MORETTI CL; MATTOS LM; MACHADO CMM; KLUGE RA. 2007. Physiological and quality attributes associated with different centrifugation times of baby carrots. *Horticultura Brasileira* 25: 557-561.

Physiological and quality attributes associated with different centrifugation times of baby carrots

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ABSTRACT

Centrifugation is one of the most important steps in the fresh-cut industry. Inadequate centrifugation can lead to increased white blush in baby carrots. The present work was carried out aiming at evaluating the effects of different centrifugation times in baby carrots physiological and quality attributes. Carrot roots cv. Alvorada were harvested and minimally processed as baby carrots. After processing, samples were placed in nylon bags and centrifuged (378 rad. s^{-1}) for 0; 30; 60; 90, and 120 seconds. Temperature of baby carrots centrifuged for 120 seconds was 63% higher than the temperature at the beginning of the experiment. Respiratory activity increased 49% when centrifugation time increased from 30 to 120 seconds. Ethylene evolution remained around 1.7 μL kg^{-1} h^{-1} until 60 seconds, increasing to 3.5 μL kg^{-1} h^{-1} at 120 seconds of centrifugation. Whiteness index increased 34% and 68% when centrifugation time shifted from 30 s to 60 s and from 30 s to 120 s, respectively. No significant changes in total carotenoids content were observed for the different tested centrifugation intervals. Baby carrots should be centrifuged for 30 seconds in order to maintain the quality and to avoid the development of white blush.

Keywords: *Daucus carota*, total carotenoids; color; postharvest; temperature; white blush.

RESUMO

Atributos fisiológicos e de qualidade associados com tempos de centrifugação de mini-cenouras

A centrifugação é uma das etapas mais importantes na indústria de processamento mínimo. A centrifugação inadequada pode levar a um aumento do esbranquiçamento em mini-cenouras. O presente trabalho teve como objetivo avaliar os efeitos de diferentes tempos de centrifugação nas características fisiológicas e de qualidade em minicenouras. Raízes de cenouras cv. Alvorada foram colhidas e minimamente processadas como minicenouras. Após o processamento, as amostras foram colocadas em sacos de nylon e centrifugadas (378 rad. s^{-1}) por 0; 30; 60; 90 e 120 segundos. A temperatura das minicenouras centrifugadas por 120 segundos foi 63% mais alta que a temperatura do início do experimento. A atividade respiratória aumentou 49% quando o tempo de centrifugação aumentou de 30 s para 120 s. A evolução de etileno permaneceu em torno de 1.7 μL kg^{-1} h^{-1} até 60 segundos, aumentando para 3.5 μL kg^{-1} h^{-1} aos 120 segundos de centrifugação. O índice de esbranquiçamento aumentou 34% e 68% quando o tempo de centrifugação alterou de 30 s para 60 s e de 30 para 120 s, respectivamente. Nenhuma mudança significativa no teor de carotenóides totais foi observada para os diferentes intervalos de centrifugação testados. As minicenouras devem ser centrifugadas por 30 minutos para manter a qualidade e evitar o desenvolvimento do esbranquiçamento.

Palavras-chave: *Daucus carota*, carotenóides totais, cor, pós-colheita, temperatura, esbranquiçamento.

(Recebido para publicação em 16 de julho de 2007; aceito em 19 de novembro de 2007)

The consumption of minimally processed fruits and vegetables has increased significantly during the last years, considering both retail and consumer level. Many factors are associated with this trend, such as the decrease in family size, population aging, decrease in the number of family members, and increase in the foodservice sector (Moretti, 2007).

The obtention of fresh-cut products involves many steps, such as cleaning, washing, trimming, coring, slicing, shredding, and other related operations. 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 & 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. These products can maintain their quality for up to 14 days, when stored in the optimum conditions.

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. Essentially, the physiology of fresh-cut fruits and vegetables is the physiology of a wounded tissue (Brecht, 1995). 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 aroma volatile profiles (Moretti *et al.*, 2002), and increase in the activity of many enzymes related with browning (Ke & Saltveit, 1989).

Among the various steps associated with minimal processing, centrifugation has a major importance, once 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 be used as well. 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. However, it is not unusual to observe processors under or over centrifuging products what can significantly affect the quality of the final product.

For baby carrots, excessive water removal during centrifugation can cause a severe loss in quality due to the development of white blush. According to different authors, white blush appears in fresh-cut carrots due to the desiccation of cellular remnants on the carrot surface (Tatsumi *et al.*, 1991) and to the synthesis of lignin. In many cases, white blush is the limiting factor in marketing the product, once consumers tend to associate it with decay. Acceptability of baby carrots in grocery stores and salad bars are significantly affected when the sticks have white blush (Tatsumi *et al.*, 1993).

Scientific papers published during the last two decades have focused different physiological and quality changes associated with fresh-cut baby carrots and the possible strategies to circumvent the existing problems. However, there is a lack in the literature concerning the relation among centrifugation time and changes in quality attributes.

The present work was carried out aiming at evaluating the effects of different centrifugation times in fresh-cut baby carrots physiological and quality attributes.

MATERIAL AND METHODS

Carrot roots cv. Alvorada were harvested at commercial fields in Brasilia, Brazil. After harvest, roots were taken to the postharvest laboratory, selected for external blemishes, graded for size (18±2 cm long), and minimally processed as baby carrots.

Roots were pre-washed in tap water, hydro cooled at 5°C, and processed as baby carrots sticks. Samples of 1.5 kg were placed in nylon bags, sanitized (NaClO, 200 mg L^{-1}, at 5±1°C), rinsed (NaClO, 3 mg L^{-1}, 5±1°C) and centrifuged (378 rad. s^{-1}) in a stainless steel centrifuge (radius = 0.14 m; F = 60 Hz) for 0; 30; 60; 90, and 120 seconds. The water tension generated by the centrifuge, considering the parameters described above, at its maximum speed, was equal to -2.8 MPa, according to the equation presented in Tyree (1997).

After each centrifugation time, the following variables were assessed: mass loss, temperature, carbon dioxide and ethylene evolution, color (L*a*b*) and total carotenoids content. Temperature was evaluated in carrots sticks surface with an infrared thermometer. Carbon dioxide and ethylene evolution were determined in a gas chromatograph. Column, injector, and detector temperatures were set at 60; 100 and 140°C, respectively, for CO_2 analysis and at 60; 100 and 150°C for ethylene quantification. The results were expressed in mL CO_2 kg^{-1} h^{-1} and μL C_2H_4 kg^{-1} h^{-1}, respectively. Color was evaluated with a hand colorimeter (L*a*b*) and whiteness index calculated according to Bolin & Huxsoll (1991), using the following equation: Whiteness index = $100 - [(100 - L)^2 + a^2 + b^2]^{1/2}$. Total carotenoids were assayed as described by Lime *et al*. (1957) and Umiel & Gabelman (1971).

Analysis were performed using a completely randomized design, with five treatments and eight replicates (n = 1.5 kg). 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

Considering the different centrifugation times tested, 30 seconds were enough to remove water in excess, and the mass of the product after centrifugation was similar to the mass after processing. Centrifugation for periods higher than 30 seconds contributed to excessive tissue dehydration. During the first 30 seconds water removal was done easily when compared to the subsequent intervals (Figure 1A). Water removal in the present work was done easily when compared to the work carried out by Silva *et al.* (2002). They worked on fresh-cut cabbage and verified that 10 minutes of centrifugation were necessary to remove water in excess, considering a centrifuge with an angular speed of 150 rad s^{-1}. This is partially explained by the highest hydraulic conductivity observed in roots (carrots) than leaves (cabbage).

Centrifugation or other procedures are recommended for most fresh-cut items for complete water removal or, in some cases, to cause slight desiccation of the surface (Cantwell & Suslow, 2002). The major objective is primarily to reduce microbial growth. In detached fruits and vegetables desiccation can also induce the production of stress ethylene (Yang, 1985).

Temperature is an important factor governing different postharvest processes. In the present experiment, the temperature of baby carrots showed a tendency to increase as centrifugation times increased (Figure 1B). Carrots sticks centrifuged for 120 seconds showed a temperature that was 63% higher when compared to the temperature of the material at the beginning of the experiment (Figure 1B). This heating probably occurred due to the friction suffered by the processed tissue against the centrifuge walls or even due to the heating of the equipment itself. The observed rise in temperature induced alteration in both carbon dioxide and ethylene evolution.

Similar results were verified by Cantwell (1992) for cabbage and by Artés *et al.* (1999) for tomatoes. The same phenomenon was observed by Watada *et al.* (1996) for distinct fresh-cut products stored under different temperatures. Increased temperature can also contribute to the loss of nutritional value of fresh-cut product, as observed for vitamin C of vegetable crops stored under different temperatures (Favell, 1998).

White blush is a serious defect in baby carrots. It was demonstrated in the present investigation that increasing centrifugation time contributed to a higher level of white blush. In fact, whiteness index increased 34 and 68% when centrifugation time increased from 30 s to 60 s and from 30 s to 120 s, respectively, showing that over centrifuging baby carrots significantly contributed to the increasing of cells desiccation (Figure 1C).

In several published studies, white blush is considered a result of both surface dehydration and enzymatic activity to form lignin (Tatsumi *et al.*, 1991, 1993; Avena-Bustillos *et al.*, 1993). According to different results, white blush formation was reported to be influenced by temperature, relative humidity (Avena-Bustillos *et al.*, 1993), degree of peeling (Bolin & Huxsol, 1991) and type of cutting surface (Tatsumi *et al.*, 1991, 1993; Bolin & Huxsol, 1991). A possible strategy to minimize or to solve the problems related to white blush in baby carrots is the application of edible coatings. The utilization of edible coatings to increase water vapor resistance aiming to reduce white blush have been tested by different authors (Avena-Bustillos *et al.*, 1993; Sargent *et al.*, 1994). Avena-Bustillos *et al.* (1994) verified that an edible sodium caseinate/stearic acid emulsion also controlled white blush and has also contributed to reduce respiration by about 20% when compared to the uncoated control.

Respiratory activity had a significant rise as centrifugation time increased. Carbon dioxide evolution increased around 49% when centrifugation time shifted from 30 s to 120 s (Figure 2A). A significant rise in CO_2 evolution was observed after 30 seconds, what is probably explained by both the excessive dehydration stress suffered by the tissue (Figure 1A) and the mechanical damage caused by the impacts and compression of baby carrots against the centrifuge walls.

The increase in respiration rate verified in the present investigation is one of the earliest physiological responses to mechanical stresses and can be linked to the induction of the phenolic metabolism and the wound healing response of the tissue. Different signals

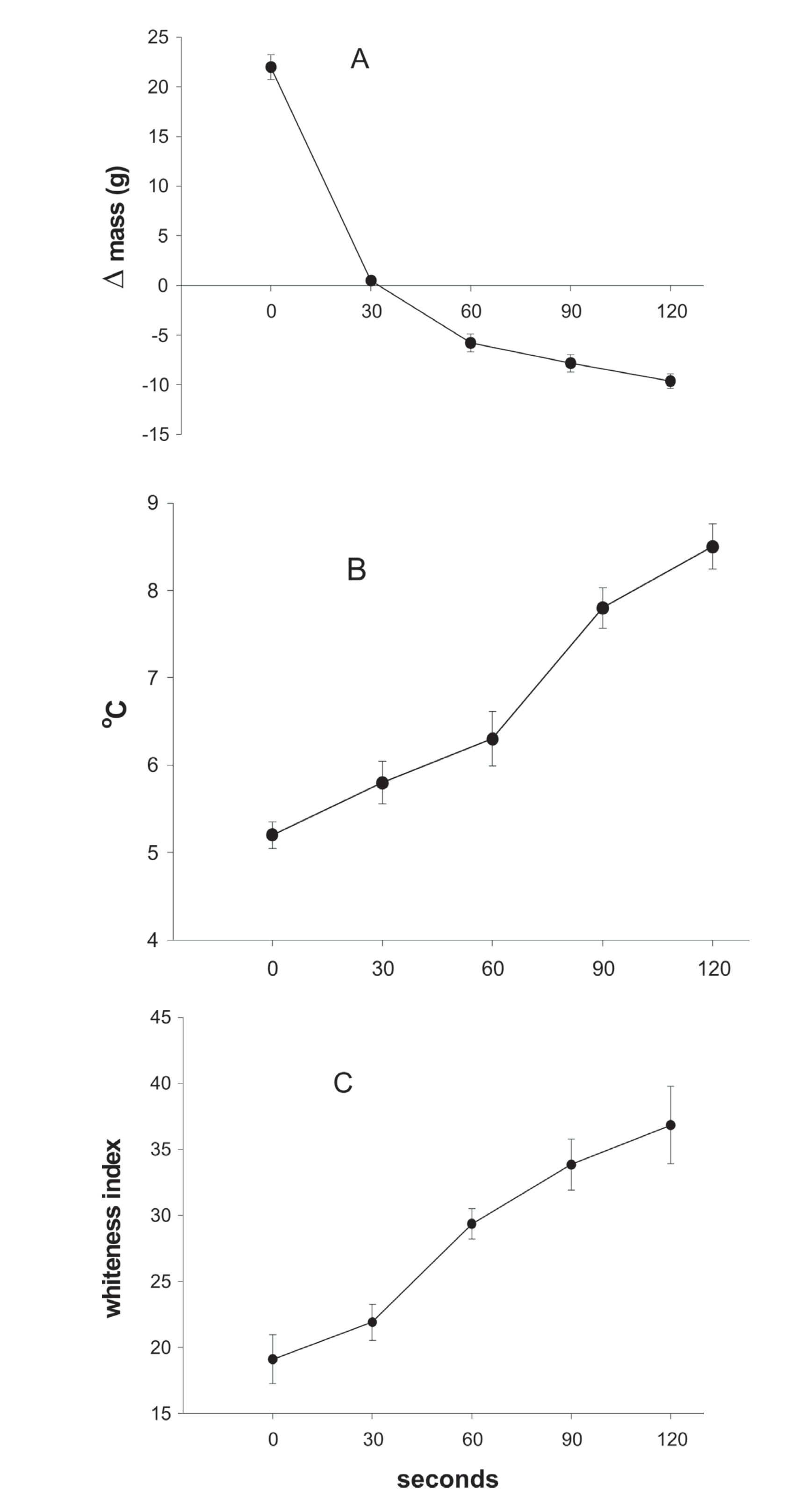

Figure 1. Mass variation (Δg) (A); temperature (°C) (B); and whiteness index (C) of fresh-cut baby carrots centrifuged for different times intervals (Δg = Mass of the product after centrifugation – mass of the product right after processing). Vertical bars mean ± SD. (Mass variation (Δg) (A); temperature (°C) (B); and whiteness index (C) of fresh-cut baby carrots centrifuged for different times intervals (Δg = Massa do produto após centrifugação – massa do produto logo após o processamento). Barras verticais significam ± SD). Brasília, Embrapa Hortaliças, 2007.

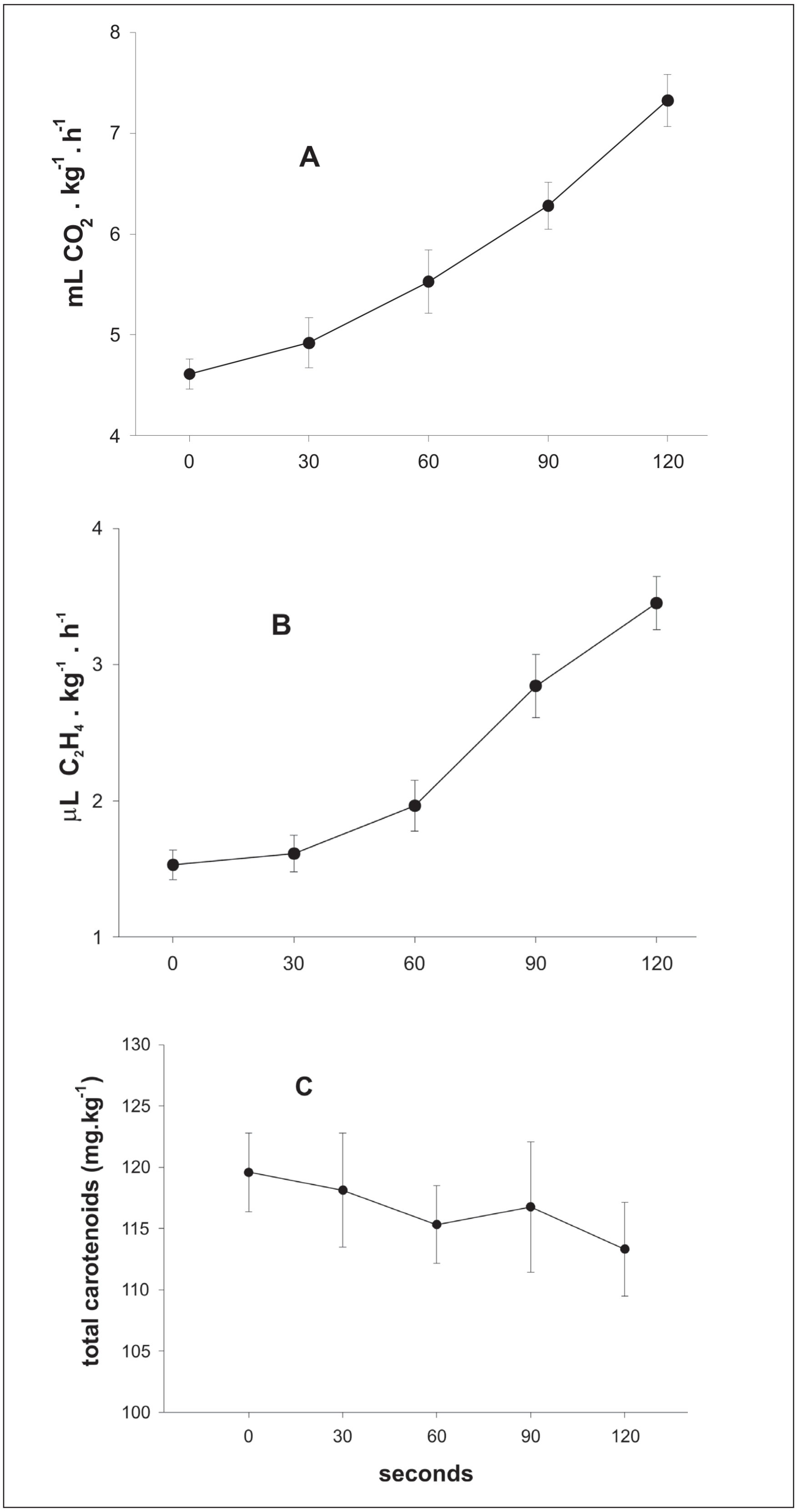

Figure 2. Respiratory activity (µL CO_2 $kg^{-1}h^{-1}$) (A); ethylene evolution (µL C_2H_4 $.kg^{-1}.h^{-1}$) (B); and total carotenoids content (mg kg^{-1}) (C) of fresh-cut baby carrots centrifuged for different times intervals. Vertical bars mean ± SD (atividade respiratória (mL CO_2 kg^{-1} h^{-1}) (A); evolução do etileno (mL C_2H_4 kg^{-1} h^{-1}) (B); e teor total de carotenóides (mg kg^{-1}) (C) de mini-cenouras centrifugadas em diferentes intervalos. Barras verticais significam ± SD). Brasília, Embrapa Hortaliças, 2007.

induced by mechanical stresses elicit physiological and biochemical responses in both adjacent and distant tissues (Ke & Saltveit, 1989). Mechanical stresses can also induce increase in respiration rate in some plant tissues, which is probably related to alfa-oxidation of fatty acids (Shine & Stumpf, 1974). This reaction oxidizes fatty acids to CO_2 and it is associated with CO_2 releasing after potato tubers slicing (Rolle & Chism, 1987).

Ethylene evolution significantly increased during the experiment (Figure 2b), remaining around 1.7 µL kg^{-1} h^{-1} until 60 seconds of centrifugation. The evolution of this hormone for the material centrifuged for 120 seconds was 214% higher than that observed for baby carrots centrifuged for 30 seconds (Figure 2b).

The increase in ethylene evolution observed is directly associated with the mechanical damage suffered by the tissue. Wound induced ethylene is associated with the onset of senescence of different products (Abeles *et al.*, 1992). Different authors verified that ethylene evolution resulting from minimal processing was enough to induce chlorophyll degradation in spinach (*Spinacia oleracea* L.); however, no effects were verified in broccoli (*Brassica oleracea* L. var. *italica*). The observed effects in fresh-cut spinach may be correlated with an increase in chlorophyllase activity due to the ethylene rise (Watada *et al.*, 1990; Yamauchi & Watada, 1991). The consequent reduction in chlorophyll level allows the revelation of carotenoids pigments, changing the product color (Heaton & Marangoni, 1996).

Carotenoid pigments are relatively stable in their natural environment, but postharvest treatments or processing operations may contribute to increase pigments degradation (Rigal *et al.*, 2000). Possible reasons for carotenoids losses in fresh tissues are autoxidation that occurs when pigments combine with oxygen in the air or are mediated through enzymatic oxidation, which is catalyzed by oxidative enzymes (Gross, 1991). The abrasion of carrot surfaces exposes the phloem, where carotenes are most concentrated, leading to the direct contact with air and light (Li & Barth, 1998).

No significant changes in total carotenoids content were observed for the different centrifugation intervals tested (Figure 2C), indicating that, apparently, the stress caused by the mechanical damage and desiccation was not severe enough to stimulate significant pigment degradation, considering that baby carrots were evaluated right after centrifuging. Further investigations should focus on the effect of different centrifugation times in the content of total carotenoids during refrigerated storage periods.

Mechanical stresses associated with centrifugation increased product temperature, carbon dioxide and ethylene evolution. Centrifugation for more than 30 seconds significantly contributed to tissue dehydration and the development of white blush. Considering the conditions this experiment was carried, it is suggested that baby carrots should be centrifuged for 30 seconds in order to maintain the quality and to avoid the development of white blush.

ACKNOWLEDGEMENTS

This research was supported by PRODETAB (Embrapa/World Bank Agreement), Grant nº. 019-01/02.

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