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QUALITY ATTRIBUTES ASSOCIATED WITH DIFFERENT CENTRIFUGATION TIMES IN FRESH-CUT CABBAGE

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Abstract. Centrifugation is one of the most important steps in the fresh-cut industry. Cabbage heads (*Brassica oleracea* var. *capitata*) “Kenzan” were harvested at commercial fields in Viçosa, MG, Brazil, aiming to evaluate the effects of different centrifugation times in fresh-cut cabbage quality attributes. After harvest, cabbage heads were taken to the postharvest laboratory, selected for external blemishes and graded for size. After slicing (2 × 1 mm thick), samples were placed in nylon bags and centrifuged (800 g_n) for 4, 6, 8, 10, 12 and 14 minutes. Mass loss, temperature, respiratory activity, ethylene evolution, total soluble solids content, total vitamin C and color (L*a*b*) were evaluated. Centrifugation for 10 minutes was enough to remove water in excess, and the mass of the product after centrifugation was similar to the mass after slicing. Temperature increased linearly with time until 10 minutes of centrifugation, shifting from 9 to 13 °C. Respiratory activity increased 125% when centrifugation time increased from 4 to 14 minutes. Ethylene evolution remained around 0.5 µL·kg⁻¹·h⁻¹ until 10 minutes, showing a peak of 3 µL·kg⁻¹·h⁻¹ at 12 minutes of centrifugation. Total soluble solids increased 29% after 10 minutes of centrifugation, shifting from 4.2 to 5.8. Total vitamin C reduced around 18% during the first 8 minutes, possibly due to the dilution effect of excess water. Brightness reduced around 60% during the first 8 minutes of centrifugation. Browning index increased approximately 110% during the first 8 minutes, and then decreased gradually until 14 minutes. It is suggested that fresh-cut cabbage should be centrifuged for 10 minutes to maintain the quality and to extend the shelf life.

The consumption of minimally processed fruits and vegetables has increased significantly during the last years, considering both the retail and the consumer level (Cantwell, 2000). Many factors are associated with this trend, such as the decrease in family size, population aging, decrease in the number of members per family, and increase in the foodservice sector (Moretti, 2001).

The processing of fresh-cut products involves many steps such as cleaning, washing, trimming, coring, slicing, shred-

ding, and other related operations (Cantwell, 2000). The main objective is to provide fresh, healthy, ready-to-eat food that, in most cases, does not need further preparation to be consumed (Rolle and Chism, 1987). Examples of fresh-cut products include peeled potatoes, shredded cabbage and lettuce, salad mixes, washed and trimmed spinach, broccoli florets, and diced onions. Considering optimum storage conditions, these products can maintain their quality for up to 14 d.

Nowadays, it is becoming popular the so called “home-meal replacement”, which combines fresh-cut vegetables and meats, poultry and sea food, contributing to a higher value-added product (Cantwell, 2000). These products are increasing their importance in the supermarkets throughout the world, including the USA, where four out of five Americans do not know what they are going to eat when they are on their way back home from work.

The physiology and biochemistry of fresh-cut products is quite similar to the same metabolic events observed in fresh fruits and vegetables that have been mechanically injured. This is easily understandable once minimal processing involves the occurrence of mechanical damages during preparation procedures. Different metabolic changes have been reported in mechanically injured tissues, such as increase in carbon dioxide and ethylene evolution (Moretti et al., 1998), alteration in flavor and aroma (Moretti and Sargent, 2000), alteration in aroma volatile profiles (Moretti et al., 2002), and increase in the activity of many enzymes related with browning (Bower and Van Lelyveld, 1985; Ke and Saltveit, 1989; Moretti et al., 2001; Nicoli et al., 1994).

Among the different steps related with minimal processing, centrifugation has a major importance; it is desirable that this process should remove at least the same amount of water retained by the product during sanitation and rinsing. Centrifugation is generally used, although other methods such as vibration screens and forced air tunnels can also be used. For lettuce products, removal of slightly more moisture (i.e., slight desiccation of the product) may favor longer post-processing life (Cantwell, 2000). For most of the centrifuges in the market, the angular speed and time of centrifugation are established according to the type of the product and to the degree of processing (Darezzo, 2000). Setting time and speed of centrifugation is a major problem once over-centrifuged tissues tend to have their commercial quality altered.

The present work was carried out to evaluate the effects of different centrifugation times in fresh-cut cabbage quality attributes.

Material and Methods

Plant material. Cabbage heads (*Brassica oleracea* var. *capitata*) “Kenzan” were harvested at commercial fields in Viçosa, MG, Brazil, taken to the postharvest laboratory, selected for external blemishes and graded for size.

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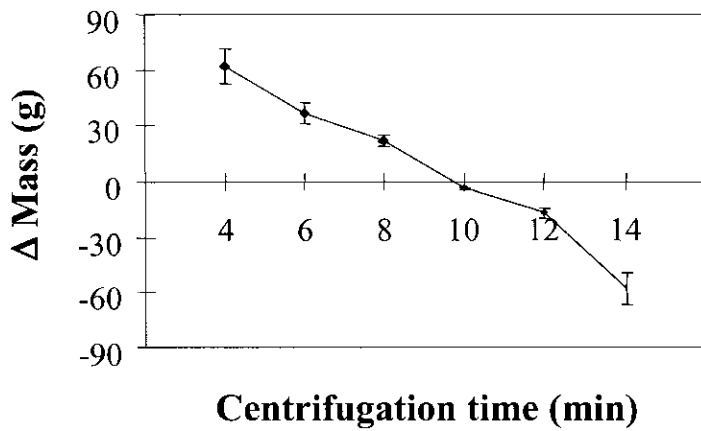


Fig. 1. Mass variation (Δg) of fresh-cut cabbage centrifuged for different times intervals ($\Delta g = \text{Mass of the product after centrifugation} - \text{mass of the product right after cutting}$).

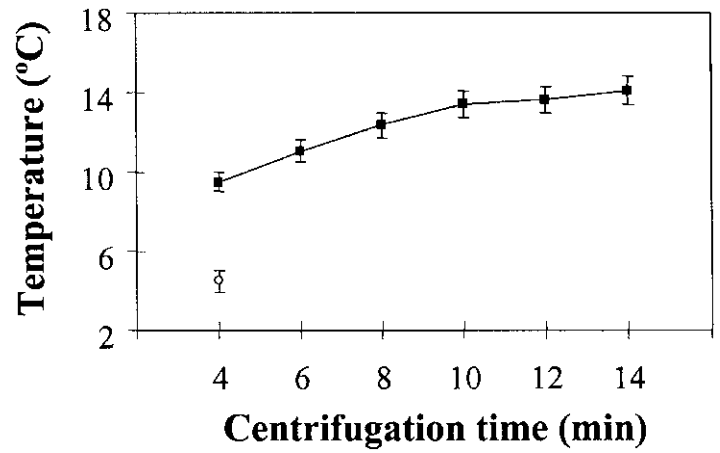


Fig. 2. Temperature variation of fresh-cut cabbage centrifuged for different time intervals \bar{x} - mean temperature before centrifugation.

Minimal processing. Cabbage heads were pre-washed in tap water, and sliced (2 ± 1 mm thick). Samples of 1.5 kg were placed in nylon bags, sanitized (NaClO , $200 \mu\text{L}\cdot\text{L}^{-1}$, at $5 \pm 1^\circ\text{C}$), rinsed (NaClO , $3 \mu\text{L}\cdot\text{L}^{-1}$, $5 \pm 1^\circ\text{C}$) and centrifuged ($800 g_n$) for 4, 6, 8, 10, 12 and 14 min.

Chemical and physical analysis. After centrifugation, the following variables were assessed: mass loss, product temperature, ethylene and carbon dioxide evolution, total soluble solids, total vitamin C, and color ($L^*a^*b^*$). Carbon dioxide and ethylene evolution were determined in a gas chromatograph (Mod. GC 14B, Shimadzu, Japan), and were expressed in $\text{mg CO}_2\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$ and $\mu\text{L C}_2\text{H}_4\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$, respectively, according to Kays (1991). Total soluble solids were determined using a desktop refractometer (Abbé, Japan). Total vitamin C was analyzed according to the procedure described in American Official Analysis of Chemistry (AOAC), adapted by Silva (2000). Color was evaluated, at each centrifuging times, with a hand colorimeter (Colortec-PCM), calibrated with white color. Browning was calculated according to Palou et al. (1999).

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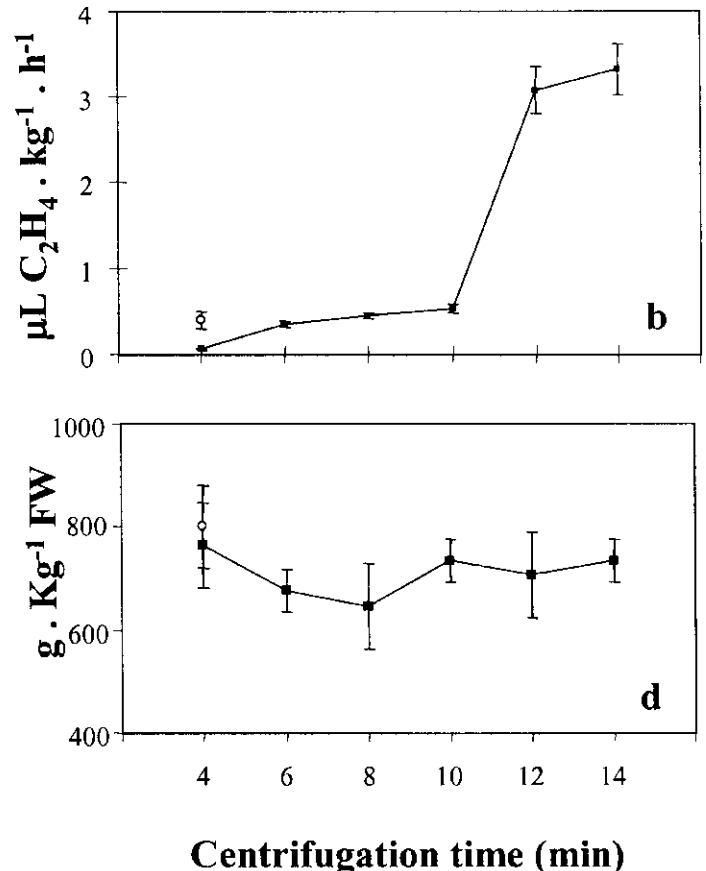
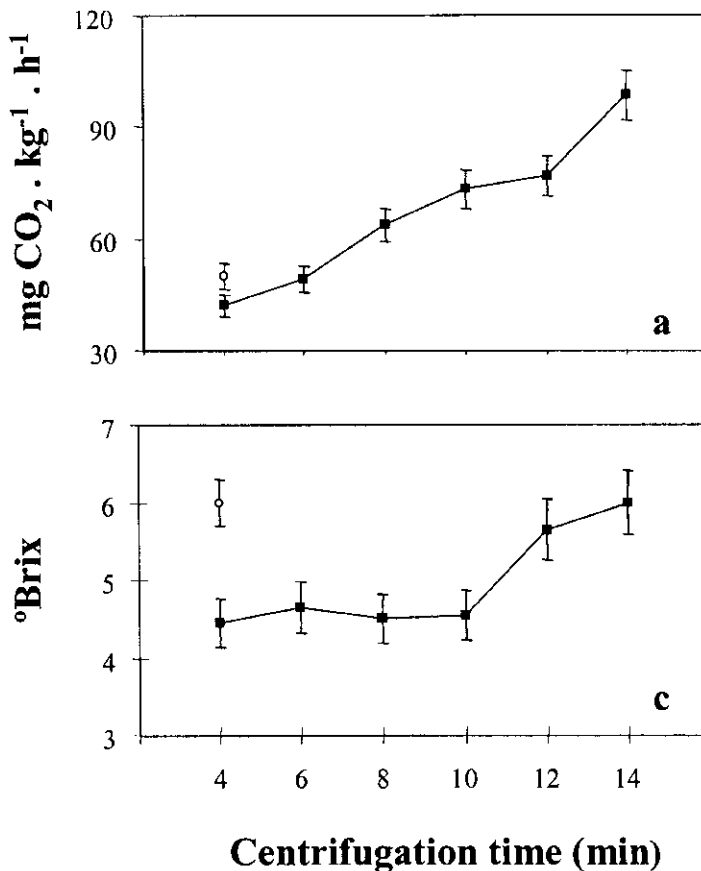


Fig. 3. Respiratory activity (a), ethylene evolution (b), total soluble solids (c) e vitamin C (d) of fresh-cut cabbage centrifuged for different time intervals. \bar{x} - mean values before centrifugation.

Experimental design and statistical analysis. Analysis were performed using a completely randomized design, with six treatments arranged (six sampling times), and four replicates. Data were subjected to analysis of variance and the least significant difference procedure was carried out. Differences between any two treatments larger than the sum of two standard deviations were always significant ($P > 0.05$).

Results and Discussion

Water loss. Centrifugation for periods lower than 10 min. did not contribute to excessive tissue dehydration. On the other hand, when centrifugation took more than 10 min, it was observed a slight tissue dehydration. Considering the different centrifugation times tested, it was verified that 10 min was enough to remove water in excess, and the mass of the product after centrifugation was similar to the mass after slicing (Fig. 1).

Temperature and carbon dioxide evolution. Temperature increased slowly with time until 10 min. of centrifugation, shifting from 9 to 13 °C (Fig. 2). This heating probably occurred due to the mechanical damage suffered by the processed tissue in contact with the centrifuge walls or even due to the heating of the equipment itself. Respiratory activity increased 125% when centrifugation time increased from 4 to 14 min. The increments in respiratory activity followed a sigmoid pattern until 12 min of centrifugation. A pronounced rise in CO₂ evolution was observed after 12 min, what is probably explained by the excessive dehydration stress and to an increase in ethylene evolution (Fig. 3b).

Cantwell (1992), working on fresh-cut cabbage, observed that respiratory activity increased when storage temperature shifted from 5 to 10 °C, reducing the shelf life of the processed product. Similar results were verified by Artés et al. (1999) on tomatoes. They observed that respiratory activity decreased around 40% when temperature was lowered from 10 °C to 2 °C. Watada et al. (1996) observed the same phenomena for distinct fresh-cut products stored under different temperatures. Increased temperature can also contribute to the loss of nutritional value of the fresh-cut product, as observed for vitamin C of vegetable crops stored under different temperatures (Favell, 1998).

Ethylene evolution. Ethylene evolution remained around 0,5 $\mu\text{L}\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$ until 10 min, showing a peak of 3 $\mu\text{L}\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$ at 12 min of centrifugation. It was observed that ethylene evolution significantly increased after CO₂ increased (Figs. 3a, b). Many researchers have observed that increasing ethylene evolution is directly associated with mechanical damage, resulting in the onset of senescence of different products (Abeles et al., 1992). Ethylene evolution resulting from minimal processing was enough to induce chlorophyll degradation in spinach (*Spinacia oleracea* L.), but no effect was verified in broccoli (*Brassica oleracea* L. var. *italica*). The observed effects in fresh-cut spinach are correlated with an increase in chlorophyllase activity due to the ethylene rise (Rodriguez et al., 1987; Sabater and Rodriguez, 1978; Watada et al., 1990; Yamauchi and Watada, 1991). The consequent reduction in chlorophyll level allows the revelation of carotenoids pigments, changing the product color (Heaton and Marangoni, 1996).

Total soluble solids and vitamin C. As observed for CO₂ evolution, total soluble solids content increments followed a sigmoid pattern, which is probably related to the dehydration stress associated with the centrifugation procedure (Fig. 3c). Total sol-

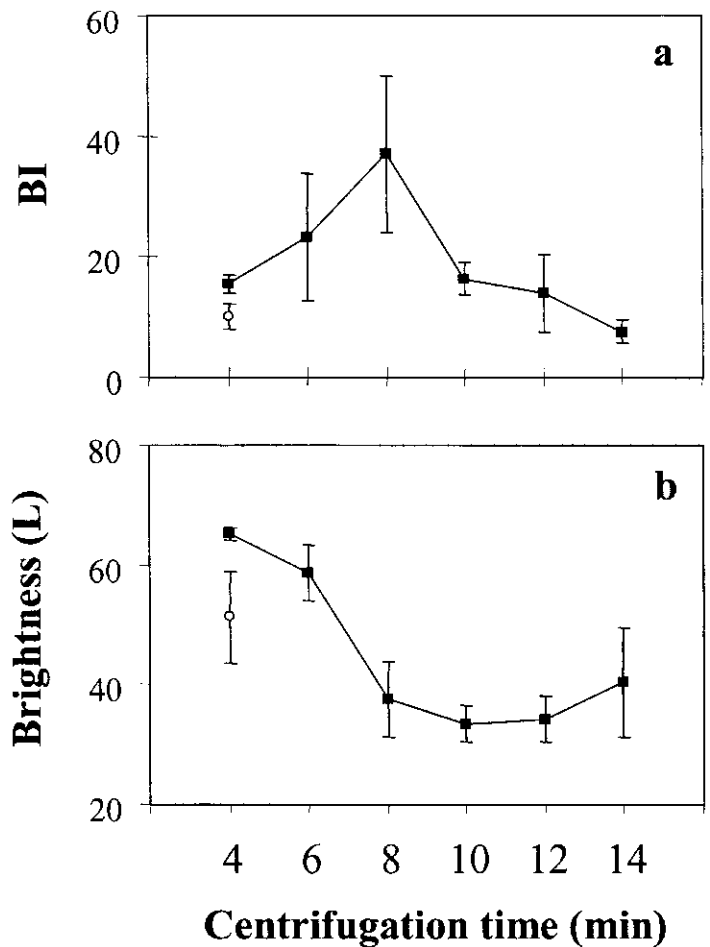


Fig. 4. Browning index (a) and brightness (b) of fresh-cut cabbage centrifuged for different time intervals. \bar{x} - mean values before centrifugation.

uble solids increased 29% after 10 min of centrifugation, shifting from 4.2 to 5.8. Regarding vitamin C content, it was verified that there was a slight reduction in the beginning of the centrifugation test (4, 6 and 8 min), with very few alterations until the end of the experiment. During the first 8 min, vitamin C content reduced around 18%, possibly due to the dilution effect of water in excess (Fig. 3d). For 10, 12 and 14 min, it was observed a tendency of increasing the vitamin C content, which is probably related to the significant water removal (Fig. 1).

Browning index (BI) and brightness. Browning index increased approximately 110% during the first 8 min, decreased abruptly between 8 and 10 min, and then showing a slight decrease until 14 min (Fig. 4a). The increase observed in the first 8 min can be related to water in excess (Fig. 1), what contributes to reduce the brightness of the fresh-cut tissue. Brightness reduced around 60% during the first 8 min of centrifugation, and kept reducing until 10 min, showing no significant changes after that (Fig. 4b).

It is suggested that fresh-cut cabbage should be centrifuged for 10 min to maintain the quality and to extend the shelf life.

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