The effect of low temperature blanching on the texture of whole processed new potatoes

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Abstract

Improving the textural quality of whole new potatoes with respect to firmness was investigated through the application of low temperature blanching at 60, 65, 70, 75, 80, 90 and 100 °C for times up to 1 h. Rate of firmness degradation upon blanching, as measured using a 7 mm diameter probe attached to an Instron (4464) Universal Testing Machine, was significantly lower at 60–75 °C than at 80–100 °C over the investigated blanching times (P < 0.05). The activity of pectin methyl esterase (PME) was determined for whole new potatoes with an optimum activity of 2.92 μmol/min/g at 65 °C for 15 min. The enzyme was rapidly inactivated after 15 min at 75 °C and after 5 min at both 80 and 90 °C. Processing was by immersion in a thermostatically controlled water bath at 90 or 100 °C for times up to 25 min and with and without blanching at 65 °C or 75 °C for 15 min. Shear force as an indicator of firmness was measured by shearing through the whole potato with a single blade (1 mm thickness) at a cross-head speed of 50 mm/min. Firmness was significantly higher (P < 0.05) for processed potatoes blanched at 65 °C than those cooked at 95 or 100 °C without blanching. Low temperature blanching offers the potential for improving texture of processed whole new potatoes.

Keywords: New potatoes; Pectin methyl esterase; Firmness; Low blanching temperature

1. Introduction

Potatoes have long been recognised as healthy, economical and low in fat food product. In response to the increasing consumer demand for convenience, high quality foods, potato processors are constantly seeking new and innovative ways of utilising potatoes.

New potatoes are an ideal raw material for the inclusion in a variety of convenience ready meals either to substitute meat or to give a mouth-feel satisfaction. From the processor point of view, new potatoes offer many advantages: they are small and generally uniform in shape and can be processed whole doing away with the need for slicing, chopping and peeling. Subsequently, this would cut down considerably on time and expenses at the preparation stage and reduce waste. Today, new potatoes are available all year round from a variety of different countries and this is a further advantage.

New potatoes are defined as potatoes that are harvested as early as 3 months after being sown, and tend to have a fragile, flaky skin and low dry matter and starch content. As the potato matures, the skin sets and the dry matter and starch content increases. In general, main crop potatoes go into long-term storage for sale the next season whilst earlies go straight into the shops.

An essential quality attribute of processed potatoes is texture, which is a function of potato structure. Generally, the potato structure could be considered as made up of two principal areas: the cortex and the pith. The cortex is made of vascular storage parenchyma, which...
is rich in starch, followed by the pith which contains less starch and is located at the centre of the tuber (Jadhav & Kadam, 1998). In new or immature potatoes, the cortex makes up a very small part of the potato, while in more mature potatoes the cortex volume can exceed that of the pith (Anzaldua-Morales, Bourne, & Shomer, 1992).

Upon processing, changes in potato texture are due to changes in structure and chemical composition. The rigid structure of the raw potato is mainly due to the pectic substances, celluloses and hemicelluloses. The pectic substances, which are the main constituents of the middle lamella, play a major role in intercellular adhesion and also contribute to the mechanical strength of the cell wall. During processing, pectic substances are brought more easily into solution than other cell wall polymers and subsequently contributing to the degradation of the potato texture.

A main step in the processing of potatoes is blanching, which is traditionally carried out within the range of 80–100 °C for short times between 20 s and 15 min (Andersson, Gekas, Lind, Oliveira, & Oste, 1994). Such high temperatures can lead to structural damage and loss of firmness in the vegetable tissue.

Low temperature blanching, in the range of 55–75 °C, has been shown to improve the firmness of cooked vegetables and fruits, reducing physical breakdown and sloughing during further processing and providing an excellent and safe way of preserving texture (Verlinden, Yuksel, Baheri, De Baerdemaeker, & Van Dijk, 2000). It has been proposed that the enzyme pectin methyl esterase (PME), native to many fruits and vegetables including potatoes, plays a role in this firming effect at low blanching temperatures (Andersson et al., 1994).

A blanching treatment that combines low temperatures for relatively long times followed by a higher temperature for a short time has been found to be effective in both minimising texture degradation of vegetables and in destroying undesirable enzymes. The firming effect of low temperature blanching is less pronounced if measured after blanching, than if measured after blanching prior to cooking. Quintero-Ramos, Bourne, and Anzaldua-Morales (1992) reported greatest loss of firmness for Jalepeno peppers blanched conventionally at 96 °C for 3 min compared to samples blanched at temperatures of 55–80 °C and then processed at 96 °C for 3 min. This would imply that the benefits of low temperature blanching only become evident after cooking.

Verlinden et al. (2000) reported that potato samples that had not been blanched before cooking had lower maximum force values than for those blanched then cooled and cooked. Although there have been substantial amounts of research directed towards investigating changes in potato texture before and after processing, apparently there has been no research work cited with respect to textural changes during the processing of new potatoes.

The objectives of this study were to investigate the effect of blanching temperatures in the range of 60–100 °C on the texture of whole new potatoes before and/after processing at temperatures of 95 and 100 °C, as well as to determine the blanching temperature at which pectin methyl esterase (PME), naturally present in potatoes, has its optimum activity and at what temperature it is denatured.

2. Materials and methods

The potato variety studied in this work was the Maris peer. Potatoes were sourced from a retail outlet where it was guaranteed that they were harvested and in the shop within a day, so there was no storage period involved. The potatoes had been pre-washed before purchase and were bought in 1 kg lots in plastic bags. They were removed from the plastic bags after purchasing and allowed to come to room temperature before any tests were carried out. Only potatoes with a diameter in the range of 35–45 mm were used for this study which corresponds to those used in the industry.

2.1. Blanching procedure

Potatoes (within the range of 35–45 mm diameter) were immersed into a cylindrical shaped wire basket (18 cm high with a 13 cm diameter, and a basket hole size of 5 mm diameter) and placed into a thermostatically controlled water bath (Grant W14, UK) using tap water. The blanching temperatures studied were 60, 65, 70, 75, 80, 90 and 100 °C. Samples of three potatoes were taken every 5 min up to 60 min blanching time and were immediately cooled for 5 min in ice water before any texture analysis.

2.2. Texture measurement after blanching

Blanched potato texture was measured using an Instron Universal Testing Machine (4464). Generally, when the texture of potatoes is being investigated, regular shaped samples either cubes or cylinders are removed from potato for heat treatments and subsequent texture measurement. Using whole potato as an experimental unit during texture measurement has not been investigated before. In the case of new potatoes, sampling whole is possible with low variations since the potatoes are generally uniform in shape. To facilitate consistent texture analysis two thin longitudinal sections from bud end to stem end were taken, so that the potato would sit steadily on the platform throughout the test and avoid excessive movement during the test. Also, this method allowed for identifying the position of the cortex and the pith and the subsequent measurement of the texture of each area separately. The potato sample, resting
on its side on the stainless steel platform, was punctured using a 7 mm-diameter probe at a cross-head speed set at 200 mm/min. Using a load cell of 500 N, four puncture tests were performed per each whole potato to cover different parts of the potato structure (see Fig. 1), and each puncture test accounted for over than 90% of the potato thickness. This texture method allowed for multiple measurements per sample thus allowing testing for significant differences over the whole potato sample. A plot of force (kN) against displacement (mm) was produced by the Instron Series IX software and maximum puncture force (kN) was recorded.

2.3. Texture measurement after processing

Blanched potato samples were subsequently processed at 95 °C or 100 °C for times ranging from 5 to 25 min. The texture of the processed sample was measured by shearing using a single blade, 1 mm thick, attached to the cross-head of the Instron Testing Machine. The processed whole potato with its skin intact was placed on the steel platform of the Instron and sheared longitudinally to a depth of 25 mm at a cross-head speed of 50 mm/min. Maximum shear force (kN) was calculated from the plot of force against displacement.

2.4. Pectin methyl esterase (PME) activity determination

PME activity was determined for samples blanched as described previously at 65, 75, 80 and 90 °C for times of 5, 10, 15, 20, 25 and 30 min. PME activity in raw potatoes was also determined. The method of Tijskens, Waldron, Ng, Ingham, and Van Dijk (1997) for determining PME activity in potatoes was applied to this study. A cubed sample of approximately 1 cm³ was cut from the centre of the potato for PME extraction. For blanched samples the potatoes were plunged into ice water for 1 min to cool, then a cube was cut from the centre and again placed into ice water to further cool before freezing. This cube was finely chopped and placed into a glass vial for freeze-drying. The sample was then frozen with liquid N₂ and freeze-dried over night. The freeze-dried sample was finely ground in a pestle and mortar and placed into an airtight container.

The sample (30 mg) was weighed out into a centrifuge tube. Ice-cold water (1 ml) was added to the tube and stirred continuously with a magnetic stirrer for an hour at 1–4 °C using an ice-bath. This mixture was then centrifuged at 10,000 × g for 3 min at 4 °C. The supernatant was removed and ice-cold 1 M NaCl (1 ml) was added to the tube. This was stirred continuously for a further hour at 1–4 °C. Following re-centrifugation at 10,000 × g for 3 min the supernatant containing the enzyme was recovered for activity determination. Pectin assay solution (2.9 ml) was added to 3 ml cuvettes and they were flooded with O₂-free N₂ and covered with parafilm. The supernatant recovered (100 µl) was added to the cuvette and the absorbance was followed at 616 nm using a UV-Spectrophotometer (Milton Roy spectronic 1201, UK) for 1 min. Activity was expressed in µmol/min/g (dry weight).

3. Results and discussion

3.1. Texture analysis of blanched new potatoes

An initial study was conducted to determine any significant differences in texture between the pith and the cortex upon the application of a range of processing treatments. Puncture testing for raw, intermediately processed and fully processed potatoes showed that there was no significant difference between the cortex and the pith with respect to texture (P < 0.05). This was expected since it is only as the potatoes mature that the cortex and the pith begin to differentiate in terms of composition.

The blanching temperatures studied were 60, 65, 70, 75, 80, 90 and 100 °C. This range covered both the low blanching temperatures (60–75 °C) and the conventional blanching temperatures (80–100 °C) so that their effect on texture could be compared.

Generally, texture measurements are taken after the processing stage for samples that have undergone a blanching treatment, but not directly after the blanching stage itself. As a result, the contribution of blanching to changes in texture upon processing is not clear.

Fig. 2 illustrates the texture degradation profile for the blanching temperatures studied. The most rapid degradation occurred at 100 °C, whereby very little changes in texture were recorded after 20 min of blanching. This temperature is the normal cooking temperature when boiling potatoes and so the degradation profile at 100 °C is a representation of the structural breakdown...
that typically occurs when cooking potatoes in a domestic situation. There was also a rapid loss of texture when blanching at 90 °C and as seen from Fig. 2, force readings became minimal after 40 min. At 80 °C a less rapid decrease in firmness than at 90 and 100 °C was observed, although still more rapid than temperatures over the range of 60–75 °C.

Over the 60 min blanching period at 100 °C there is a 96% loss in firmness as compared to raw potatoes, 84% when blanching at 90 °C and 67% when blanching at 80 °C.

For the blanching temperatures within the range of 60–75 °C, changes in texture were minimal and accounted for less than 20% of the initial raw texture value. The results illustrated in Fig. 2 exhibit similar trend to those reported by Fuchigami, Miyazaki, and Hyakumoto (1995) for carrots and Spiess, Gierschner, and Grunewald (1987) for potatoes.

Analysis of the blanching temperatures using ANOVA showed that these temperatures could be grouped according to their effect on texture. The mean texture values at 60–70 °C were significantly different to those at 80 °C ($P = 0.0027$). Texture values obtained at 80 °C were significantly different from those at 90 and 100 °C ($P < 0.05$). There was a significant difference between 90 and 100 °C for up to 15 min blanching ($P > 0.05$), however, after these times the effect become significant ($P < 0.05$). Accordingly, blanching temperatures could be grouped into those, which caused minimal degradation (60–75 °C), those, which caused intermediate degradation (80 °C) and those, which caused rapid degradation (90–100 °C).

### 3.2. Analysis of pectin methyl esterase activity during blanching

PME activity at blanching temperatures of 65, 75, 80 and 90 °C was investigated to determine if PME activity at these temperatures could be related to patterns of texture degradation observed during blanching. Fig. 3 shows that PME is activated when blanching at both 65 and 75 °C but is rapidly inactivated at 75 °C after 10 min and at 80 and 90 °C after 5 min. There was a significant effect of blanching temperature on PME activity ($P < 0.05$). The observed activity at blanching temperatures of 65 °C and 75 °C was significantly different ($P = 0.03$), as is the activity at 65 °C and 80 °C ($P = 0.00034$) and 65 °C and 90 °C ($P = 0.00031$). However, differences were not significant when PME activities were compared at 75 °C and 80 °C ($P = 0.157$) or at 75 °C and 90 °C ($P = 0.189$). Such behaviour was in agreement with the observations of Andersson et al. (1994) that PME is rapidly inactivated above 70 °C. As Fig. 3 shows an initial decrease in activity at 5 min followed by an increase in activity for 65 °C and 75 °C. This decrease could be due to the fact that the sample was taken from the centre of the potato and the potato core had not reached the applied soaking temperature within 5 min and subsequently PME was not fully activated (Gonzalez-Martinez, Ahnre, Gekas, & Sjoholm, 2004). At all of the temperatures tested, activity is seen to eventually decline rapidly at higher temperatures (80 and 90 °C). Tijskens et al. (1997) reported that the activity of PME decreases with time at the different blanching temperatures used in their study for potatoes and carrots. They also noted that heat resistant activity, that is, an activity that remains after treatment, seems not to exist as the observed activity at all temperatures tended to decrease to zero. This implies that the enzyme can be denatured completely at each temperature, provided there is sufficient time. Optimum activities reported for PME in different studies varies due to variations in composition and variety, however all reported values lie in the range of 50–70 °C. Optimum activity for PME in this study was observed at 65 °C after 15 min blanching period.
At 75°C there was a rapid fall off in activity after 10 min with complete inactivation after 20 min blanching. At the higher temperatures of 80°C and 90°C inactivation was rapid after 5 min. The findings that PME was rapidly inactivated at 75°C and higher agrees with the findings in the literature (Andersson et al., 1994; Fuchigami et al., 1995; Moreno-Perez, Gasson-Lara, & Ortega-Rivas, 1996).

3.3. Texture analysis of processed whole new potatoes

The aim of this section was to investigate the behaviour of the potatoes when further heat treatment is applied. This step represents further processing of potatoes after blanching (as would be carried out in the industry) and to include processing of the potatoes with and without a pre-processing treatment. Processing temperatures of 95°C and 100°C were chosen using times of 5 up to 25 min as initial studies showed that no major structural degradation took place upon processing at times exceeding 25 min. Processing was carried by immersion in water at the required processing temperature as this was the common method used by potato processors contacted for this study. Fig. 4 shows shear force values versus time for the studied treatments in which it is evident that low temperature blanching improve the texture of the potato after processing. The average shear force for a fully processed edible new potato was found to be in the range of 3 N. This value was obtained using a commercial minimally processed product of new potatoes after following the recommended cooking instructions.

In order for various comparisons to be made, the texture of potatoes that underwent several treatments was measured by shearing as shown in Table 1.

The combination of a single blanching treatment and a two step treatment allow the effect of a pre-processing step on the texture of the processed product to be compared with the texture of potatoes processed without a pre-treatment.

Blanching temperatures of 65°C and 75°C were chosen since these temperatures produced minimal texture degradation of potatoes during blanching. Although the appropriate temperature for blanching appeared to
be 65 °C, since this is the temperature where PME has its optimum activity, it was necessary to include 75 °C as well. This was done to determine whether the higher level of PME activity at 65 °C would result in a firmer potato after processing compared with a potato pre-treated at 75 °C, where PME activity was lower.

The texture values for blanching at 65 °C and 75 °C are shown in Fig. 5 and those for processing (with no pre-treatment) at 90, 95 and 100 °C are shown in Fig. 6. A processing temperature of 90 °C is shown purely for comparison. Maximum shear force was taken to be indicative of the fracture point of the potatoes.

It can be seen from Fig. 5 that shear force at 65 °C generally increases with increasing blanching time. However, at 75 °C shear force increases up to 15 min blanching time then decreases after 20 min and levels off. This is consistent with the findings for PME activity at 75 °C, i.e. PME activity falls off after 10 min at 75 °C and is completely inactivated after 15 min. The increase in shear values at 65 °C may be due to the fact that the firming effect of the PME strengthens the structure of the potato making it firmer and it continues to have a firming effect as blanching time increases. This is reflected in the PME activity at 65 °C which shows PME activity increasing as blanching time increases up to 15 min then dropping off slightly at 20 min, but continuing to remain active up to 30 min. However, despite the slight difference in the behaviour of the potato at blanching temperatures of 65 °C and 75 °C there was no significant difference found between shear force values for these temperatures (P < 0.05).

From Fig. 6 it is apparent that significant texture degradation had taken place at the higher temperatures of 90, 95 and 100 °C compared to the degradation profile seen in Fig. 5. As seen before the use of higher blanching temperatures results in a greater and more rapid loss of structure than the use of low blanching temperatures such as 65 °C and 75 °C, where the change in texture is almost negligible. The change in texture at 90, 95 and 100 °C represents a loss of firmness of 71.55%, 82.19% and 84.37% respectively, compared to the raw potato.

This compares to an overall increase in firmness for temperatures of 65 °C (54.79% increase) and 75 °C (16.44 increase), over the 30 min blanching period. Other authors reported this phenomenon, i.e. an increase in firmness to values greater than those for raw or fresh samples (Truong, Walter, & Bett, 1998).

Figs. 7 and 8 show the trends for texture degradation (indicated by a decrease in shear force with time) when potatoes are processed with no pre-treatment (95 and 100 °C) and with a pre-treatment (blanching at 65 and 75 °C followed by processing at 95 or 100 °C). The difference in the behaviour of the potato when processed at 95 compared to 100 °C (without any pre-treatment) is clear. Even though the temperature difference is only 5 °C the loss of firmness at 100 °C over 25 min is much more rapid than at 95 °C over the same time period. It takes 20 min at 95 °C to reach a stage where texture changes are minimal compared to only 10 min at 100 °C. In addition, it would appear from Figs. 7 and 8 that using a pre-treatment does improve the texture of the potato after processing and therefore gives a firmer end product.

### Table 1
Treatments applied prior to texture measurement of whole new potatoes

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Blanching temperature (°C)</th>
<th>Blanching time (min)</th>
<th>Processing temperature (°C)</th>
<th>Processing time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Blanched</td>
<td>65 and 75</td>
<td>5–30</td>
<td>95 and 100</td>
<td>5–30</td>
</tr>
<tr>
<td>Processed</td>
<td>None</td>
<td>None</td>
<td>95 and 100</td>
<td>5–25</td>
</tr>
<tr>
<td>Blanched</td>
<td>65</td>
<td>5–30</td>
<td>95 and 100</td>
<td>5–25</td>
</tr>
<tr>
<td>and processed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blanched</td>
<td>75</td>
<td>5–30</td>
<td>95 or 100</td>
<td>5–25</td>
</tr>
</tbody>
</table>

![Fig. 5. Maximum shear force profile for potatoes blanched at 65 and 75 °C.](image-url)
An analysis of variance (ANOVA) was applied to the obtained shear force values in order to investigate whether there was a significant difference in the final texture of the processed potato when blanching temperature of 65 °C is compared to 75 °C, if the processing temperature used have a significant effect on the final

Fig. 6. Maximum shear force profile for potatoes blanched at 90, 95 and 100 °C.

Fig. 7. (a) Maximum shear force values for potatoes blanched at 65 °C followed by processing at 95 °C. (b) Maximum shear force values for potatoes blanched at 65 °C followed by processing at 100 °C.
texture, and if there is a significant difference between firmness of the processed product in the absence or presence of a pre-treatment.

Upon investigating the effect that blanching temperatures used (65 and 70 °C) had on the texture after processing, a significant difference \( (P < 0.05) \) was found between the firmness of potatoes blanched at 65 °C then processed at 95 °C and those blanched at 75 °C and processed at 95 °C. The same was applicable for potatoes blanched and then processed at 100 °C. Samples blanched at 65 °C gave a firmer product than those at 75 °C after processing for both processing temperatures. An interesting observation is that when texture was measured after blanching, i.e. before processing, there was no significant difference between shear force values for 65 and 75 °C \( (P > 0.05) \). So, it would appear from this that the firming effect of low temperature blanching only becomes evident after processing. This agrees with the findings of Wu and Chang (1990) whereby the firmness of broccoli and asparagus was enhanced when processing was preceded by a blanching step.

The fact that blanching at 65 °C gives higher shear force values after processing at both 95 and 100 °C than blanching at 75 °C may be related to PME activity at these temperatures since PME has its optimum activity at 65 °C and in fact had higher levels of activity at 65 °C for all times after 5 min. Wu and Chang (1990) reported that the blanching temperatures which gave the best firmness after processing for each vegetable corresponded to the temperature for optimum PME activity for each vegetable, implying a relationship between PME activity and improved firmness after processing.

Although blanching at 65 °C before processing produced a potato that was significantly firmer than that pre-processed at 75 °C, it did not actually produce a product that was significantly different to that processed at 100 °C with no pre-treatment \( (P > 0.05) \). Despite this, there was a difference in the potatoes that received a pre-treatment compared to those that had not, from a visual perspective. Potatoes processed at 100 °C with no pre-treatment began to disintegrate rapidly after 10 min processing. The skins began to wrinkle and become loose.
(detach from the flesh of the potato), sometimes coming off with the least amount of friction. Often the potatoes would have small pieces missing or hanging off when they were removed from the processing water prior to texture measurement. On the other hand, potatoes that had received a pre-blanch at 65 °C did not disintegrate at any time during the processing, even after 25 min. Their skins remained intact and the flesh remained firm.

It would appear that blanching at 65 °C before processing at 100 °C has the effect of enabling the potato tissue to withstand the thermal effect of such a high temperature for longer than if there had been no pre-treatment. The observations made during the blanching and processing experiments at 75 °C as the blanching temperature were not the same as for 65 °C. The potatoes still tended to disintegrate and the skins to wrinkle after 15 min at 100 °C and 20 min at 95 °C, particularly when the longer blanching times at 75 °C were used. This would point to the fact that a pre-blanching temperature of 75 °C does not lead to any significant improvement in the quality of the processed potato, be it firmness or appearance or suitability to further processing, unlike blanching at 65 °C.

Shear force values for potatoes that have been pre-blanched at 65 °C are mostly higher than that for potatoes pre-blanched at 75 °C at all blanching times and for both processing temperatures (Fig. 8a and b). In contrast to the firming effect brought about by a pre-treatment at 65 °C, a pre-treatment at 75 °C seems to have no effect. There was no significant difference in texture when a 75 °C pre-treatment is used prior to processing at 95 °C or 100 °C for any blanching time compared to processing without a pre-treatment at 95 °C and 100 °C.

At 75 °C, the fact that PME reaches its optimum activity at 15 min and is, thereafter, rapidly inactivated, means that the structure of the potato tissue is not sufficiently strengthened or reinforced to withstand further textural degradation at high processing temperatures.

There is a significant difference between the texture of potatoes processed at 90 °C without a pre-treatment and those receiving a blanching step at 65 °C for 15, 20, 25 and 30 min. This corresponds to the times when PME has its optimum activity at 65 °C and may provide evidence for the relationship between PME and this firming effect. If this is the case then the reason that there is no significant difference at 65 °C for 5 and 10 min could be due to lack of complete heat penetration into whole potato at these times because of thermal lag, resulting in incomplete activation of PME.

4. Conclusion

Using a low temperature pre-treatment; 65 °C, in combination with a typical high processing temperature range such as 95–100 °C, resulted in an increase in the force required to shear whole new potatoes as compared with processing treatments without a pre-blanching step. Moreover, this study indicated that a pre-treatment at 65 °C resulted in a high quality end product whereby skins of the potato remained intact and the flesh remained firm even after 25 min of processing at 100 °C. Although there was no significant difference (P > 0.05) in recorded texture measurements for potatoes blanched at 65 °C and at 75 °C, however, upon processing at 100 °C for both blanching temperatures, potatoes that were blanched at 65 °C showed significantly firmer texture (P < 0.05) than those blanched at 75 °C. The activity of PME increased when blanching was carried out at 65 °C and resulted in subsequent strengthening in the potato structure upon further processing as it appears that the firming effect of low temperature blanching only becomes evident after processing. It is proposed that the treatments studied in this work enhance the potato elasticity thus making it less breakable and more suitable for further processing such as the inclusion in potato based minimally processed products.

References


