Effects of Cutting Direction on the Changes of Microorganisms and Pectic Substances in the Partially Processed Carrot during Storage
(Studies on Physiological and Chemical Changes of Partially Processed Carrot—Part IV)

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The changes of microorganisms and pectic substances of partially processed carrots (PPC) were determined with respect to cutting direction. The increase of microbial counts occurred in all tissues and both lengthwise cut sections (LCS) and crosswise cut sections (CCS). The microbial count in the xylem of LCS increased at a greater rate than those of phloem at 20°C. The counts in both tissues of CCS increased slightly and were similar for experimental periods at 20°C. PPC stored at 1°C contained low numbers of microorganisms and maintained acceptable commercial quality for experimental periods. The concentration of soluble pectic substances (WP) in both tissues of LCS increased and insoluble pectic substances (EP and HP) decreased after onset of decay at 20°C. In the xylem and phloem of CCS, WP did not show significant changes and EP and HP decreased slightly up to the end of the holding time. (Received Dec. 4, 1995)

Introduction

Partially processed vegetables and fruits (PPP) are becoming popular in Japan, U.S.A., and Europe, but for all PPP, the tissue destruction caused by the mechanical processing results in elevated respiration and transpiration and increased likelihood of microbial degradation. A disadvantage of PPP is that their shelf life may be greatly reduced as compared to the intact products. Keeping the quality of PPP during handling and storage is recommended by the utilizing or modifying practices and a combination of two or more of these for intact products.

Partially processed carrots (PPC) are frequently used. Among the earlier experiments with PPP several studies were for PPC and some treatments for maintaining quality of PPC were also attempted. On the other hand, effects of cutting methods on quality and storability of PPP have been studied in lettuce, carrots, and potatoes. Our latter studies have shown that the deterioration rate of line slices was obviously faster than that of ring slices in pepper fruit and lengthwise cut sections decayed more rapidly than crosswise cut ones in carrots. But only a few previous studies which clarified the reason for differences in the storabilities induced by cutting modes and direction of PPP have been reported.

Generally, levels of total extracted pectic substances in fruits increase with maturation but do not show apparent changes after harvest. Pectin degradation is one of the factors affecting softening in products during storage. The degradation of pectic substances occurred along with microbial degradation.

The primary object of this study was to determine the effect of cutting direction on the changes of microorganisms and pectic substances in the PPC after cutting, which could indicate the importance of various factors which influence the storability of the PPC.

Materials and Methods

Material

Carrots (Daucus carota L. var. sativa DC, unknown cultivar) were obtained from Sakai Wholesale Market (Sakai city, Osaka). The carrots were selected for their uniform size and shape, and wiped with paper towels.
Partially processed carrots (PPC) were prepared in two ways by using a kitchen knife under ordinary circumstances in a room. Lengthwise cut PPC divided into eight equal parts were defined as lengthwise cut sections (LCS) and crosswise cut PPC of 1 cm thickness were defined as crosswise cut sections (CCS).

Packaging and Holding: A 100g PPC was placed into a transparent plastic tray (15 cm x 22 cm, depth: 6 cm). The tray was then inserted in a low density polyethylene package (thickness: 0.03 mm, LDPE-P) and sealed. Three replicated samples of each treatment were kept in a 20°C or 1°C dark room and the appearance-quality and decay of the PPC were evaluated by visual observation, noting color change, softening, development of undesirable odors, and presence of mold on the PPC. The changes in appearance of tissue caused by pectolytic breakdown can be an indication of microbial growth. The arrows in Fig. 1 and 2 indicate the onset of decay.

Microorganisms assay

The number of bacteria was determined by the plate count method. Carrot samples (xylem and phloem, 1g, respectively) were homogenized with 50ml of autoclaved deionized water in a Waring blender. A dilution series was prepared, and appropriate dilutions were plated on the following medium. For bacteria, sodium albuminate agar (pH 6.8) was employed. All plates were incubated at 20°C and the bacteria counts were conducted after 7 days.

Extraction and analysis

20 g of fresh carrot tissues (xylem and phloem) was boiled at 80°C in 80ml ethanol (80%) for 20 min. It was homogenized in a Waring blender and the homogenate was passed through a filter. The residue was washed three times with 30ml of 80% ethanol and the residue was used as alcohol-insoluble solids (AIS).

Pectic substances were prepared from AIS and determined as described by Yoshioka et al. Pectic substances were partitioned into three fractions based on their solubility in different solvents. The AIS was suspended in 20ml of distilled water and stirred overnight at 20°C. The mixture was centrifuged and the supernatant was used as the water-soluble fraction (WP). The residue was resuspended in 40ml of 0.05M EDTA in 0.05M sodium phosphate (pH 4.5) and heated at 80°C for 30 min. in a water bath. The suspension was centrifuged and supernatant was used as the EDTA-soluble fraction (EP). The residue was resuspended in 40ml of 0.05N HCl and heated at 85°C for 2 hr. in the water bath. The suspension was centrifuged and supernatant was used as the HCl-soluble fraction (HP). The contents were estimated by determining the uronic acid contents with meta-hydroxydiphenyl as described by Blumenkrantz and Asboe-Hansen.

Results and Discussion

Appearance-quality and decay

Visual quality decreased during storage and the rate of change in the lengthwise cut sections (LCS) was faster than that of the crosswise cut sections (CCS). Visual quality was significantly preserved at 1°C for experiment period (data not shown).

The arrows in Fig. 1 and 2 indicate the onset of decay. The onset in LCS was faster than in CCS. These data support the latter reports that the deterioration rate of line slices was obviously faster than that of ring ones.
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in pepper\textsuperscript{14,15} and LCS decayed more rapidly than CCS in carrots\textsuperscript{16} and cucumbers\textsuperscript{22}. In a tissue comparison, the xylem decayed more rapidly than the phloem in LCS and this result was in agreement with the fact that deterioration in LCS occurred first at the xylem part and subsequently at the phloem\textsuperscript{16}, that the sections prepared from the xylem were more perishable than those of phloem\textsuperscript{17}, and that the high ratio of the transverse area to the vertical one could slow the respiration rate and thereby extended the shelf life of the carrot sections\textsuperscript{17}. These data demonstrated that cutting, one kind of mechanical processing, influenced the physiological changes of xylem more than phloem.

Growth of microorganisms

The total microbial count in PPC increased during holding at all temperatures and rates of increase were greater at the higher temperature (Fig. 1). PPC stored at 1°C contained low numbers of microorganism and maintained acceptable commercial quality for 14 days. Increase of microbial counts occurred in all tissues and both LCS and CCS. The microbial count in the xylem of LCS increased at a greater rate than those of phloem at 20°C. The counts in both tissues of CCS increased slightly and were similar for 14 days holding at 20°C.

The initial level of bacterial population in this study was ca. $10^2$/g in both tissues. Controls of the growth of microbes by chemical treatments do not completely achieve control because of the spreading growth in the tissues.

Some approaches to improve the shelf life of carrots were reported that, for example, a CaCl\textsubscript{2} treatment maintained firmness and reduced microbial growth of PPC\textsuperscript{7}, a NaCl solution treatment resulted in less white tissue of PPC\textsuperscript{10}, sodium caseinate–stearic
acid was particularly effective in ameliorating the disorder of PPC\textsuperscript{23}, ozone-treated carrots were lighter (higher L values) and less intense in color than control carrots\textsuperscript{24}, the growth of aerobic mesophilic and lactic microflora was strongly inhibited by gamma irradiation and sensory analysis demonstrated a preference for irradiated shredded carrot\textsuperscript{25}, a steam treatment retarded surface discoloration, soluble phenolic and isocoumarin production and lignin formation\textsuperscript{26}, and sucrose–fatty acid esters for PPC were valuable in extending shelf life\textsuperscript{27}. However, all of these treatments, except the gamma irradiation, have been generally of little value in extending the shelf life of PPC, because the prolongation of the shelf life was due mainly to the effect of these treatments for cut surface.

In general low temperature storage suppresses the growth of microbes to some extent. Bolin et al.\textsuperscript{11}) reported that the microbial load of the initial product influenced the storability of shredded lettuce.

**Changes of pectic substances**

At the time of preparation, concentrations of insoluble pectic substances (EP and HP) were significantly higher in the phloem than in the xylem of both LCS and CCS and the difference in soluble pectic substances (WP) was not significant between tissues (Fig. 2).

The concentration of WP in both tissues of LCS (Fig. 2-left) remained constant during the first 3 days of holding and increases of WP occurred after onset of decay. Levels of EP and HP in both tissues of LCS did not show significant changes during the first 3 days and then decreased after the onset of decay. These decreases continued up to the end of the holding.

In the xylem and phloem of CCS (Fig. 2-right), WP did not show significant changes and EP and HP decreased slightly up to the end of holding.

Both physiological and microbial actions can initiate biochemical changes that lead to quality loss of PPP\textsuperscript{28}. In this report, WP increased and EP and HW decreased after the onset of decay, thereby it is suggested that the increase of WP and decrease of EP and HW was possibly due to microbial actions.

**Literature Cited**

カットニンジンの保持に伴う細菌ならびにベクチン物質の変化に対する切断方向の影響
—カットニンジンの生理・化学的变化に関する研究（第4報）—

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筆者らはカット野菜・果実の生理・化学的特性ならびに品質保持技術に関する研究を行い、ピーマン、ニジン、キュウリでは切断形状が異なると腐敗速度に差の生じることを明らかにしている。貯蔵性に差の生じる理由を明らかにするための実験を試みており、本研究ではカットニンジンの保持に伴う細菌ならびにベクチン物質の変化を調べた。

実験材料および方法
市販のニンジンを維管束に平行に8等分したカットニンジン（以下縦切り）と1cmの厚さで維管束に直角に切断したカットニンジン（輪切り）を包丁で調製し、有孔ポリエチレン包装後、20℃もしくは1℃で保持し、適宜分析に供した。微生物は希釈平板法で調べ、ベクチン物質はアルコール不溶性物質の水可溶性（WP）、EDTA可溶性（EP）、塩酸可溶性（HP）画分のベクチンについて常法で分析した。

結果および考察
1. 1℃保持14日間では外観の変化はほとんどなく細菌の増加も少なかった。20℃保持では縦切りの木部における細菌の増加が最も顕著で、帯部がそれに続いた。輪切りにおける細菌の増加は縦切りより少なく、組織間の差異も小さかった。

2. 20℃保持中の縦切りでは木組織のWPは腐敗開始後に増加し、EPならびにHPは減少した。外観変化の少なかった輪切りでは木組織ともWPの変化はなく、EPとHPはわずかに減少した。

3. カットニンジンにおけるベクチン物質のWPの増加は、EPならびにHPの可溶化によるもので、可溶化は細菌によって誘導されることが明らかとなった。

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