Electron Microscopic Morphometry of Cell Wall Swelling in Rehydrated Carrots and Green Beans: The Influence of Various Blanching, Drying and Storing Parameters

Monika Grote and Hans Georg Fromme*
Institute of Medical Physics, Münster University, Hüfferstr. 68, D-4400 Münster, Federal Republic of Germany

Introduction

Food scientists know that the quality of dried vegetables and, last but not least, of the rehydrated consumable products does not depend only on the characteristics of the raw material but also on the influences of food processing.

This processing in the widest sense includes all the technological parameters employed (blanching, drying, and storing conditions).

Some light-optical investigations on tissue alterations that occur during such processing of vegetables have been reported previously (e.g. Simpson and Halliday [1], Reeve and Leinbach [2], Sterling [3], Reeve [4]).

During the last few years, however, more and more attention has been paid also by electron-microscopists to the morphological changes of the fine structure of cells and tissues (e.g. Davis et al. [5-9], Pomeranz [10], Vaughn [11]).

It is hoped by such ultrastructural analyses to get down to the very roots of the long-known gross morphological alterations and – by correlating cellular findings with food technology parameters – to optimize the quality of dried and rehydrated vegetables. In a previous paper (Grote and Fromme [12]) the authors presented a transmission electron-microscopic study of the basic morphological changes involved in the blanching, cooking, dehydration and rehydration of green bean pod tissue. There we found that cell wall broadening – probably due to the swelling and dissolution of the matrix material (pectin and protopectin) within the wall – is a predominant feature in processed plant tissue. This swelling is always greatest in rehydrated cells. The present paper gives the results of a transmission electron-microscopic study, which by morphometrical measurements determines the influence of various defined food technology parameters on the cell wall structure of dried and rehydrated green beans and carrots.

Material and Methods

Two varieties of green beans ("Koralle", "Cascade") and of carrots ("Bauer’s Kieler Rote", "Zino") were analysed. Blanching, drying and storing of the vegetables were carried out at the Institute of Food Technology – Fruit and Vegetables Technology – in Berlin as part of a correlated research project (AIF project No. 3664). Some of the results of this project were published by Bieilig and Schweiger [13]. For drying under defined and reproducible conditions, a hot-air drying system previously designed was used (Bieilig et al. [14]). The dried...
samples were rehydrated by cooking to “doneness” according to re-
ports from the Berlin Institute of Food Technology where the op-
timum cooking time for each sample had been previously determined
determined by sensory and texture tests.
Samples were prepared for transmission electron-microscopy as
described by Grote and Fromme [12]. For morphometrical meas-
urements of cell wall diameters the semi-automatic image-analysis sys-
tem MOP AM/03 (Kontron, Germany) was used. In each test 10–15
separate measurements were made on at least three parallel samples,
and the mean values were calculated.
Since the morphological appearance of the boiled raw material
was considered to be the “ideal” for a rehydrated vegetable, the mea-
sured cell wall thickness of the boiled raw tissue was put at 100. Cell
wall alterations in dried and rehydrated samples were expressed as
percentages of this value.

Results
1 The Influence of Blanching
1.1 Influence of Different Blanching Times. Blanching
in water for different periods led to different degrees of
cell wall swelling after rehydration (Tables 1 and 2). The values in these Tables show that cell wall swelling
in the rehydrated tissue is correlated with different
blanching times: the longer the blanching time, the
greater the cell wall swelling. Different cooking times
of the dried samples (the longer the blanching time, the
shorter the cooking time of the dried tissue) do not
seem to cancel out the influence of blanching.

1.2 Influence of the Addition of NaCl to the Blanching
Medium. Blanching with variable concentrations of
NaCl led to a general increase in cell wall thickness and
maceration of the tissue in the rehydrated carrots as
compared with blanching in pure water (Table 3). It is
remarkable that the addition of 3% NaCl causes al-
most the same amount of cell wall swelling in 5 min as
the addition of 5% in 10 min. Blanching with NaCl re-
duced the cooking times of the samples considerably.

2 The Influence of Drying
2.1 Dehydration in Dried Air. If the relative humidity
of the drying air was reduced to 3%, the samples ex-
hibited less cell wall swelling than parallel samples
dried in air with a relative humidity of 21% (Table 4). Lowering the relative humidity also led to a reduction
of the cooking times and a better conservation of
chlorophyll.

2.2 Residual Water Content of the Dried Vegetables. As
Table 5 shows, the morphological structure of the rehy-
drated carrots is adversely affected by a comparatively
high water content (>10%) of the dried product. Re-
ducing the residual water content to 6% by prolonged
drying reduces cell wall swelling considerably. There
were no significant differences with regard to the cook-
ing times.

Table 1. Influence of different blanching periods upon the degree
of cell wall swelling in rehydrated green beans (var. “Cascade”)

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Blanching time (min)</th>
<th>Cell wall swelling (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>3</td>
<td>125</td>
</tr>
<tr>
<td>B2</td>
<td>6</td>
<td>167</td>
</tr>
<tr>
<td>B3</td>
<td>9</td>
<td>190</td>
</tr>
<tr>
<td>B4</td>
<td>12</td>
<td>192</td>
</tr>
</tbody>
</table>

Table 2. Influence of different blanching periods upon the degree
of cell wall swelling in rehydrated carrots (var. “Zino”)

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Blanching time (min)</th>
<th>Cell wall swelling (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>6</td>
<td>99</td>
</tr>
<tr>
<td>C6</td>
<td>10</td>
<td>119</td>
</tr>
</tbody>
</table>

Table 3. Influence of blanching in different blanching media upon
cell wall swelling in carrots (var. “Bauer’s Kieler Rote”) after drying
and rehydration

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Blanching time (min)</th>
<th>Blanching medium</th>
<th>Cell wall swelling (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>2</td>
<td>H₂O</td>
<td>212</td>
</tr>
<tr>
<td>C2</td>
<td>5</td>
<td>H₂O + 3% NaCl</td>
<td>287</td>
</tr>
<tr>
<td>C3</td>
<td>10</td>
<td>H₂O</td>
<td>244</td>
</tr>
<tr>
<td>C4</td>
<td>10</td>
<td>H₂O + 5% NaCl</td>
<td>293</td>
</tr>
</tbody>
</table>

Table 4. Influence of the relative humidity of the drying air upon
cell wall swelling in rehydrated green beans (var. “Koralle”)

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Blanching time (min)</th>
<th>Relative humidity (%)</th>
<th>Cell wall swelling (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B5</td>
<td>6</td>
<td>21</td>
<td>189</td>
</tr>
<tr>
<td>B6</td>
<td>6</td>
<td>3</td>
<td>125</td>
</tr>
</tbody>
</table>

Table 5. Influence of the residual water content of dried carrots
(var. “Bauer’s Kieler Rote”) upon cell wall swelling after rehydration

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Residual water content (%)</th>
<th>Cell wall swelling (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C7</td>
<td>6</td>
<td>122</td>
</tr>
<tr>
<td>C8</td>
<td>13</td>
<td>200</td>
</tr>
<tr>
<td>C9</td>
<td>18</td>
<td>173</td>
</tr>
<tr>
<td>C10</td>
<td>22</td>
<td>184</td>
</tr>
<tr>
<td>C11</td>
<td>6</td>
<td>126</td>
</tr>
</tbody>
</table>