras-chave: brócolis; qualidade pós-colheita; embalagem com atmosfera modificada; massa embalada.

1 – INTRODUCTION

Broccoli which is an important source of vitamins and anticarcinogenic property substances [23], presents a short shelf-life, especially at room temperature, due to immaturity of the texture in the moment of the harvest as well as to physiological factors regulated by genetic mechanisms [30]. Several changes are observed along its senescence and some are easily observed as the yellowing generated by the chlorophyll degradation, the flower buds opening, the loss of turgidity, off-odors development, nutritional value reduction and the increase in the peroxidase activity [14].

The cool storage and the modified atmosphere packaging (MAP) can be pointed out among the techniques used to delay the senescence and to promote the shelf life extension [14]. These techniques have been described as efficient on the control of respiratory rates, chlorophyll and vitamin C levels retention and reduction in the O_2 levels and increase in the CO_2 [18,32]. Weight is among the several variables that interfere in last two aspects mentioned previously. Increase in the weight, when considering an equal packaging size, promotes reduction in free volume, and also conducts to faster changes in the environment atmosphere in the package. On the other hand higher amounts of product cause more intensive and faster changes due to higher quantities of texture, which consume more O_2 and produce more CO_2. Several mathematic models are able to foresee atmosphere changes into packages, confirming these affirmations [5, 15].

This work aimed to study the influence of different broccoli amounts on its post harvest quality.

2 – MATERIAL AND METHODS

2.1 – Plant material and material packaging

Broccoli (*Brassica oleracea* L. cv Legacy (Asgrow)) was harvested when the heads were completely developed

[1.] *Recebido para publicação em 25/07/2003. Aceito para publicação em 28/09/2004 (001175).*

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and without opened florets. The harvest of the heads were carried out until 9a.m. and the material was immediately transported in plastic containers to the Vegetable Processing Laboratory of CEFET-PR (Centro Federal de Educação Tecnológica do Paraná), which is about 15km from the harvest location. The polymeric film used was the polypropylene bi-oriented (ITAP/BEMIS, Cambé-PR, BRA) (thickness = 40 micron; PO_2 > 2.000cc.m^2.dia^{-1}).

2.2 – Product preparation

The experiment was completely randomized, in the factorial system 5 x 6 with 3 replications. There were 6 levels of weight (PP1=240.0g packaging; PP2=270.0g packaging; PP3=300.0g packaging; PP4=330.0g packaging; PP5=360.0g packaging; Control=300.0g no packaging) and 5 levels of time (3 days; 6 days; 9 days; 12 days; 15 days).

At the laboratory, broccoli samples were submitted to an initial selection, externally sterilized in 100ppm NaOCl, drained in a domestic centrifuge and florets were cut from the stalks (≈ 200mm). The broccoli florets were kept in the bags (size = 25 x 15cm) according to the different treatments. After the sealing they were stored in a controlled cool room at 1°C, during the period of 15 days. Control samples were kept in plastic tray without package. There was no humidity control.

2.3 – Determinations

The broccoli was analyzed and characterized at time zero. The other determinations were realized for 3, 6, 9, 12 and 15 days.

2.3.1 – Weight loss

The broccoli florets were weighed at each sampling period and weight loss was expressed as a percentage of the initial fresh weight [7].

2.3.2 – Aroma, color and texture

Reference tables were created by the author, similar to TOIVONEN & DEELL [29], to evaluate the aroma, color and texture of the broccoli samples. The sensory evaluation was conducted by the main author using a trained panel of three judges as a pilot test. Aroma was evaluated using the scale: 5=no off-odors, 3=light off-odors but noticed and 1=strong off-odors. For the color evaluation, it was used the scale: 5=dark green, 3=light green, 1=yellowing/yellow. Texture was evaluated using the scale: 5= very firm, 4=firm, 3=lightly wilted, but acceptable, 2=wilted, 1= very wilted.

2.3.3 – Vitamin C

The iodine titrimetric method [17] was used and the results were expressed in initial level percentage.

2.3.4 – Peroxidase activity

The peroxidase assay was carried out as the method reported by CLEMENTE [6]. The extract of peroxidase was prepared using sodium phosphate buffer solution 0,1 M (ph=6,0) to extract peroxidase soluble fraction, and NaCl 1,0M in sodium phosphate buffer 0,1M (ph=6,0) to extract peroxidase ionically bound fraction. The determination of enzymatic activity was made by spectrophotometer (Femto 700 plus, λ = 460nm). The results were expressed as the initial activity percentage.

2.4 – Statistical analysis

Data (aroma, color and texture) were analyzed by the analysis of variance (ANOVA) procedure using the statistical program SAEG. Factors that present significative difference (P< 0,05) were submitted to average tests (Tuckey).

3 – RESULTS AND DISCUSSION

Table 1 presents broccoli characteristics at zero time.

TABLE 1. Broccoli samples characteristics at zero time.

Characteristic	Value
Color evaluation (score)	3,0
Aroma evaluation (score)	5,0
Texture evaluation (score)	5,0
Vitamin C (mg.100^{-1}g)	58,5
Chlorophyll (mg.100^{-1}g)	11,3

Aroma rating scale: 1=strong off-odor; 3=ligth off-odor but noticed; 5=no off-odors.
Texture rating scale: 1=very wilted; 2=wilted; 3=lightly wilted; 4=firm; 5=very firm.
Color rating scale: 1=yellow/yellowing; 3=light green; 5=dark green.

3.1 – Weight loss

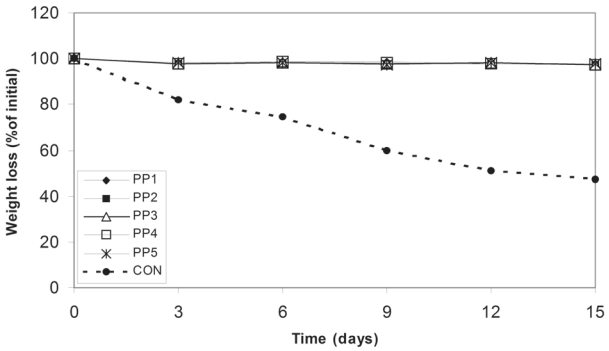

FIGURE 1. Effect of amount of broccoli wrapped on weight loss in broccoli florets during storage at 1°C over 15 days.

Figure 1 demonstrates a characteristic difference between packaged treatments and the Control (unpacked sample). This difference is due to the protection warranted by the package that presents steam water barrier properties [13]. It was observed that the Control sample showed the highest loss which was constant along the time. The weight loss was more intensive on the first three days due to the reduction in gradient of water potential between the product and the atmosphere. [3] For packaged treatments it was observed little loss weight (< 3%) as it was expected,

for the minimall process promote the transpiration of the product [4]. This loss was, however, under the critical levels (5%) [11, 28].

3.2 – Aroma, color and texture

The aroma data (*Table 2*) showed a strong difference between packaged samples and the Control one (unpacked), although some of them, did not differ significantly from the last one. While the Control samples was scored as "no off-odors", the other treatments presented scores between "strong off-odor" and "light off-odor but noticed". The Control sample showed the best scores along the experiment. The time did not influence the results, except to PP1 and PP2 treatments. The development of "off-odors", easily noticed in packed treatments, occurred partly due to the cool temperature conditions, which are related to sulfurous components synthesis, responsible for "off-odors" [19]. In control treatment the synthesized odors components were dispersed and did not accumulate as in packed treatments. The data presented by other authors confirm these results [28].

The collected data showed that the treatments with higher amount of product (PP4 and PP5) presented a decline of their aroma scores along the time, ranging from "light off-odor, but noticed" to "strong off-odor". In these treatments there was a intense "off-odor" components synthesis due to a higher amount of the product, and consequently, higher amount of product are responsible for more intensive changes on atmosphere composition in the package, with lower O_2 and higher CO_2 concentrations. These conditions increase the synthesis of acetaldehyde and ethanol [14]

TABLE 2. Effect of amount of broccoli wrapped on aroma scores in broccoli florets at 1°C over 15 days

TREATMENTS	SCORES*				
	TIME (days)				
	3	6	9	12	15
PP1	1.0 Bb	3.8 Aab	3.4 ABab	2.3 ABab	3.6 Aab
PP2	2.1 Ab	3.4 Aab	1.2 Ab	2.1 Ab	2.3 Aab
PP3	1.6 Abb	1.8 ABb	1.4 Bb	4.1 Aab	3.6 Aab
PP4	1.8 Ab	2.3 Aab	3.2 Aab	1.4 Ab	1.0 Ab
PP5	2.9 Aab	3.1 Aab	2.1 Ab	1.4 Ab	1.6 Ab
CONTROL	5.0 Aa	5.0 Aa	5.0 Aa	5.0 Aa	5.0 Aa

Means followed by the same minuscule letter in column and the same capital letter in line are not significantly different (LSD for $P < 0.05$).
Rating scale: 1=strong off-odor; 3=ligth off-odor but noticed; 5=no off-odors.
*Means of rating by 3 judges.

Some samples showed increase in their aroma scores along the time (PP1, PP3), which seems to be caused by the dispersion of the volatile components through the package, that, in the first moment did not happen so fast as its synthesis, causing the "off-odors" [16].

The results obtained on texture (*Table 3*) evaluation were similar to the ones on weight loss. There was a clear difference between all the packaged treatments and the Control sample, which received the worst scores, from "wilted" to "very wilted". On the 3rd day, the Control sample was inappropriate to be commercialized. Texture and weight loss present a clear relation and this explain the scores received by the no packaged treatment. Similar results were found by other authors [11, 28].

TABLE 3. Effect of amount of broccoli wrapped on texture scores in broccoli florets at 1°C over 15 days

TREATMENTS	SCORES*				
	TIME (days)				
	3	6	9	12	15
PP1	2.5 Bb	3.5 Aa	3.3 ABa	3.4 ABa	3.6 Aa
PP2	3.0 Aab	3.5 Aa	3.2 Aa	3.1 Aa	3.5 Aa
PP3	3.7^{A}a	3.4 Aa	3.3 Aa	3.8 Aa	3.6 Aa
PP4	3.6 Aa	3.5 Aa	3.6 Aa	3.4 Aa	3.5 Aa
PP5	3.8 Aa	3.3 Aa	3.5 Aa	3.8 Aa	3.6 Aa
CONTROL	1.9 Ab	1.4 Ab	1.1 Ab	1.2 Ab	1.3 Ab

Means followed by the same minuscule letter in column and the same capital letter in line are not significantly different (LSD for $P < 0.05$).
Rating scale: 1=very wilted; 2=wilted; 3=lightly wilted; 4=firm; 5=very firm.
*Means of rating by 3 judges.

The color of the samples did not present great differences (*Table 4*) whereas most of the results were close to "light green" conditions, which was the product initial condition. Influence on the color of the samples by the treatments were not observed, except on the 15th day when the PP4 treatment was the only one that showed significative reduction, receiving the worst score (1,6), which fits in the yellowing/yellow condition, therefore in appropriate to be commercialized.

TABLE 4. Effect of amount of broccoli wrapped on color scores in broccoli florets at 1°C over 15 days

TREATMENTS	SCORES*				
	TIME (days)				
	3	6	9	12	15
PP1	3.1 Aa	3.1 Aa	2.8 Aa	3.0 Aa	3.0 Aab
PP2	3.0 Aa	2.7 Aa	3.6 Aa	2.7 Aa	3.6 Aa
PP3	2.5 Aa	3.2 Aa	3.3 Aa	3.2 Aa	2.3 Aab
PP4	2.7 Aa	3.8 Aa	2.8 Aba	2.5 Aa	1.6 Bb
PP5	3.6 Aa	3.4 Aa	2.5 Aa	2.7 Aa	3.6 Aa
CONTROL	3.2 Aa	3.2 Aa	2.9 Aa	3.4 Aa	3.0 Aab

Means followed by the same minuscule letter in column and the same capital letter in line are not significantly different (LSD for $P < 0.05$).
Rating scale: 1=yellow/yellowing; 3=light green; 5=dark green.
*Means of rating by 3 judges.

The good color retention was a result of the cool storage, which prevents the chlorophyll degradation [25, 31]. The absence of significative difference among packaged treatments demonstrated in this study, possibly occurs because the temperature effect has been more preponderant on this characteristic. Mathematical models studies for *Brassica oleracea* var. *acephala* stand out the importance of cooling for shelf-life extension of minimally processed products and affirm that atmosphere composition shows more relevance for temperature condition over the ideal ones[10]. The results obtained about color evaluation are similar to those found by TOIVONEN [28]

We suggest that future studies should accomplish sensorial analysis by trained panelists with five people or more, for better evaluation of sensorial quality of broccoli.

3.3 – Vitamin C

For all treatments, a decrease on vitamin C levels (*Figure 2*) was observed along the time, compared to the zero time, with more accentuated decrease registered on the 9th and 12th days. Several authors have noticed in their researches this same tendency about vitamin C levels, caused by the natural degradation [1, 21]. In some treatments as PP3, PP2 and Control sample, increase on vitamin levels on the 6th and 9th days were observed. This notable increase occurred due to the tendency of some vegetable texture to present addition in their vitamin C levels due to ripening [22]. This may indicate, that an increase on ascorbic acid rates occurs because of the vegetable stress. The harvest, manipulation, cut and cooling (1°C) can promote stress conditions, so the plant increases the ascorbic acid synthesis as a protection mechanism [26].

At the end of the experiment, the Control sample was the treatment that presented the lowest residual vitamin C levels, as expected and observed by other authors [1, 27]. The greater loss of humidity observed for this treatment explains the intensive losses of vitamin C. It occurred also due to the effect of atmosphere change inside the package which promoted vitamin C retention as a function of the CO_2 increment as the O_2 reduction [2]. In the packaged treatments, PP3, PP4 and PP5 showed the worst levels of residual vitamin C as the intensive changes in atmosphere cause injuries, promoting a lower retention of vitamin. Generally, high CO_2 concentrations cause vitamin C degradation [20].

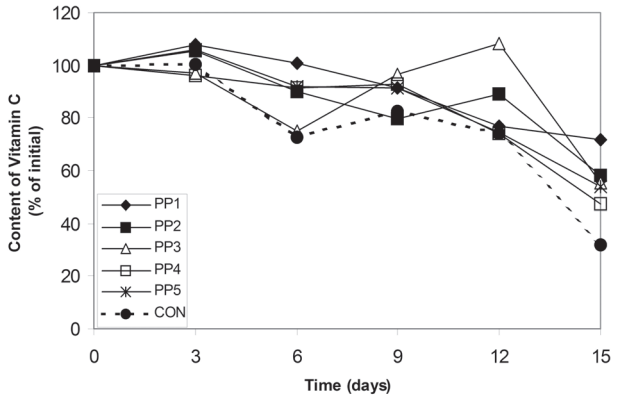

FIGURE 2. Effect of amount of broccoli wrapped on vitamin C retention in broccoli florets during storage at 1°C over 15 days.

3.4 – Peroxidase activity

The results demonstrated a sharp decay in enzymatic activity (*Figure 3*), which was verified on the 3rd day for PP4 and PP5 treatments, and on the 6th day for the others. After the 9th day, this decay becomes more regular, due to the delay in the modification of the atmosphere. The general decrease in the enzymatic activity for all treatments occurred due to the cool temperature, as, this is an important fact that interferes in the peroxidase activity [12], although some authors verified increase in the enzymatic activity in similar temperature [2, 24]. About the sudden decrease in peroxidase activity in PP4 and PP5 treatments, this might be explained because these treatments presented the higher amounts of product which promoted a faster and more intensive modification on the atmosphere in the package, as predicted by the mathematic models studied by CAMERON, BOYLAN-PET & LEE [5]. This intensive modification in the atmosphere can contribute to a gas composition which reduces the peroxidase activity, although it can achieve higher levels of CO_2, causing injuries that increase an enzymatic activity, as seen at the end of the experiment about the PP5 treatment [8]. In treatments with lower amounts of product, the alteration did not achieve drastic conditions which warranted lower peroxidase activities.

From the 9th day to the end of the experiment, there was a clear difference between packaged treatments and the Control sample which proves that atmosphere change is related to a lower enzymatic activity [2]. During this experiment variations on enzymatic activity were also observed. The enzymatic activity increased sometimes and these variations probably occurred cause the disintegration of the membrane and degradation reactions, which produced hydrogen peroxide [9]. So there was an increase in peroxidase activity which eliminated that compound. An other explanation is the emergence of more stable enzyme forms in specific conditions [12].

It is interesting to notice that the higher enzymatic activity demonstrated by PP5 treatment and the Control sample after the 9th day, occurred at the same time that a decrease on vitamin C levels was observed in these treatments. The relation between peroxidase activity and vitamin C contents can be explained, as, the ascorbic acid presents antioxidant properties [4].

The procedure was very similar for ionic fraction activity (*Figure 4*), with a sharp decay on the 3rd day. The variations in enzymatic activity for each treatment were also observed, with eminence for the Control one, due to the physiologic stress and loss of membrane integrity [9]. For the other treatments, specially, PP4 and PP5, after the initial sharp reduction, a constant uniformity was observed. At the end, the Control sample, PP3 and PP2 were the treatments that presented the higher values for the peroxidase activity. Perhaps the level alteration on gas concentration that occurred in these treatments was not sufficient to reduce the enzymatic activity.

It was observed that the reduction on ionic fraction activity was faster and more intense than the soluble fraction. It occurs because there are different

isoenzymes groups that form ionic fraction and soluble fraction of peroxidase, which present different characteristics as tolerance to gas concentrations and inactivation enzymatic temperature [30].

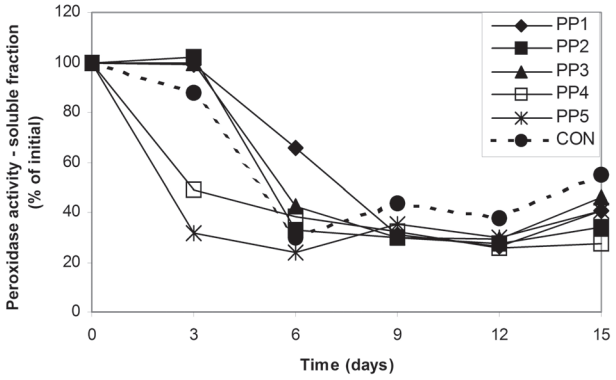

FIGURE 3. Effect of amount of broccoli wrapped on peroxidase activity (soluble fraction) in broccoli florets during storage at 1°C over 15 days.

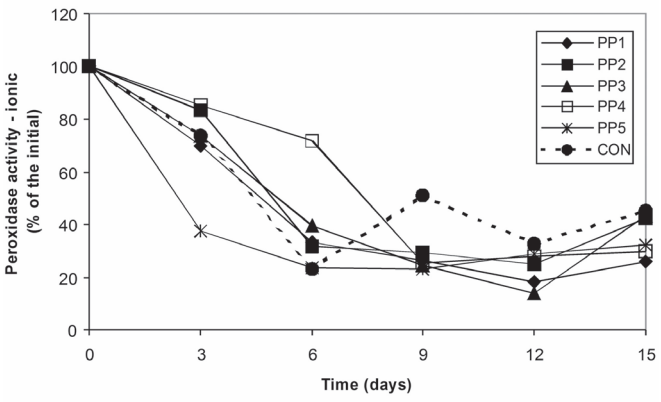

FIGURE 4. Effect of amount of broccoli wrapped on peroxidase activity (ionic fraction) in broccoli florets during storage at 1°C over 15 days.

4 – CONCLUSIONS

The results demonstrated that MAP is an efficient technique, especially for the conservation of broccoli weight, turgidity and vitamin C, though the efficiency of this technique on color was not verified. It was observed that different amount of the product affected the quality of packaged broccoli. The treatments with higher amounts of product and lower headspace showed the worst performance on vitamin C retention and aroma evaluation but the best results on peroxidase activity in the initial stages. The results expected for the peroxidase activity were not observed for the period after the initial stages.

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6 – ACKNOWLEDGMENTS

Thanks to Cooperativa Lar (Medianeira-Pr/BRA) e Itap/Bemis (Cambé-Pr/BRA) for the special contribuition.