한국농화학회지 제 37권 제 2호(1994)
Agricultural Chemistry and Biotechnology
Vol. 37, No. 2, pp. 77~84(1994)

Physico-chemical properties of whole sweetpotatoes on precooking and frozen storage

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Abstract : Sweetpotatoes were baked (BK), microwaved (MW), microwaved/baked (MWBK), and microwaved/hold/microwaved (MWHO). Sugars, Huntercolors, compression and shear forces, sensory scores, moisture content, starch, and alcohol insoluble solids (AIS) were determined for each treatment. The BK roots contained higher ($p<0.05$) amount of sugars and less ($p<0.05$) starch. The MW roots contained higher ($p<0.05$) amount of starch, AIS, and less ($p<0.05$) sugar. The BK product resulted in the least ($p<0.05$) compression and shear forces needed to break it. The MW product demanded the greatest ($p<0.05$) force. The MWHO showed very similar results to the BK. Sensory scores for the BK and the MWHO sweetpotatoes were very acceptable. In color scores, the MWHO products were very acceptable and similar to the BK in flavor (Received February 14, 1994; accepted April 4, 1994).

Introduction

In recent years, consumption of sweetpotatoes has declined eventhough , sweetpotatoes are a good source of vitamin C and dietary fiber and a favorable source of calories.[1-5] Developing new products from sweetpotatoes has always been of interest to foodprocessors, and farmers as well as to consumers.[6,7] New sweetpotato products not only offer convenience and interest to consumers, but also expand the market and food supply for a long storage. However, since sweetpotatoes have high carbohydrate contents and active amylolytic enzymes, there is rapid breakdown in product firmness during storage.[8-12]

Recent interest has shifted into development of new and improved uses for sweetpotatoes.[13] Efforts to increase consumption of sweetpotatoes have been conducted on new products.[14,15] However, there is little information available on microwave heating and frozen storage conditions. Microwave heating is a new technology. As a result, the characteristics of microwave heating are not as well understood by the public. Microwaves have a great penetration power, and food products being heated in them have high heat gradients. Foods containing high moisture and fat readily absorb microwave energy.[16] A frozen precooked (microwaved) ready-to-eat product may be an attractive alternative to conventional baked sweetpotatoes. Also such products can have long shelf life due to frozen storage.

The objectives of this study were: 1) to determine the effects of four different processes: microwave heating/holding/microwave heating (MWHO), microwave heating/baking (MWBK), microwave heating (MW), and baking (BK) on some chemical and physical characteristics of whole sweetpotatoes. and 2) to determine if an acceptable whole sweet-

Key words : Sweetpotato, Microwave, Bake, Physico-chemical properties
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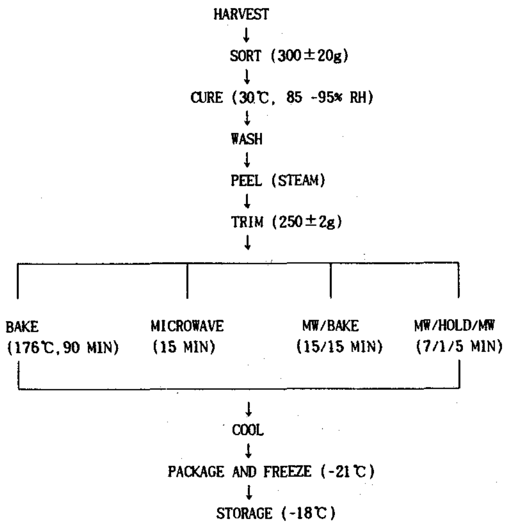

Fig. 1. Flow diagram for preparation of whole sweetpotatoes subjected to various cooking treatments.

potato product that resembled a baked product could be developed by using microwave energy.

Materials and Methods

Materials

Materials, 'Centennial' sweetpotatoes (SPs), were used. After harvesting, roots were cured by holding in a room for seven days at 30℃ and 85 to 90% relative humidity (RH). The roots were then stored at 15℃ and 85 to 90% RH until processed. Only medium SPs, between 7.5 and 8.7 cm in dia. and between 10.2 and 22.0 cm in length were used.

SPs were washed (Fig. 1) in ambient temperature (22℃) water using a rotary spray washer. Water spray was used to wash off the lossened peel after steam peeling at 100℃ for 3 min. The roots were weighed and ends trimmed to a weight of 250± 2 g before anytreatment. SPs were randomly assigned to 1 of 4 treatment lots, each treatment had 2 sweetpotatoes with 250± 2 g each, and then processed as follows:

Lot I (MW): SPs were placed in a microwave oven model EMS-3727(2450 MHz, 1400 W) over a rotating dish at 5 RPM, and given a microwave treatment of 15 min at full power until an internal temperature of 99℃ was reached, then allowed to cool 1 hr.

Lot II (BK): This treatment (baking) was used as the control. SPs were placed in a prewarmed conventional oven at 176℃ and baked for 90 min until an internal temperature of 99℃ was reached. After baking, SPs were allowed to cool for 1 hour at roomtemperature.

Lot III (MWBK): SPs were cooked by microwave (15 min) at full power, subsequently baked for 15 min at 176℃ to doneness prior to cooling 1 hr at room temperature.

Lot IV (MWHO): SPs were cooked by microwave to 80℃ for 7 min in a container, held 1 min and then cooked again by microwave (5 min) at full power prior to cooling for 1 hr.

Each cooked sample was individually placed in polyethylene bags and air rejected (vacuum), individually quick frozen (IQF) for a day at −20℃, and stored in a freezer at −18℃ until analyzed.

Analyses

Sugars; glucose, fructose, sucrose, and maltose were analyzed by High Pressure Liquid Chromatography (HPLC) with a Bio-Sil amino 5s resin column as outlined by Picha.[5] The mobile phase was degassed HPLC-grade 75% acetonitrile: 25% water at flow rate of 1.0 ml/min. Color was analyzed by a Hunter/Labscan 6000 0/45°. Spectrocolorimeter as outlined by Silva[17] with appropriate modifications. The instrument was standardized using an orange reference color tile D33C-327. Four Hunter color measurements for each sample were made and the average of 4 values calculated.

Chroma (SI=(a2+b2)1/2), hue (tan-1(b/a)), and La were calculated.[18] Shear force values were obtained and reported as N/g (SF) required to shear one SP (250 g± 2 g) with a CS-1 standard shearcell. The shear force was recorded on a texturecorder.[19] The instrument was set at a drive speed of 30 cm/min, a chart speed of 30 cm/min, a transducer range of 1/30, and load range of 0~500 g.

The higher shear values indicated a firmer product. The compression force (CF), N/g.cm, was calaulated as the linear part of slope of the shear texturgram. The total energy (TE) was calculated as the energy

Table 1. Effect of processing treatment, and frozen storage time on Hunter Color values of whole sweetpotatoes

Treatment	Attribute					
	L	a	b	HUE[X]	SI[Y]	La[Z]
Process						
BK	47.16a	27.49a	26.16a	43.59ab	37.96a	1296.78a
MWBK	46.99a	26.88b	26.04a	44.11a	37.43b	1263.11b
MWHO	45.95b	26.81b	24.50b	42.43c	36.32c	1232.77c
MW	44.14c	25.74c	24.08c	43.10bc	35.26d	1136.26c
Storage Time (days)						
0	46.03NS	26.92NS	24.95b	42.84b	36.72NS	1239.78NS
45	45.95	26.70	25.36a	43.54a	36.84	1228.42
90	46.21	26.56	25.25a	43.55a	36.66	1228.49

a, b, c, d-Means within columns not followed by a common letter differ ($p<0.05$).
NS-Not Significant ($p<0.05$)
X-HUE=tan-1(b/a) (measure color)
Y-SI=saturation index=(a2+b2)1/2 (chromaticity)
Z-La=L×a (measure orange color and brightness)

to compress and shear force sample (J/g).

Sensory evaluation was determined by taste panelists as outlined by Ammerman *et al.*.[2] Eight experienced and trained panel members were used to evaluate the cooked SPs. The panelists evaluated flavor, texture, appearance, color, moisture, uniformity, lack of fiber and overall score using a 10 point scale.

Moisture content was analyzed by oven method as outlined in method 925.10 (AOAC).[20] Starch content was analyzed colorimetrically as outlined in method 979.10 (AOAC).[20]

Alcohol-Insoluble Solids (AIS) were analyzed as outlined by Szyperski *et al.*.[21]

Statistical Analysis

Significant differences at the 5% level of probability were tested using the General Linear Model.[22] Controls were compared to each treatment combination by using Fischer's protected Least Significance Difference (LSD) Technique.[23]

Results and Discussion

The baked product had higher ($p<0.05$) color attributes (Table 1), except for hue which was intermediate. The MW product had the lowest ($p<0.05$) La, a common measure of color in SPs. This is probably the result of oxidation and other reactions that lead to discoloration of the product.[24-29] Chroma or SI was also lowest ($p<0.05$) for the MW product. This may indicate lower beta-carotene content of the product.[30-33] These changes were reflected on chroma and discolation and eye appeal ratings by taste panelists. During frozen storage, L, b and hue values changed (Table 1). Higher ($p<0.05$) L values were measured after 90 days and hue values after 45 days. Panelists did not notice changes in discoloration over time, but they did in eye appeal and chroma.

The force necessary to compress (CF) and shear (PF) the product was affected by treatment (Table 2). The MW product demanded the greatest ($p<0.05$) force. CF and PF were intermediate for MWBK and MWHO product. These results are directly related to the amount of starch converted or gelatinized during the process. Higher starch conversion for the BK products (Table 2) resulted in a 'softer' product while higher amounts result in a 'tougher' product.[12,34,35] Ungelatinized starch is in the form of small granules within the cells and upon gelatinization, they swell and make the product less rigid. Upon hydrolysis due to

Table 2. Effect of processing treatment on shear force, compression force, total energy, starch, and alcohol-insoluble-solid (AIS) of whole sweetpotatoes

Treatment	Shear Force (N/g)	Compression Force (N/cm.g)	Total Energy (J/g)	Starch[X]	AIS[X]
BK	0.89d	11.96d	0.31c	15.56c	16.53c
MWBK	1.52c	23.20c	0.42b	20.24b	25.48b
MWHO	1.72b	27.12b	0.49a	19.69b	26.96b
MW	3.12a	44.22a	0.50a	37.65a	44.60a

X-Percentage by dry weight basis
a, b, c, d-Means within column not followed by a common letter differ ($p<0.05$).

Table 3. Effect of processing treatment and frozen storage time on shear force and total energy of whole sweetpotatoes

Treatment	Storage Time (days)					
	0	45	90	0	45	90
	--Shear Force (N/g)--			-Total Energy (J/g)-		
BK	1.06c	1.03d	1.00c	0.33c	0.31c	0.32b
MWBK	1.51b	1.44c	1.66b	0.40b	0.40b	0.44b
MWHO	1.66b	1.79b	1.63b	0.48a	0.50a	0.46a
MW	3.04a	3.09a	2.96a	0.50a	0.50a	0.47a
MEAN		1.82			0.43	
CV (%)		6.73			5.19	

a, b, c, d-Means within column not followed by a common letter differ ($p<0.05$).

cooking and endogenous enzymes, they produce lower molecular weight dextrins and sugars which make the product less resistant to compression and shearing since they do not fill cells and thus do not contribute to turgor. Moreover, other cell components such as pectic substances are hydrolized during cooking at high temperature, thus loss of rigidity in the product. Compression and shear force necessary to break the MWBK roots increased ($p<0.05$) after 90 days of storage (Table 3). However, this was not the case in the BK roots, and the other two treatments yielded mixed results with no clear trend. Starch and AIS were higher ($p<0.05$) in the MW treated roots (Table 2) and lower ($p<0.05$) in the BK roots. This confirms the fact that there is a higher conversion rate of starch to dextrins and sugars in the BK process leading to a product with large voids in the cell structure(occupied by water and sugars)[14] as compared to the MW product. Both the MWBK and MWHO treatments had equal amounts ofstarch and AIS and were lower than in the MW roots but higher than in the BK roots. Since sta-

Table 4. Effect of processing treatment and frozen storage time on maltose content of whole sweetpotatoes

Treatment	Storage Time (days)		
	0	45	90
	--Maltose (% w/w)--		
BK	7.94a	7.84a	7.59a
MWBK	7.09c	6.89c	6.89c
MWHO	7.39b	7.29b	7.19b
MW	5.94d	5.84d	5.94d
MEAN		6.98	
CV (%)		1.47	

a, b, c, d-Means within columns not followed by a common letter differ ($p<0.05$).

rch is part of AIS, one can note that there were little alcohol insoluble solids other than starch (AIS-starch) remained in the BK treated roots but that was not the case in other treatments. These other components, such as pectic substances, cellulose, hemicellulose, proteins, and others are more difficult to hydrolize than

Table 5. Effect of processing treatment and frozen storage time on fructose, glucose, sucrose, maltose, and total sugars of whole sweetpotatoes

	Fructose	Glucose	Sucrose	Maltose	Total Sugars
Process		———Sugar content (% w/w)———			
BK	0.45a	0.70a	5.99a	7.75a	14.89a
MWBK	0.44a	0.63b	5.55b	6.92c	13.54c
MWHO	0.40a	0.54c	5.55b	7.22b	13.70b
MW	0.33b	0.56c	5.05c	5.86d	11.79d
Storage Time (days)					
0	0.42a	0.60a	5.56a	7.09a	13.67a
45	0.44a	0.60a	5.61a	6.96b	13.61a
90	0.38b	0.62a	5.53b	6.90b	13.43b

a, b, c, d-Means within columns not followed by a common letter differ ($p<0.05$).

Table 6. Effect of processing treatment and frozen storage time on appearance sensory ratings of whole sweetpotatoes

	Eye Appeal	Intensity of Color	Uniformity of Color	Freedom from Discoloration
		———Sensory rating[X]———		
Treatment				
BK	6.62d	6.56c	6.44c	6.44d
MWBK	7.06c	7.32b	7.03b	7.03c
MWHO	7.47b	7.54b	7.26b	7.30b
MW	8.26a	8.02a	7.86a	7.73a
Storage Time (days)				
0	7.66a	7.70a	7.34a	7.26a
45	7.16b	7.13b	6.91b	7.20a
90	7.24b	7.26b	7.20a	7.10a
MEAN	7.36	7.36	7.15	7.13
CV (%)	17.07	16.13	17.46	18.74

a, b, c, d-Means within columns not followed by a common letter differ ($p<0.05$).
X-On a 10 point scale with "10" being highest and "6" being acceptable.

starch, and thus their presence after relatively mild cooking. This contributed to the tougher texture of MWBK and MWHO products as compared to BK product (Table 3).

Maltose (Table 4) was higher ($p<0.05$) for the BK product, followed by the MWHO product, the MWBK product and finally the MW product at each storage time. This confirms conversion of starch to sugars since maltose formation is an indicator of cooking of SP roots[5,24] since it is not found in raw roots. In general, fructose, maltose, sucrose, and glucose were higher ($p<0.05$) in the BK product. The MWHO product was the second in total sugars after the BK (Table 5), this was substintiated by taste penelists. Time in storage had no effect ($p>0.05$) on total sugars (Table 5) but fructose and maltose showed slight decreases.

Eye appeal, chroma, color uniformity, and freedom from discoloration as affected by process (Table 6) were higher ($p<0.05$) for the MW and lowest ($p<0.05$) for the BK product. This is the result of least cumulative processing (time-temperature) by the MW, thus less surface heating and more resemblance to a raw product. Both the MWBK and MWHO treatments were scored the same (Table 6) except in eye appeal where

Table 7. Effect of processing treatment and frozen storage time on moistness of whole sweetpotatoes

	Moistness
Treatment	– – Sensory rating^X – –
BK	8.82a
MWBK	7.68b
MWHO	7.76b
MW	6.58c
Storage Time	
0 DAY	7.97a
45 DAYS	7.45b
90 DAYS	7.72ab

a, b, c-Means within columns not followed by a common letter differ ($p<0.05$).
X-On a 10 point rating scale with "10" being very moist and "1" being very dry from a whole sweetpotato.

MWHO scored higher ($p<0.05$).

Analysis for time effect on the four before-mentioned treatments, indicated that scores at time 0 were higher ($p<0.05$) than at 45 and 90 days in frozen storage (Table 6), except for freedom from discoloration, where there were no differences ($p>0.05$). Color uniformity scores were the same ($p>0.05$) after 90 days than at time 0 (Table 6). These results indicate that there was some discoloration over time, probably due to oxidation of pigments (carotenoids)[30,31] and/or enzymatic reactions.[29,36] However, all scores for treatment effect were higher than 6.0 and in most cases higher than 7.0, indicating that regardless of treatment or storage, the product is acceptable in appearance to panelists.

Smoothness ratings were highest ($p<0.05$) for BK product (Table 8) while lowest ($p<0.05$) for the MW product. This might be the result of uneven heating, undercooking, and/or surface dehydration. Smoothness scores were lower ($p<0.05$) after 45 days of frozen storage (Table 8), probably due to freezing effect (cell breakage with loss of turgor and surface dehydration). Moistness scores, which are related to starch content, were highest ($p<0.05$) for the BK product (Table 7) and lowest ($p<0.05$) for the MW product. This is directly related to amount of starch present, with larger amounts resulting in a 'dryer' mouthfeel.[13] Since the

Table 8. Effect of processing treatment and frozen storage time on smoothness, lack of fiber, and flavor of whole sweetpotatoes

	Attribute		
	Smoothness	Lack of Fiber	Flavor
Treatment	– – Sensory rating^X – –		
BK	8.47a	8.49a	7.31a
MWBK	7.67b	7.67b	6.47b
MWHO	7.83b	7.95b	7.15a
MW	6.34c	6.79c	5.93c
Storage Time (days)			
0	7.81a	7.80a	6.89a
45	7.41b	7.63a	6.48b
90	7.51b	7.74a	6.78a
MEAN	7.58	7.73	6.72
CV (%)	14.28	16.49	17.75

a, b, c-Means within columns not followed by a common letter differ ($p<0.05$).
X-On a 10 point rating scale with "10" being very smooth, void of fiber and typical sweetpotato flavor and "1" being crumbly, high in fiber and of bland taste.

BK product results in the highest conversion of starch to sugars, moistness is highest.[9,37,38] If one relates this to the structure of the product, one can see that the BK product had large voids (occupied by sugarsand water) while the MW product resulted in little void space and thus higher starch content. Moistness scores did not change for the BK and MWBK products (Table 7) over time while they decreased ($p<0.05$) for the MWHO and MW treatments. This might be the result of starch retrogradation and water loss during storage.

Lack of fiber was higher ($p<0.05$) for the baked product (Table 8) while flavor scores for the baked and MWHO products were the same (Table 8). The MW product was scored lowest ($p<0.05$) on flavor (Table 8).

Thus one can conclude that a microwave-hold-microwave process will result in a product of similar flavor and more appealing to the eye than a baked-only product. The MW alone results in a marginal product, as far as flavor is concerned (Table 8). Lack of fiber scores did not change ($p>0.05$) over time (Table 8), while flavor scores fluctuated but ended-up same as initial scores.

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고구마의 가열방법과 저장성에 따른 이화학적 성질

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초록 : 고구마를 1) 베이킹(baking), 2) 고주파가열(microwaved), 3) 고주파가열/베이킹, 4) 고주파가열/정지/고주파가열의 방법으로 가열하여 고구마의 당, 색도, 조직감,관능검사, 수분함량, 전분, 알콜불용성 성분을 측정하였다. 1)의 방법은 당의 함량은 높았으나 전분의 함량은 낮았다 2)의 방법은 전분과 알콜불용성 성분은 높고 당의 함량은 낮았다. 조직감 측정결과 1)의 방법에서는 압축력과 전단력이 가장 낮은 값을 나타내었고 2)의 방법은 가장 높은 값을 나타내었다. 4)의 방법은 1)의 방법과 모든 측정치에서 유사한 결과를 나타내었다. 관능검사 결과 1)의 방법과 4)의 방법은 높은 기호도를 나타내었다. 4)의 방법은 향에 있어서 1)의 방법과 유사하였으며, 색도 역시 높은 기호도를 나타내었다.