Effect of Blanching on Structural Quality of Dried Potato Slices

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Mechanical properties of potato slices were monitored during blanching, as indicators of structural changes. As expected, blanching resulted in weakening of potato structure. Gelatinization, which occurred during the first 2 min, did not promote an immediate weakening of the potato tissue. More than 80% of the changes in mechanical properties occurred during the first 30 min of blanching. Potato slices blanched for 2 and 30 min as well as unblanched ones were dried in a convective air drier at 48 °C. Bulk and true density, porosity, and shrinkage were monitored with time. Blanched potatoes resulted in a significantly more compact, less porous product with lower effective water diffusivity than unblanched potatoes. The results indicated that changes that occurred during the first 2 min of blanching had a much greater influence on structural quality of dried potatoes than changes that occurred from 2 to 30 min of blanching.

Keywords: *Potato; drying; blanching; structure*

INTRODUCTION

There is a demand for high-quality dehydrated shelf-stable foods for convenient, quick-cooking dishes for home consumption as well as for manufacturers. In particular, dried potatoes are being studied as a source of carbohydrates, alternative to pasta or rice, for food systems such as instant soups or salads. In this kind of system, the quality of dried potatoes depends mainly on their structural properties, since texture is one of the most important sensory attributes (van Marle et al., 1997a).

Much research has been conducted in the past to control the quality of dried potatoes. Most of this research has been focused on the study of the drying operation itself. Recently, Magee and Wilkinson (1992), Wang and Brennan (1996), Iciek and Krysiak (1995), and Zogzas et al. (1994) studied the effect of various parameters of convective drying (temperature, air velocity, air humidity, flow direction) on potato quality. Isiek and Krysiak (1993) and Bouraoui et al. (1994) compared the effects of both convective and microwave drying also on potato quality. Mudahar et al. (1990) optimized the convective drying operation to obtain high-quality dried potatoes using response-surface methodology.

The quality of dried food products depends not only on the drying process itself but also on the various steps of the whole process chain. Structural changes occurring during some of these steps (for example, during transport or as a consequence of pretreatments) could have an important influence on the final quality of the products. Moreno-Perez et al. (1996) found that a low-temperature blanching (60−70 °C) before conventional blanching (94 °C) increased firmness and hardness of rehydrated sweet potato. Mazza (1983) concluded that blanching increased the rate of drying of carrots but treating the carrots prior to drying with starch or sulfite solutions did not have any effect. Eshtiaghi et al. (1994) compared the effect of high pressure and freezing as pretreatments on potato drying. They showed that freezing had a significant influence on decreasing the drying rate and on increasing the amount of water rehydrated.

Blanching is an operation previous to drying that is performed on potatoes and other vegetables to denature enzymes responsible for commercially unacceptable darkening and off-flavors (Burr and Reeve, 1973). Potatoes are blanched in the industry by heating with hot water or steam. Blanching temperatures vary between 93 and 100 °C and blanching times between 2 and 12 min depending on the blanching temperature and the piece size (Talburt and Kueneman, 1987). Alternative to a heat treatment are chemical treatments such as the addition of sulfite or sulfur amino acids on the surface (Molnar-Perl and Friedman, 1990).

Consequences of blanching by heating are loss of soluble solids (Tomasula et al., 1990), enzyme denaturation, air removal from the tissue, hydrolysis and solubilization of structural polymers such as protopectin (Bourne, 1976; van Marle et al., 1997b), and gelatinization of starch granules that results in swelling to several times the original granule size (Olkku and Rha, 1978). These consequences make the internal structure of blanched potato different from that of the unblanched one. These structural changes likely influence the quality of the dried product. If the relationship between structural changes during blanching and final quality is known, blanching could be used not only to avoid darkening and off-flavors but also to provide the structural changes required for textural quality.

Therefore, there is a potential improvement of the properties of dried food products by manipulating operations other than drying itself. The objective of the research presented in this paper was to quantify the effect of blanching on the structural quality of potato slices. Two tasks were accomplished: (1) characterization of structural changes during blanching and (2) identification of the effects of those changes on the structural quality of the dried product.

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S0021-8561(97)00671-7 CCC: $15.00
Published on Web 01/23/1998

MATERIALS AND METHODS

Materials. Potatoes variety *accent* were obtained from a local farm and stored at 7 °C, 95% RH, and in the dark during the 3 months during which the experiments were carried out. Potatoes were peeled and cut in slices perpendicularly to the main axis of the whole tuber. The slice dimensions were 4 cm of diameter and 0.8 cm of thickness. Slice weights were measured, and only those in the 9.5−10.5 g range were used in the experiments.

Blanching. Blanching was carried out by placing the potato slices in dionized water at 90 °C for various times. After this, the treated samples were cooled down in cold water.

Compression Test. Stress and strain at break in uniaxial compression of potato cylinders were carried out in an Overload Dynamics type S900 (Overload Dynamics, Schiedam, NL) with a 200N sensor load and 10 mm/min head speed. Cylindrical samples 0.8 cm in diameter obtained from blanched and unblanched potato slices were used for the compression tests. At least five replicates were used in each measurement.

Glucose and Moisture Content. Glucose loss from potato slices during blanching was calculated by measuring the glucose content of the blanching water (using the enzymatic essay described by Kunst et al., 1984) and performing a material balance. Two replicates were measured for each sample. Moisture of the potato slices was determined by drying during 48 h in a 85 °C vacuum oven at 6665 Pa (50 mmHg) pressure. Four replicates (one potato slice/replication) were used in each analysis.

Gelatinization of Starch Granules. The occurrence of gelatinization of the starch granules was determined by loss of birefringence in polarized light. An optical microscope with cross-polarizers was used for this determination.

Drying. Unblanched potato slices as well as blanched (for 2 and 30 min) ones were dried in a convective air drier Brabender Realtest type KSF 250/OR (Duisburg, Germany). Potato slices were placed on a screen inside the drier so that air was forced to circulate over and under the slices. Consequently, drying could be assumed to occur in one dimension, perpendicular to the air flow. The drying conditions were 48 °C, 10% RH, and 3.5 m/s air velocity. A total of 30 potatoes slices were dried simultaneously for a maximum of 17 h. Samples were drawn periodically from the drier to monitor structural properties and water content.

Bulk Density. Samples were first weighed and then their volumes were measured by volume displacement using *n*-heptane. An experimental apparatus for volume measurement similar to the one described by Zogzas et al. (1994) was used. Six potato slices grouped in two, three, or six replications were used in each bulk density determination. Grouping of samples was done to assure similar volumes in each bulk density sample. Since volumes of the potato slices decreased with time, the number of slices per group increased with drying time.

True Density. Samples used for bulk density were also used for true density because *n*-heptane could be removed by evaporation very quickly. Samples were ground in a coffee grinder Braun type 4041 (Mexico) for 1 min, and then a known amount was placed in an air pycnometer Beckman model 930 (Beckman Instruments Inc., Fullerton, CA) to determine true density. Two replicates were performed for each sample.

Porosity. Porosity can be defined as the volume of air over the total volume, that is:

$$\epsilon = \frac{V_a}{V_s + V_w + V_a} \tag{1}$$

Porosity can also be defined in terms of true and bulk density:

$$\epsilon = 1 - \frac{\rho_b}{\rho_t} \tag{2}$$

This formula was used for calculating the porosity of the samples.

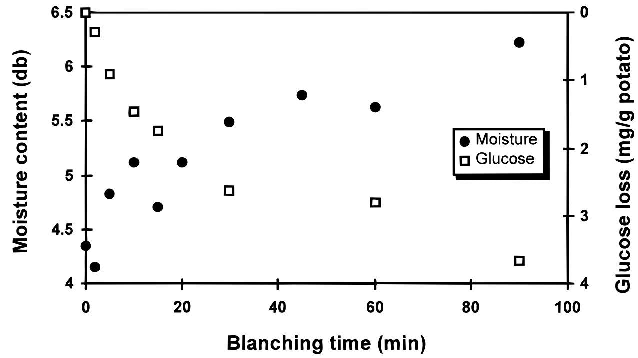

Figure 1. Effect of blanching time on moisture content and glucose loss from potato slices (g potato referred to initial potato weight in wet basis).

Thickness, Diameter, and Volume Shrinkage. Thickness, diameter, and volume shrinkage are defined as $L(t)/L_0$, $\phi(t)/\phi_0$, $V(t)/V_0$, respectively. Diameter and thickness of the slices at different drying times were measured using a caliper and a micrometer (Mitutoyo No. 7305, Japan), respectively. Perez and Calvelo (1984) and Wang and Brenman (1995) expressed volume shrinkage in terms of bulk density and the water content as follows:

$$\frac{V(t)}{V_0} = \frac{\rho_{bo}(1 - W_o)}{\rho_b(1 - W)} = \frac{\rho_{bo}(1 + M)}{\rho_b(1 + M_o)} \tag{3}$$

This formula was used to calculate volume shrinkage during drying of the different samples.

RESULTS AND DISCUSSION

Effect of Blanching on Structure of the Potato. Potato slices were blanched for various times. Analysis showed that there was a significant water uptake during blanching as well as loss of glucose from the potato tissue (Figure 1). Glucose was measured as an indicator of soluble solids that were leaking out of the slices during the treatment.

Centers of the blanched potatoes were analyzed for gelatinized starch at different blanching times. Birefringence was not observed in any of the samples but the unblanched ones. It can be concluded that gelatinization took place in the whole slice during the first 2 min of blanching. In addition, blanched potatoes were left overnight at room temperature to observe visually the development of any darkening. Since no darkening occurred after 2 min blanching as opposed to unblanched slices, denaturation of the enzymes responsible for darkening was considered to be complete in the whole slice after that time.

The previously described changes in the potato tissue as well as other important ones such as the depolymerization and solubilization of pectin materials (Bourne, 1976; van Marle et al., 1997b) have an important influence on the structure of the blanched potatoes. This is reflected in changes in their mechanical properties, particularly in its flexibility and strength. This was quantified by strain and stress at break in a compression test.

As expected, there was a decrease in strain at break as a consequence of blanching (Figure 2), showing that the tissue became less flexible. In addition, stress at break as well as the ratio stress/strain at break (Figures 3 and 4) decreased with blanching time, showing a decreased potato tissue strength. After 45 min, strain at break decreased to almost 30% of the initial value.

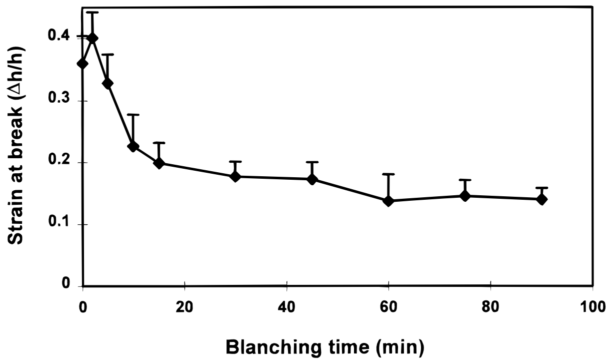

Figure 2. Effect of blanching on strain at break in a compression test (h = height of sample). Bars represent standard deviations.

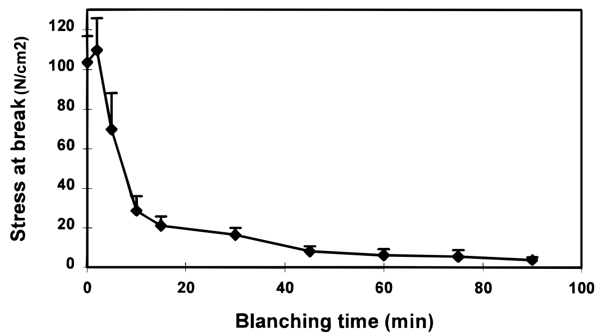

Figure 3. Effect of blanching on stress at break in a compression test. Bars represent standard deviations.

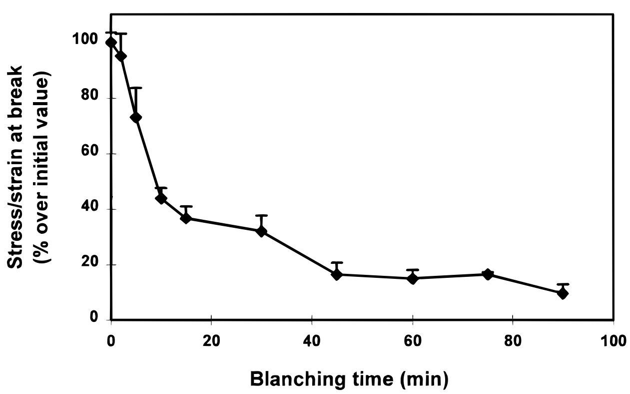

Figure 4. Effect of blanching on the ratio stress/strain at break in a compression test. Bars represent standard deviations.

The loss of strength was more dramatic, since stress at break after blanching for 45 min was less than 10% of the initial value. Note that >80% of the changes in the mechanical properties occurred in the first 30 min. Spiess et al. (1987) also reported that most of the changes in shear stress of potato slices blanched at 90 °C occurred during the first 30 min.

It is also interesting to note that both stress and strain at break increased after 2 min. Even though they were not found to be significantly different from stress and strain of the unblanched product (t-test, $p < 0.05$), they were out of the trend (weakening and loss of flexibility with blanching time). However, the ratio stress/strain at break decreased during the same blanching time (Figure 4). The increased strain at break indicates that the tissue became more flexible during the first 2 min of blanching. The fact that the ratio stress/strain at break decreased indicates that the tissue became less strong despite the absolute increase in stress at break. More stress was required to break the tissue because the elongation was longer, not because the tissue was stronger.

Moreno-Perez et al. (1996) found an increase in strength of sweet potato after a moderate heat treatment. They attributed this effect to the action of pectin methylesterase in low-temperature–long-time blanching. This enzyme, once activated for the moderate heat treatment, could demethylate cell pectins, which may result in the formation of insoluble pectins with the consequent reinforcement of cellular structure. In our case, since we used higher blanching temperatures, those enzymes were probably inactivated. It is possible that the water taken up during the first 2 min resulted in a plasticizing of the tissue so elongation at break was longer. Another possibility is that the gelatinization of the starch, which occurred within the first 2 min, made the potato tissue more flexible.

It is important to note that the gelatinization of starch did not promote an immediate weakening of the tissue. Other phenomena such as hydrolysis and solubilization of cell wall polymers as well as loss of turgor pressure due to the death of cells are likely causes of the observed decreased in flexibility and strength after 2 min.

Effect of Blanching on Quality of Dried Potatoes. Unblanched slices together with potatoes blanched for 2 and 30 min were dried and their structural characteristics compared. Two minutes was considered the minimum blanching time to avoid darkening, and from a structural point of view, gelatinization of starch granules took place all over the tissue. Thirty minutes of blanching represented an extreme treatment in which most of the chemical and structural changes have occurred as it was shown by the analysis of the mechanical properties.

Drying Kinetics. The rate of drying decreased with time from the beginning in all treatments; therefore, no constant rate period was observed in any sample. However, it is likely that there was a short constant rate period (in which the surface of the potato was saturated with water) but before taking the first sample after 2 h drying. After this time, internal diffusion was the mechanism that dominated the dehydration, and as consequence the drying rate was decreasing with time.

M_{eq} was considered to be achieved after 17 h drying. Potatoes that were blanched for 30 min had lower M_{eq} (7% db) than potatoes blanched for 2 min (9.5% db) or unblanched potatoes (9.6% db). The changes that happened after 2 min, particularly the loss in soluble solids, have likely affected the composition of the potatoes so drying could have been more intense. Figure 5 shows the moisture content of the sample during drying in terms as the dimensionless M^* defined as:

$$M^* = \frac{M_{ave} - M_{equ}}{M_o - M_{equ}} \quad (4)$$

If the slices are considered as infinite slabs, when $M^* < 0.6$ the following formula could be applied to describe the loss of moisture (Aguilera and Stanley, 1990):

$$M^* = \frac{8}{\pi^2} \exp\left(-\frac{\pi^2 D_{eff} t}{L^2}\right) \quad (5)$$

In Figure 5 the slope of the lines is proportional to the effective diffusivity (D_{eff}). Unblanched potatoes had the

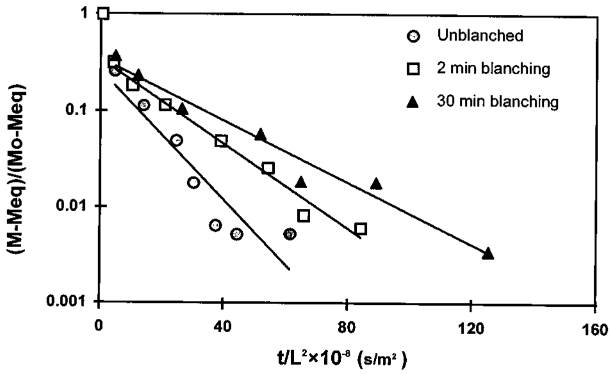

Figure 5. Effect of blanching on drying kinetics. Dimensionless moisture content vs the ratio of drying time over square thickness is plotted.

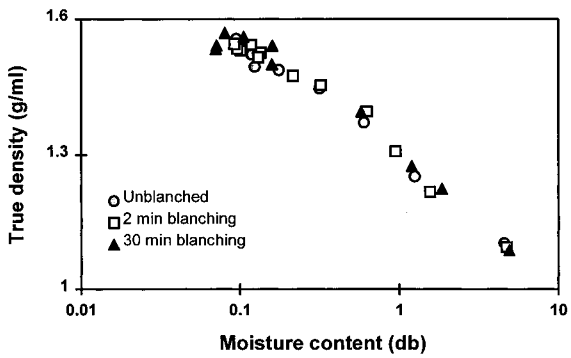

Figure 6. Effect of blanching on true density of potato slices during drying.

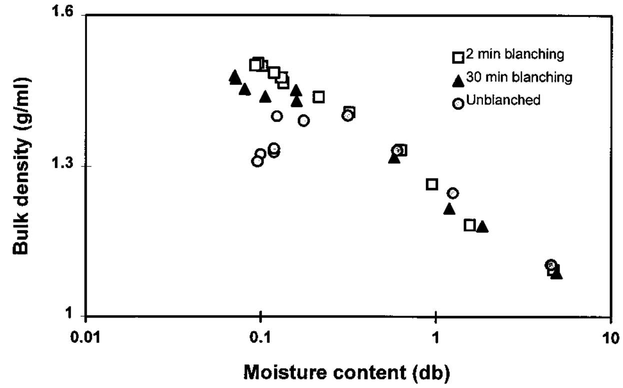

Figure 7. Effect of blanching on bulk density of potato slices during drying.

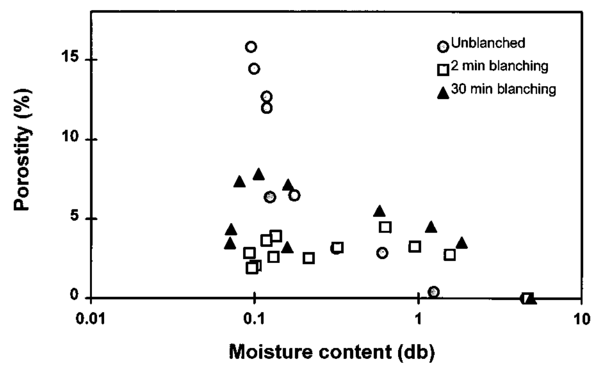

Figure 8. Effect of blanching on porosity of potato slices during drying.

highest slope, and as a consequence, the calculated D_{eff} for unblanched potatoes (7.86×10^{-11} m^2/s) was higher than the one for 2 min blanching (5.12×10^{-11} m^2/s) or 30 min blanching (3.74×10^{-11} m^2/s).

The fact that the difference in D_{eff} is larger between unblanched and blanched samples than between both blanching treatments indicates that changes of structure that affected water diffusivity were more important during the first 2 min than after that period. Gelatinization seems to affect more the mobility of water during drying than the other structural changes that made the potato tissue weaker and less flexible. Marousis et al. (1991) also found that gelatinization reduced water diffusivity of granular corn starches.

True Density, Bulk Density, and Porosity. True density decreased slightly with blanching time, reflecting loss of soluble solids and water uptake during this treatment, since the density of solids is higher than the density of water (Figure 6). For the same reason, the true density of the potato slices increased with drying time, regardless treatment, because of the decreased water content. No significant differences between treatments were appreciated (Figure 6).

For all samples before drying, bulk density was found to be identical to true density because the internal air content (and so the porosity) was negligible. Once drying started, there was shrinkage of the structure as water left the system and at the same time air-filled pores started to form. Bulk density increased in all samples with drying time, indicating that collapse of the potato structure was more important that the formation of pores (Figure 7). The bulk density of unblanched potatoes increased until the moisture content was about 0.12 (db). Then, it decreased as drying continued (Figure 7). This indicates that structure collapse ended. Thus, the volume of the samples did not change with further loss of water, resulting in an increased porosity (Figure 8). On the other hand, bulk density of both blanching treatments increased steadily with decreased water content, showing that collapse of the structure did not end during the drying time.

The evolution of both true and bulk density with moisture content affected porosity. The porosity of unblanched potato remained below 5% until the end of the structure collapse ($M \approx 0.12$). Then, there was a sudden increase up to 15%. This increase in porosity did not occur in blanched samples. In this case, porosity increased during the first 3 h, and then it did not vary significantly with decreased moisture content, as indicated by the ANOVA of a regression analysis with $p < 0.05$. The average porosities of 30 and 2 min blanched samples were found to be 5.2 and 3.0%, respectively. By performing a t-test, they were found to be significantly different ($p < 0.05$).

The effect of air drying on density and porosity of foodstuffs has been reported in the past. Continuous structure collapse during drying (and the resulting continuous increase in bulk density) was reported for carrots, pears, and garlic (Lozano et al., 1983) and celery (Karathanos et al., 1993). A limited structure collapse was reported for both unblanched potato and sweet potato (Lozano et al., 1983; Wang and Brennan, 1995), which confirms our finding. Karathanos et al. (1993) attributed the structure collapse to the high mobility of the matrix composed of water and soluble solids within the cell wall polymer, when the temperature was above the glass transition temperature (T_g). When the temperature is above T_g the system is in the rubbery state and structural changes, including structural collapse, may occur. On the other hand, if the temperature

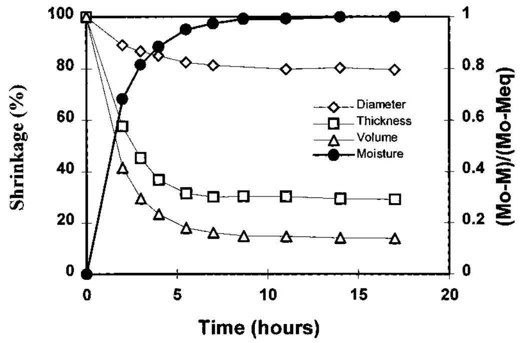

Figure 9. Effect of drying on diameter, thickness, and volume shrinkage in potatoes blanched for 2 min.

is below T_g the system is in the glassy state and no structure collapse occurs (Karel, 1991). During drying, as water leaves the system, the glass transition temperature increases, because of the decreased plasticizing effect of the water. In our case, for unblanched potatoes, once $M < 0.12$, structure collapse stopped and so likely $T_g > T_{drying}$. For blanched potatoes (both treatments), since structure collapse did not stop, probably $T_g < T_{drying}$ during the whole drying process.

The main difference between the structure of blanched potatoes (2 or 30 min) and the unblanched ones is the gelatinization of the starch granules. The fact that starch crystals turned into an amorphous state and the consequence swelling of starch granules likely made the curve T_g vs M shift down. Decreased T_g with decreased crystallinity in amylopectine gels (at equal M) has been reported by Kalichevsky et al. (1992). Then, as a consequence of starch gelatinization, $T_g < T_{drying}$ during all drying times despite the decrease in water content. Other changes, such as loss of soluble solids or hydrolysis of pectin materials that continued from 2 to 30 min blanching did not affect as much the density and porosity, since both blanching treatments have similar tendencies.

Shrinkage. Shrinkage of 2 min blanched slices is shown in Figure 9. Shrinkage of unblanched and 30 min blanched potatoes were very similar to shrinkage of 2 min blanched potatoes, and therefore, the respective figures were not included in this paper. Most of the shrinkage happened in the first 5 h as most of the water was leaving the system. Shrinkage is directly related to water loss. As expected, in all samples, thickness shrinkage was more important than diameter shrinkage, since drying occurred mainly in the direction of the thickness. Initial volume was reduced to 13% in both blanching treatments and to 17% in the case of unblanched potatoes (Figure 10). Final thickness of unblanched potatoes was relatively higher than that of blanched ones and final diameter was relatively lower (Figure 10), which had an important influence on the final shape. This different shrinkage behavior in blanched and unblanched potatoes, regardless of blanching time, also reflected different internal structure.

CONCLUSIONS

During the first 2 min of blanching, enzymes responsible for potato darkening were inactivated and at the same time starch gelatinization took place. This gelatinization, although it did not weaken the nondried potato, made changes in the structure that significantly affected properties of the dried product. Blanched potatoes resulted in a significantly more compact, more

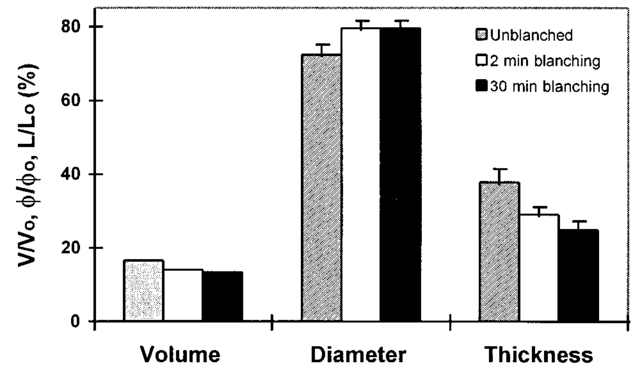

Figure 10. Effect of 17 h drying on the reduction of volume, diameter, and thickness with respect to the original ones in unblanched and blanched potato slices. Bars represent standard deviations.

dense dried product, with a consequent lower porosity and lower effective water diffusivity. Gelatinization changed the internal structure in such a way that structure collapse did not end during the drying process. On the other hand, structure collapse of unblanched slices ended during drying, and this was likely the cause of the observed differences.

Other consequences of longer blanching such as loss of soluble solids or hydrolysis of pectin materials made the non-dry potato less flexible and weaker (cooked potato). However, the effect of these changes on the properties of the dried product is not as important as in the case of starch gelatinization. Further analysis of the effect of blanching on mechanical and rehydration properties is needed to complete this study.

ABBREVIATIONS (SYMBOLS) USED

V, total volume (mL); ρ, density (g/mL); ϵ, porosity (%); L, thickness (cm); ϕ, diameter (cm); W, moisture content wet basis (g water/g sample); M, moisture content dry basis (g water/g dry solids); D_{eff}, effective water diffusivity (m^2/s); T, temperature (°C); t, time (h, s); (subscripts) a, air; s, solids; w, water; b, bulk; t, true; eq, equilibrium; ave, average; o, initial; g, glass transition.

ACKNOWLEDGMENT

The assistance provided by Dr. T. van't Vliet and Dr. M. Zwietering is greatly appreciated.

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Received for review August 4, 1997. Revised manuscript received November 19, 1997. Accepted November 25, 1997.

JF970671P