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RESEARCH NOTE

Effect of blanching pretreatment on color and texture of apple slices at various water activities

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Equilibration of Red Delicious apple slices to water activities below about 0·6 resulted in increased hardness in blanched, sulfited and untreated control slices as measured by the force required to shear the slices. As their water activity was lowered toward 0·29, blanched slices became about 2·5 times harder than the sulfite or untreated samples. Brown color development in the slices as measured by the C.I.E. value L was maximal at a_w near 0·7 and less on either side of this water activity. Brown color development over 8 week storage at ERH 53, 65 and 75% was accompanied by rapid loss of polyphenol oxidase activity and progressive loss of total phenol. Packaging and storage of fruit leathers and apple slices are discussed in the light of these results.

Keywords: Apple slices, blanching color, texture.

INTRODUCTION

Dried apple pieces are often incorporated in dried breakfast cereals to provide fruit character and textural contrast in the product. Moisture transfer to the low water activity cereal from the higher water activity dried fruit creates a problem when the fruit pieces become very hard. This problem can be reduced by coating the dried fruit pieces, but in truly 'natural' cereals in which this option is unacceptable, another strategy would be desirable.

Bourne (1986) has shown that apple tissue becomes harder as its water activity is reduced to about 0·12. The hardness increase with decreasing a_w is approximately logarithmic as would be expected for a gel system (Beveridge *et al.*, 1980) and small increases in the water holding capacity of the sample could result in significant softening of the dried fruit piece through the plasticizing effect of the additional water.

Studies of blanched fruit mashes have shown extensive particulate disruptions increasing exposure of macromolecular complexes to the aqueous phase, suggesting enhanced intraparticule water binding as the mechanism for increased juice cloud stability (McKenzie & Beveridge, 1988). Formation of this gel-like network by a blanching pretreatment could result in retention of water by dried fruit giving softer fruit pieces. The plasticizing effects of water retained by the expanded macromolecular complex in fruit blanched pre-drying may result in a longer shelf life of the cereal, fruit mixture.

MATERIALS AND METHODS

Sound, good quality, Red Delicious apples obtained from research station orchards, which had been stored for 6 months at 0°C were peeled, cored and sliced perpendicular to the core axis in a Hobart meat slicer to form pieces of 6 mm thickness. Sulfite treatment consisted of dipping slices in 75 ppm SO_2 (as potassium metabisulfite) for 1 min. Blanching was accomplished in flowing steam for 1 and 3 min intervals. Saturated salt solutions of magnesium chloride, potassium carbonate, magnesium nitrate, sodium nitrite and sodium chloride were used to provide theoretical equilibrium relative humidities (ERH) near 33, 44, 55, 65 and 75% (Bourne, 1986) in chambers made from sealed 15 litre plastic pails and equipped with plastic mesh shelving to hold samples. Prior to placing in each chamber, the

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apple slices were dipped in 5% (w/v) aqueous potassium sorbate to inhibit mould formation during storage. The apple slices were pre-dried briefly in a drying cabinet to remove surface moisture, then stored in the chambers at 25°C until reaching constant weight (equilibrium) in 6–8 weeks. The actual a_w of apple slices were measured after equilibration. Color and texture were assessed on samples stored in chambers ranging from 0·327 to 0·753 a_w theoretical. A separate experiment to evaluate color, total phenol and polyphenol oxidase activity of stored apple slices was performed in chambers with ERH of 52·9, 65·0 and 75% theoretical. Apple slices were removed on a biweekly basis to measure color, then freeze-dried for later total phenol and enzyme analysis.

Texture

The force required to cut through one slice of apple tissue trimmed to be 2 cm long was determined with an Instron Model 4201 equipped with a single blade cell. Individual measurements were replicated six times.

Total phenol

Total phenols were determined by the method of Slinkard and Singleton (1977) after solubilization of 0·1 g freeze-dried powder in 10 ml boiling water to destroy possible residual polyphenol oxidase. The extract was assayed after centrifugation at 2000 rpm (~800 × *g*) in an IEC HN-SII bench-top centrifuge with gallic acid as standard and reported as milligram per gram dry powder. Assays were performed in duplicate.

Polyphenol oxidase activity

Freeze-dried powder (0·75 g) was extracted in a mixture containing 5 g AG 1-X8 ion exchange resin (acetate, 100-200 mesh, Bio-Rad, Richmond CA), 0·5 ml Triton X-100 (BDH Chemicals, Toronto, ON), 3 g insoluble polyvinyl pyrrolidine (PVP, prewashed with 50 ml 0·02 M acetate buffer, pH 6·2), and 25 ml 0·02 M acetate buffer (pH 6·2). The mixture was stirred for 30 min, then filtered through 934AH grade Whatman filter paper. Polyphenol oxidase (PPO) activity was determined, in duplicate, on this extract as reported by Galeazzi *et al.* (1981).

Browning

The extent of brown color development was assessed by the chromaticity value L of the CIE color system as suggested by Sapers and Douglas (1987). Measurement was made (six replicates) by a Minolta Chroma Meter CR-200 (Osaka, Japan).

Water activity

Water activity was determined, in duplicate, using a Rotronic Hygroskop DT (Rotronic Instrument Corp., Huntington, NY) at 25°C according to manufacturer's instructions.

RESULTS AND DISCUSSION

Blanched apple slices were similar in texture to sulfited or untreated apple slices at water activities between 0·70 and 0·77 (Table 1) as measured by force required to shear a standardized sample. However, as water activity decreased below 0·57 the blanched samples became increasingly harder than the sulfited or untreated samples, indicating blanched apple tissue would be unsuitable for use in dried cereal mixes. During the 8 week equilibration to constant water activity, all apple slices browned depending upon the water activity. Brown color development (Table 2) (low chromaticity L) was maximal between a_w equals 0·57 and 0·77, perhaps near 0·70. This pattern of behaviour is common to many foods systems which brown at intermediate water activities during drying or later storage (Labuza & Saltmarch, 1981), and is commonly attributed to Maillard reactions involving fruit amine–carbohydrate reactions (Eichner & Ciner-Doruk, 1981; Feather, 1982; Labuza & Baisier, 1992). Studies on Maillard browning are commonly done at elevated temperatures (above 40°C)

Table 1. Effect of equilibrium water activity on force (Newtons) required to shear dried apple slices. Slices equilibrated over salt solutions 8 weeks to assure equilibrium moisture

Treatment	Force (Newtons) a_w				
	0.77	0·70	0.57	0.42	0.29
Blanched (1 min)	43·0a	52·9a	68·0b	92·4b	189a
Blanched (3 min)	46·5a	54·5a	74·4a	107·4a	191a
Sulfite (75 ppm)	35·2b	37·9c	45·8d	80·6b	92·9b
Untreated (Control)	47·2a	47·5b	59·3c	82·4b	76·4b

Force values represent the means of 6 observations. Means within a column sharing the same letter are not significantly different ($P > 0·05$).

Table 2. CIE chromaticity[a] value L after 8 weeks of storage at several a_w. Brown color development indicated by lower L

a_w	Control (untreated)	Sulfur dioxide (75 ppm)	Blanched (1 min)	Blanched (3 min)
0·27	82·3a	87·5a	80·2a	77·7a
0·42	84·0a	84·9ab	78·2a	72·6b
0·57	81·9a	84·7b	79·2a	72·1b
0·70	58·2c	52·8d	47·1c	47·2d
0·77	64·3b	71·8c	66·0b	59·5c

[a]Chromaticity values represent the mean of 12 observations. Means within a column sharing the same letter are not significantly different ($P > 0·01$).

because the reactions occur slowly at room temperature and require more than 10 weeks to cause significant browning (Wong & Stanton, 1993; Beveridge & Harrison 1987), and because the drying or concentrating procedures which cause or potentiate these reactions are carried out at elevated temperatures. However, in fruit systems, ascorbic acid is well known to contribute to brown color development (Wong & Stanton, 1993) and phenolic compounds can be oxidized in the absence of oxidase enzymes, and subsequent condensation reactions can lead to brown pigment formation (Singleton, 1987). Both of these possibilities offer alternative explanations for relatively rapid brown color development in dried fruit systems. Bolin and Steele (1987) have attributed 60–70% of nonenzymatic browning in apples to these latter oxidative reactions.

In the present case, temperature was near ambient and the reaction was well along by 8 weeks of storage. Possible phenolic compound involvement in the observed brown color development was examined by measurement of color, phenol and polyphenol oxidase activity levels in dried samples at the water activities bracketing maximum color development. No treatment control apple slices initially showed high levels of PPO activity (Table 3) as would be expected, but this activity had dropped considerably (64 units) in the first week and had disappeared completely by the second week. PPO analysis showed enzyme levels to be undetectable for subsequent weeks 4, 6 and 8 (data not shown). In the sulfited or blanched samples the initial PPO levels were undetectable and remained undetectable for all samples taken up to the final sampling at 8 weeks providing no evidence for PPO mediated reactions or regeneration of PPO. Concurrent with this loss of PPO activity and the development of brown color was the decrease in total phenol content of the slices in all treatments. This is explainable in the untreated control where initial levels of PPO were considerable, but would not be expected in the sulfited or blanched treatments where PPO is inhibited or destroyed. Phenol compounds are capable of undergoing oxidative degradation and develop brown color during these polymerization reactions; and this appears likely in this case.

Table 3. Browning index (L), phenol and polyphenol oxidase (PPO) levels related to equilibrium water activity after 8 weeks of storage

Treatment	a_w	L	Phenol (mg g^{-1})	PPO (g^{-1})
Control (no treatment)	0·99[a]	75·9 ± 3·3	5·56	679
	0·53	58·2 ± 6·1	1·38	—
	0·65	49·4 ± 4·0	0·92	—
	0·75	51·5 ± 3·9	1·09	—
Sulfur dioxide	0·99[a]	78·9 ± 1·4	8·55	27
	0·53	66·5 ± 3·9	3·75	—
	0.65	50·0 ± 3·7	3·55	—
	0·75	61·8 ± 3·3	4·26	—
Blanched (3 min)	0·99[a]	53·6 ± 1·6	5·77	—
	0·53	37·6 ± 1·1	3·07	—
	0.65	29·6 ± 1·9	2·23	—
	0.75	36·9 ± 2·3	2.38	—

[a]Assumed water activity of apple slices before equilibration to stated a_w (Bourne, 1986). Represent 0-time or initial values.
± Values are standard deviation (n = 6). Phenol is average of duplicate analysis.
— Undetectable.

CONCLUSIONS

Blanching apple tissue as a means of enzymatic browning control is a useful technique for products to be stored as intermediate moisture foods such as dried apple slices or fruit leathers but is detrimental to texture when the apple tissue is to be used or stored at a_w below 0·5–0·6. Browning during and subsequent to drying is still of concern but careful storage of dried apple products at a_w slightly below 0·6 may provide improved shelf life while maintaining a texture exhibiting low shear force values. Storage at a_w near 0·7 is to be avoided because of enhanced browning at this water activity. The possibility that the browning occurring at reduced water activities is due to, or complemented by, phenol polymerization exists and should be investigated further, nevertheless, packaging of intermediate moisture dried apple products in nonoxidative atmospheres (Bolin & Steele, 1987) may provide further improvements in shelf life when combined with selection of appropriate conditions of water activity.

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