WFL Publisher
Science and Technology

Journal of Food, Agriculture & Environment Vol.4 (1) : 11-16. 2006

www.world-food.net

Effects of pre-treatments on the physicochemical quality and sensory acceptance of osmo-air-dehydrated 'dwarf' golden apples (*Spondias cytherea* Sonn.)

Jeanette Browne and Neela Badrie*

*Department of Food Production, Faculty of Science and Agriculture, University of the West Indies, St. Augustine, Republic of Trinidad and Tobago, West Indies. *e-mail: nbadrie@yahoo.com, badrie@carib-link.net, jeanette_browne@hotmail.com*

Received 11August 2005, accepted 21 November 2005.

Abstract

The objectives of the study were to investigate the effects of fruit peeling, high (95°C) and low temperature (24°C) brining and addition of red or yellow colourant on physicochemical quality and sensory acceptance of osmo/air dehydrated (OD) candied dwarf golden apples (S*pondias cytherea* Sonn). From a survey, only 3.6% had consumed golden apples as candied products. Green mature fruits were initially immersed in brine solution (5 g 100 g^{-1} NaCl or 10 g 100 g^{-1} NaCl) for 18 h, soaked in 40ºBrix acidified sucrose/corn fructose syrup for 24 h, followed in 65ºBrix corn fructose/sucrose syrup for 24 hours at 24°C and convection-air-dried at 45ºC for 24 hours. Focus groups found that OD golden apples with peel were tough and rubbery. Hot brining resulted in a less ($P<0.05$) orange colour, softer ($P<0.05$) and more acceptable texture. Red-coloured OD fruits in 5 g 100 g^{-1} NaCl were more acceptable (liked moderately to extremely) compared to yellow-coloured products (liked slightly to moderately). The pH of OD golden apples was 3.4–3.6, total soluble solids (TSS) 73.6-76.3°Brix and titratable acidity 0.35–0.63 g 100 g^{-1} citric acid. On storage at 24°C for 6 weeks, TSS increased, texture became firmer, pH decreased, colour became significantly ($P<0.05$) darker and more yellow OD golden apples were microbiologically stable (<10 cfu g^{-1}) for total aerobic counts, lactic acid bacteria and yeasts and moulds throughout storage.

Key words: Golden apples, *Spondias cytherea* Sonn, corn syrup/sucrose solution, osmo/air dehydration, physico-chemical quality, sensory acceptance.

Introduction

Golden apple (*Spondias dulcis* Forst syn. *Spondias cytherea* Sonn.) is a traditional minor crop in the Caribbean [1] and is a member of the Anacardicaceae family [2, 3]. Among its various colloquial names are otaheite apple, Tahitian quince, Polynesian plum, golden apple, June plum, pommecythere and ambarella [4]. The fruit is found throughout Asia, Australia, Central and South America, the Caribbean and parts of Africa [4,5]. The golden apple has received little recognition from the scientific community of the Caribbean region [6], which may be attributed to the fact that historically it was of insignificant commercial importance [7]. The introduction of the 'dwarf' variety of golden apple to the Caribbean has resulted in many advantages to the processor over the 'tall' existing variety, as harvesting is easy, the fruits bruise less easily, are more uniform in size, have softer spines and thinner skin and the pulp is not as acidic [8]. The 'dwarf' variety fruit is smaller in size than the 'tall' variety fruit and hence is not readily suitable for export [7]. On ripening, the rind as well as the pulp of the fruit turn golden-yellow and the flesh is juicy and slightly acid[4]. The shelf life of the green fresh fruit is 6-8 days to ripe stage and 9-10 days for overripe stage [9].

Osmo-dehydration is gaining interest due to its role as a pre-treatment that can be part of effective integrated quality strategies for improving characteristics of the matrix or as one hurdle in a combined processes approach [10]. It is a method for the partial removal of water by immersion of food in concentrated solutions or syrups of soluble solids, without phase change [12, 13]. During osmotic pre-concentration, two major concurrent flows take place simultaneously under the water and solute activity gradients across the semi-permeable cell membrane. Water flows from the product into the osmotic solution whereas osmotic solute is transferred from the solution into the products solution [13, 14] which results in an increase in water activity of the solution [15, 16] and effective reduction of product water content with minimal damage to fresh product attributes [17]. A third transfer process is the leaching of product solutes (sugars, acids, minerals and vitamins) into the medium, although recognised as affecting the sensory and nutritional characteristics is considered negligible[18]. OD has been applied in combination with air dehydration to improve the quality of air-dehydrated apricot cubes [19].

To our knowledge, there has been no published work on osmo-air dehydration (OD) of the 'dwarf' golden apples. Processing of golden apples could add value to the fruits, lengthen the storage life and utilise rejected fruits for the local markets [1]. Dwarf golden apples have been utilised in canning as whole golden apple and puree in syrup [8], hot sauces with or without fruit peel [20] and reduced-sodium hot sauces [21]. Therefore, the objectives of this study were to apply osmo-air dehydration (OD) in the utilisation of golden apples, to investigate the effects of pre-treatments of including fruit peeling, low and high temperature brining and addition of red or yellow colourants on the physicochemical and sensory acceptance of candied products and to investigate the shelf-life of the products.

Methodology

Golden apple utilisation: A survey was conducted to determine the usage of golden apples and preference of flavoured OD golden apples. The survey comprised of seventy-eight respondents (24% males; 76% females), who were from East, West, South, North and Central regions of Trinidad, West Indies. Their ages ranged from 13 yrs to over 40 years (35.9% 13-18 yrs; 35.9% 19-25 yrs; 11.5% 26-31yrs; 3.8% 32-40 yrs and 12.8% over 40 yrs).

Dwarf golden apples: Dwarf golden apples were obtained from the University Field Station, St. Augustine, Trinidad and Tobago. Fruits were selected on maturity, size, appearance and colour. The green mature fruits were stored for 3 days at 24°C prior to OD processing. They were of average fresh mass of 85.57±4.1 g with length of 5.60±0.73 cm and diameter of 4.29±1.63 cm. Fruits were washed in water, sanitised in clorinated water (300 ppm) and either peeled (P) manually or unpeeled (UP). The weighed golden apples were cut in quarters (~5.0 cm length x 3.5 cm width x 1.1 cm thickness) or halves horizontally (~ 6 cm length x 5 cm width x 1.5 cm thickness).

Preliminary pre-treatment trials: Peeled (P) or unpeeled (UP) weighed fruits were immersed in 5 g 100 g^{-1} non-iodised NaCl or 10 g NaCl 100 g^{-1} non-iodised NaCl (Naisa Brand Products, Bejucal, Trinidad, West Indies) in the ratio of 2: 1 (brine to fruits v/w) for 18 hours. Brined fruits were immersed in 40°Brix acidified 0.1 g 100 g^{-1} citric acid (pH 2.84±0.02; Thomas Scientific, England) syrup (10:1; sucrose {Caroni Ltd, Couva, Trinidad, West Indies} to corn fructose syrup (Karo light corn syrup with real vanilla, ACH Food Company Inc., Memphis, Tennessee, USA) followed by soaking in 65°Brix (2.4: 1 sucrose to corn fructose syrup) at 24°C for 24 hours. The ratio of sucrose/corn fructose syrup to fruit was 2:1 (v/w). The OD golden apples were hot air-dried (Model D-783 Dipl. Ing Ehret GmbH, Emmendingen 14 EHRET Germany)at 45°C for 24 hours.

Focus groups: The OD candied golden apples from preliminary treatments which were peeled (P) and unpeeled (UP) quartered fruits and brined in 5 g 100 g^{-1} NaCl (5 g) or 10 g 100 g^{-1} NaCl (10 g) at 24°C to give P5g24°C, UP5g24°C, P10g24°C and UP10g24°C treatments were evaluated by two small groups of untrained (20-50 years) panellists comprising of 4 staff members and 8 students of the University of the West Indies, Trinidad. Focus group evaluation was used in the identification and exploration of specific sensory characteristics [22] of the OD air-dehydrated golden apples and to evaluate panellists' attitudes, opinions and perceptions [23]. By determining consumers' reactions to the product, their responses could be used in the redesign of products[24]. The moderator guided the discussion as described by Meilgaard *et al.* [25]. The sessions were held as a round-table discussion at the sensory evaluation room of the Department of Food Production, University of the West Indies. The objectives of the study by focus group approach were explained to panellists. Each treatment was evaluated on colour, texture, flavour and size. Based on consensus of opinions (unstructured approach) by panellists, the processing conditions which yielded the most acceptable candied golden apples were selected for further processing variations to improve on quality.

Modified OD air-dehydration: Fig. 1 shows the steps in the OD which were applied to golden apples based on the feedback of focus groups. Hot-water blanched (95°C for 3 minutes) peeled golden apple halves were soaked in 5 g 100 g^{-1} NaCl at low (room- 24°C) temperature or in high temperature (95°C) NaCl brine with the incorporation of either 0.03 g 100 ml^{-1} brine FD&C red (R) no. 40 (adura red) or FD&C sunset yellow (Y) no. 6 (Tastemakers Ltd, Port-of-Spain, Trinidad, West Indies) for 18 hours at 24°C. The brined fruits were immersed in acidified 40°Brix sucrose/corn syrup and then in reused corn fructose/sucrose syrup adjusted to 65°Brix as in preliminary treatments. These four treatments (P5g24°CR; P5g 24°CY; P5g95°CR; P5g95°CY) were evaluated for sensory acceptance and analysed on physico-chemical and microbiological quality during storage at 24°C for 6 weeks.

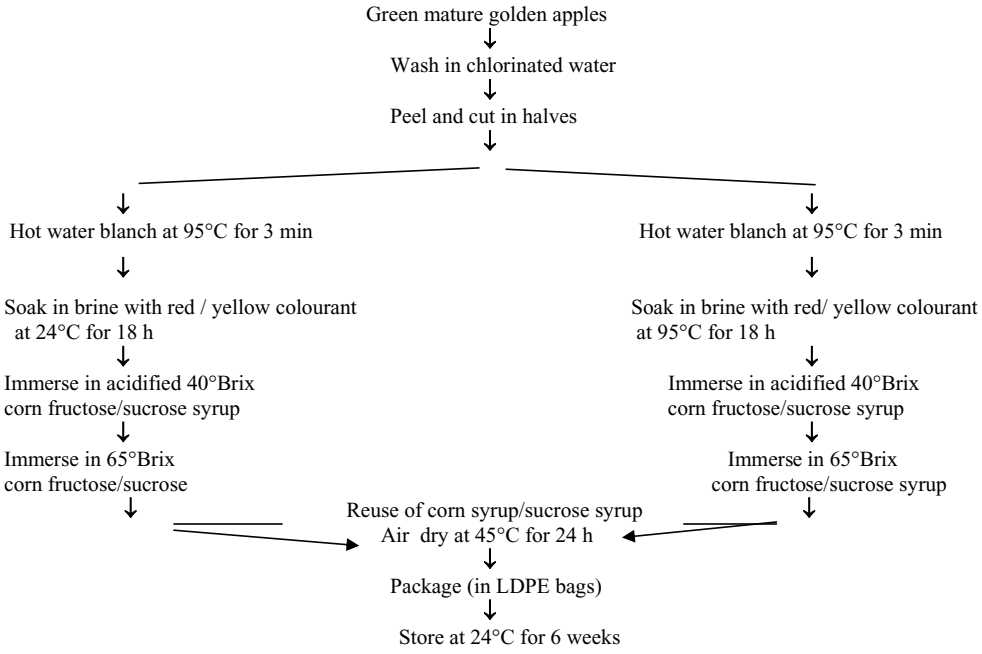

Figure 1. Flow diagram of osmo-air dehydration of golden apples.

Physico-chemical analyses: The chromatic parameters 'L', 'a' and 'b' values were measured on fresh golden apple halves and OD candied golden apples through plastic Ziplock bags at three locations. The instrument was calibrated against a white tile (Minolta calibration plate Cr A 43). Colour was measured using a Minolta Chroma Meter (model # Cr-200b Minolta Co, Japan). 'L' value represented lightness and darkness (100-white; 0-black); positive 'a' is redness, positive 'b' is yellow, negative 'a' is green and negative 'b' is blueness. The hue angles (H°) were calculated as described by Francis [26, 27] with 0, 45, 90 and 180 representing bluish red, orange, yellow and green respectively. The texture of the fruit sample was

measured using a penetrometer (Koehler Instrument Company Inc. K 19550 Series Digital Bohemia, USA). The plunger and aluminium cone used in texture evaluation had a weight of 49.5 g. The speed of the plunger was set at 1 second. Titratable acidity (TA) expressed as g 100 g^{-1} citric acid was measured on 20 g of homogenised golden apple slices with 100 ml of distilled water and titrated with 0.1 N NaOH [28]. The indicator used was phenolphthalein. Total soluble solid (TSS) determined as °Brix content was determined by a hand-held refractometer (Atago Model N-4E, 30-65°Brix and 45-82°Brix, Vee Gee Scientific Inc., Kirkland, Washington). The pH was measured at 24°C using an electronic pH meter (Hanna Instruments, model 8417, Milano, Italy) equipped with a combination of a glass electrode and a temperature probe. The salinity of brine and OD air-dehydrated golden apple was measured using a Fisher conductivity meter (model 152, Fisher Scientific Co., Fair Lawn, NJ). Salinity was expressed in NaCl g 100^{-1} ml. Moisture content (MC) of the fresh and treated fruits was determined by oven-drying at 60°C until constant weight) in the Plus II Oven (Sanyo Gallenkamp PLC, Riverside Way, Uxbridge Middlesex UB8 2YF, United Kingdom, Model 0PL075. DTIC) (Method 934.06) [29].

Microbiological analyses: Serial dilutions of samples and media plates were enumerated as outlined by Benson [30] to detect the presence of lactic acid bacteria (Tomato Juice Agar, TJA, Oxoid, Basingstoke, England), moulds and yeasts (Potato Dextrose Agar, PDA, Oxoid), *Escherichia coli* (Eosine Methylene Blue Agar EMB, Oxoid) and total aerobic mesophilic micro-organisms (Plate Count Agar, PCA; Difco, Detroit, MI). TJA, PCA and EMB plates were incubated at 35°C (Fisher Isotemp Incubator, 200 Series Model 2308, England) for 48 h and PDA plates at 28°C for 24 h. Microbiological testing on OD candied products was conducted over 6 weeks at 2-week intervals. Microbial counts were recorded as log cfu g^{-1} **.**

Hedonic testing: According to IFT/SED [31], 50-100 responses are considered desirable in consumer sensory testing. Sensory evaluation was conducted under controlled conditions at 24±1°C under fluorescent lights. The three-digit coded samples (Pg24°CR; P5g24°CY; P5g95°CR; P5g95°CY) were served in a random order to each the 50 untrained panellist to avoid presentation errors. A modified hedonic test was performed using a 1-7- structured scale with the following definitions: 7 like extremely, 6 like moderately, 5 like slightly, 4 neither dislike nor like, 3 dislike slightly, 2 dislike moderately, 1 dislike extremely [33, 34]. Panellists were asked to give their purchase intent by indicating whether they 'would definitely purchase', 'would purchase', 'may probably purchase' and 'may not purchase'. Also comments were solicited from the panellists about the candied OD golden apples.

Statistical analysis: The experimental design comprised of four treatments using peeled (P) golden apple halves which were soaked in either 5 g 100 g^{-1} NaCl brine at 24 or 95°C for 18 h with incorporation of either red (R) or yellow (Y) colourant to give 4 treatments (P5g24°CR; P5g24°CY; P5g95°CR; P5g95°CY). A 2-sample t-test determined significant differences ($P<0.05$; $P<0.01$) between peeled (P) and unpeeled (UP), low-temperature and high-temperature brining and colourants (red and yellow) on quality parameters. Effect of storage on physicochemical parameters was determined by one-way ANOVA and where the F value was significant, Fisher LSD ($P<0.05$) was used to separate means. The statistical programme employed was Minitab 13 Release for Windows, 2000 (Minitab Inc, 3081 Enterprise Drive, State College Pa 16801-3008, USA).

Results and Discussion

Utilisation of golden apples: Only 3.6% of respondents had utilised golden apples as OD candied products, thus indicating the significance of this study (Table 1). The major form of utilisation was as pickles (53.0%) with preference for a sweetened and peppered (38.0%) flavour. There was a preference for coloured (54.0%), particularly red colour (25.4%) OD air-dehydrated products over the natural coloured OD candied golden apples.

Focus group response: From the focus group evaluations, OD golden apples from low-temperature 5 g 100 g^{-1} brining had better salt-sugar balance and texture than those in 10 g 100 g^{-1} NaCl. Panellists found that OD products brined in 10 g 100 g^{-1} NaCl were 'too salty' (NaCl 2.0–3.5 g 100 g^{-1} golden apple) compared to those in 5 g 100 g^{-1} (NaCl 1.0-1.5 g 100 g^{-1} OD golden apple). Salt has the capacity to penetrate osmosed tissue to a greater depth than sucrose while the sucrose accumulates in the thin sub-surface layer of the fruits [13, 14], hence the predominance of the salty taste as highlighted by the focus groups. Katerson and Badrie [21] found that the effects of brining and debrining of dwarf golden apples were significant ($P<0.05$) on all sensory and physicochemical attributes of 'reduced sodium' hot sauces. Solute uptake during osmotic dehydration modifies the composition of the final product and provides a means of direct product formulation i.e. controlled introduction of selected solutes to enhance taste, colour, texture, stability and safety [10].

The inclusion of the peel in golden apples resulted in tough and rubbery OD candied golden apples, particularly for those unpeeled fruits in 10 g 100 g^{-1} NaCl brine. Bidaisee and Badrie [33] found that cashew apples which were brined prior to osmotic-air dehydration in sucrose syrup were firmer. The size of both peeled and unpeeled OD fruit quarters was regarded as 'too small' and found to be 'too spiny'. Upon the removal of water from the fruits after osmotic dehydration and air drying, the shrinkage of the fruit's tissues resulted in the showing of the spines and endocarp, which were unacceptable in appearance and mouthfeel. According to Lazarides et al. [11], the presence of salt in the osmotic solution can hinder the formation of the compacted surface layer, thus allowing for higher rates of water loss and solids gain. Hence fresh golden apple halves were used in the modified osmo-air-dehydration process.

Effect of pre-treatments: Tables 2 and 3 show significant differences between peeled (P) and unpeeled (UP) OD candied golden apples for TSS ($P<0.05$), texture ($P<0.01$), pH ($P<0.04$) and 'L' ($P<0.01$). Peeled candied products had higher TSS, softer texture, lower pH and were less ($P<0.01$) dark. During osmotic processing, water flows from the product into the osmotic solution, whereas osmotic solute is transferred from the solution into the product [17]. The peel of fruit can impede the flow of water and acids from readily moving in and out of the fruit [34].

Hot brining at 95°C resulted in softer ($P<0.05$) texture (deeper penetration with texture meter) and lower ($P<0.01$) pH of OD candied golden apples. Table 3 shows that brining was significant only ($P<0.05$) on hue as candied products were less orange at

Table 1. Consumer usage of golden apples.

Question	Responses,% n= 78
Do you like golden apples?	
'yes'	99.0
'no'	1.0
Would you consume osmo-dehydrated golden apples, if they were osmo-air dehydrated?	
'yes'	68.0
'no'	28.0
'no response'	4.0
In which forms would you prefer to utilize golden apples?	
Pickled salted and peppered; commonly known as 'chow'	53.0
Fresh fruit	23.0
Amchar (Indian pickle)	5.0
Curried	5.0
All forms	6.0
No form	4.0
Candied (OD products)	3.6
Would you consume golden apples or pommecythere, it they were osmo/air dehydrated?	
'yes'	68.0
'no'	28.0
'no response'	4.0
Preferred flavour of candied product	
Sweetened/peppery	36.0
Sweetened/salted/peppery	26.0
Sweetened	15.0
Peppery	10.0
Salted /sweetened combination	4.0
Salted/peppery combination	4.0
Would you prefer to have a coloured osmo-air dehydrated product?	
'yes'	54.0
'no'	38.0
'no response'	8.0
If , there is a preference for a coloured product, which colour ?	
Red	25.4
Yellow	21.0
Green/natural	2.2
Other	3.8

95°C than at 24°C. Blanching and high process temperatures favour solids uptake yielding lower water loss/sugar gain ratios[35]. Elevated temperature of the osmotic solution (e.g. brine) above 60°C can lead to the denaturation of the cell and leaching of the cell contents [36]. Exposure to temperature below 50-60°C could result in only partial removal of cell contents via osmosis until equilibrium was met [36]. Brining, a method similar to osmotic dehydration [13, 14] causes leaching of fruit acids. Sucrose uptake and mass transfer have been positively correlated to the increase in process temperature [40]. However, there was no significant ($P>0.05$) difference in TSS due to brining temperature (Table 2). It can cause the leaching of nutrients and substance such as fruit acid [34].

The moisture loss from osmotic-dehydration was between 35-40% which increased to 65-70% on air-convection drying. Pretreatment before OD has been reported to facilitate greater moisture removal during dehydration and also to improve on the quality of the dried product [38, 39]. Product treatments and process conditions affecting the integrity of natural tissue have a severe effect on mass exchange [11]. Disruption of structural barriers improves water and solute diffusivities within the product, resulting in faster equilibration in favour of higher solute uptake. According to Torreggiani and Bertolo [40], a partial dehydration step is useful to set the ingredients in the required moisture range,

Table 2. Effect of pre-treatments on physicochemical quality of osmo-air-dehydrated golden apples.

Parameter	TSS (°Brix)	Texture cm/s	pH
Fresh golden apples			
Peeled (P)	8.10	1.6	3.60
Unpeeled (UP)	8.80	1.7	3.58
SEM	0.10	0.01	0.01
P value	0.10	0.09	0.10
OD -dehydrated			
Peeled (P)	73.50	2.33	3.57
Unpeeled (UP)	54.75	2.16	3.61
SEM	0.38	0.06	0.02
P value	0.02*	0.00**	0.04*
Brining			
Low temp, 24°C	74.83	2.04	3.41
High temp, 95°C	75.08	2.44	3.38
SEM	0.46	0.00	0.02
P value	0.26n.s	0.02*	0.00**
Storage, wk			
0	73.58^{b}	2.32^{a}	3.45^{a}
4	74.50^{b}	2.37^{a}	3.44^{a}
6	76.33^{a}	2.15^{b}	3.33^{b}
SEM	0.26	0.02	0.01
Level of significance	0.00**	0.00**	0.00**

SEM standard error of mean ; * significant at $P<0.05$; ** significant at $P<0.01$ n.s.not significant. Means in columns with different superscripts are significantly different ($P<0.05$). TA of fresh fruit; 0.43-0.82% citric acid ; peeled OD 0.37-0.64% citric acid, unpeeled OD-0.42-0.63% citric acid.

whereas a finer adjustment of water activity, sensory properties and other functional properties is better achieved by the osmotic dehydration step. At high sugar concentrations, an additional increase in concentration (above 65%) did not promote faster weight loss [41]. The higher weight reduction after the drying process indicated that during osmotic dehydration, there was partial water removal process [41, 42]. Depending on raw material properties, osmotic solution characteristics and process duration up to 70% of the initial water can be removed from a plant tissue by osmotic dehydration [11]. The osmo-air dehydrated products had 23.9-27.4 g 100 g^{-1} moisture.

The titratable acidity was citric acid 0.60 g 100 g^{-1} fresh golden apple and 0.35-0.63 g 100 g^{-1} OD candied golden apple. Ponting et al. [41] indicated that the decrease in acidity in the osmotic dehydration of fruits can be remedied by adding a fruit acid to the osmotic medium. However, the addition of citric acid did not restore the citric acid less during processing.

Effect of storage: On storage ($P<0.01$), TSS increased, texture became firmer and pH decreased (Table 2). Table 3 shows that by week 4 of storage at 24°C, there were significant changes in all colour parameters except hue. Colour became more intense yellow. On storage OD preserves attributes such as colour, texture and aroma [43] and reduces water activity, providing high moisture products (Aw = 0.92 to 0.97) [44] and extended shelf-life [45].

Microbiological analysis: All OD candied products had less than 10 cfu g^{-1} for each microbial type during the storage period at 24°C for 6 weeks. For confectionery products moulds and yeasts should not exceed 100 cfu g^{-1} and aerobic plate count should be less than 10 cfu g^{-1} [46]. The low microbial count of OD candied golden apples may be due to low pH, intermediate moisture and high TSS.

Table 3. Effects of pre-treatments and storage on colour of golden apples.

Treatment	'L'	'a'	'b'	Chroma	Hue^{o}
Fresh peeled	48.49±0.24	-9.23 ± 1.92	27.13 ± 2.97	28.88± 2.47	90.73±14.67
Fresh unpeeled	66.83±0.93	-1.33±1.11	20.90 ± 0.92	21.00 ± 0.93	93.51±3.08
P value	0.00	0.39	0.16	0.08	0.88
Osmo-dehydration					
Peeled	50.08±0.23	2.03±0.18	19.73±0.26	21.37±1.25	77.95±3.76
Unpeeled	46.67±0.08	0.26±0.04	19.08±0.15	19.14±0.94	88.55±0.94
P value	0.01	0.10	0.30	0.01	0.00
Temp ^{o}C brining					
24	40.93± 0.43	6.96±1.15	5.25±1.80	7.00± 1.13	43.19 ± 15.60
95	41.70±0.43	5.49± 0.44	4.25±0.95	5.49± 0.44	56.02 ± 12.56
P value	0.36	0.11	0.27	0.09	0.02
Storage					
0	41.32^{a}±0.31	2.79^{b}±0.47	4.75^{c}±0.98	6.24^{c}±0.62	49.61^{c}± 9.75
2	40.93^{a}±0.35	2.76^{b}±0.50	4.98^{c}± 1.02	6.47^{c}±0.66	52.48^{b}± 9.04
4	39.13^{b}±0.64	3.96^{a}±0.85	6.54^{b}±0.84	8.44^{b}±0.51	57.79^{a}±7.75
6	30.91^{c}±1.11	6.35^{a}±1.51	13.67^{a}±0.66	13.14^{a}±1.11	57.14^{a}± 6.70
P value	0.00	0.03	0.00	0.00	0.88
Colourant					
Yellow	41.03±0.46	1.38±0.33	7.81±0.67	22.31±1.58	91.78±1.91
Red	41.70±0.43	9.00±2.17	3.35±0.95	19.31±1.41	52.56±5.73
P value	0.35	0.03	0.04	0.02	0.00

Means ± SE with different superscripts were significantly different (P<0.05)

Table 4. Effects of temperature of brining and colour addition on hedonic scores of sensory attributes of osmo-dried golden apples.

Treatment	Appearance	Colour	Flavour	Texture	Overall acceptance
Temp ^{o}C, Brining					
24	5.84	5.84	5.73	5.79	5.80
90	6.47	6.24	6.42	6.06	6.30
SEM	0.09	0.96	0.09	0.10	0.30
Level of significance	0.00**	0.00**	0.00**	0.03*	0.02*
Colourant					
FD& C Yellow	6.02	5.80	6.03	5.79	5.91
FD& C Red	6.29	6.28	6.12	6.06	6.19
SEM	0.09	0.09	0.09	0.10	0.09
Level of significance	0.03*	0.01**	0.51n.s	0.06 n.s	0.03*

** P<0.01; *P<0.05; n.s not significant; 7 like extremely; 6 like moderately; 5 like slightly; 4 neither like nor dislike; 3 dislike slightly; 2 like moderately; 1 dislike extremely

Sensory acceptance: Table 4 shows that brining temperature was significant on all sensory attributes of osmo-air-dehydrated products with higher overall sensory acceptance for products from hot brining at 95 C (6-7 like moderately to extremely) compared to lower-temperature (24^{o}C) brining (5-6 like slightly to moderately). Higher temperature brining resulted in softer (Table 2) and a more desirable sensory texture (Table 4). Panellists commented that OD candied golden apples from low temperature brining were 'too crunchy'.

Table 4 shows that panellists favoured more the red coloured OD candied golden apples for appearance (P<0.05), colour (P<0.01) and overall acceptance (P<0.05) than the yellow-coloured products. The higher sensory acceptance for red-coloured OD candied products ('L' 41.70±0.43, 'C' 19.31±1.41, H^{o} 57.14± 6.70; Table 3) was also reflected by the 25.4% preference for red colourant (Table 1). Of all the respondents in the survey, 68.0% indicated that they would purchase the red-coloured OD products if available on the market. The overall sensory acceptance of the red-coloured OD candied product was 6.19 (liked moderately to extremely). Solute uptake and leaching of natural acids, colour and flavour compounds out of osmo-dehydrated plant tissue affect sensory properties, since they modify (to a certain extent) its natural composition [38, 47]. Osmotic pre-treatment contributes to retention of flavour in convectively dried fruits, making them more acceptable as ready-to-eat snacks compared to totally air-dried products [11]. They have better texture and lower shrinkage compared to traditionally dried products.

Conclusions

From the survey, 68% consumers reported that they would consume OD candied golden apples, if available on the market. Hot-brined, red-coloured OD candied golden apples had higher overall acceptability (liked moderately to extremely) than yellow-coloured products from low-temperature brining (liked slightly to moderately). Hot-brining of fruit halves resulted in softer-textured products compared to low-temperature brining. Products were microbiologically stable (<10 cfu g^{-1}) due to the intermediate moisture content, high TSS and low pH. Colour changes were significant (P<0.05) from week 4 of storage at 24^{o}C.

Acknowledgements

We acknowledge the technical assistance of Ms Vidya Bridgebassie, Mr. Esau Mohammed and Mr. Christopher Garcia of the Microbiology Laboratory and the statistical assistance of Mr. Bruce Laukner of the Caribbean Agricultural Research Development (CARDI).

References

[1]Daulmerie, S. 1994a. Possibilities for processing golden apple. Proceedings of the Third Regional Workshop on Tropical Fruits, St. George's Grenada, 16-20 May, 1994. Port-of-Spain, Trinidad and Tobago. Inter-American Institute for Cooperation on Agriculture (IICA), Port-of-Spain, Trinidad, West Indies, pp. 155-157.

[2]Winsborrow, C. 1994. Golden apple production. Proceedings of the Third Regional Workshop on Tropical Fruits, Grenada, 16-20 May, 1994. Inter-American for Cooperation on Agriculture (IICA), Port-of-Spain, Trinidad and Tobago, pp. 113-114.

[3]Persad, C. 1997. Golden apple, *Spondias cytherea* tree. Tropical Fruits Newsletter **23**:11-13.

[4]Morton, J.F. 1987. Fruits of Warm Climates. Media Incorporated, Greensboro, North Carolina, USA.

[5]Popenoe, J. 1979. The genus *Spondias* in Florida. Proc. Florida Hort. Soc. **92**:277-279

[6]Bauer, T., Kim, J. and Baldeo, I. 1993. A preliminary study on the golden apple (*Spondias dulcis*). Production and Marketing. International Institute for Cooperation on Agriculture (IICA), St. George's, Grenada, pp. 8-10.

[7]Andall, R.P. and Baldeo, S. 2000. The effect of fruit and inflorescence pruning on fruit size and yield of dwarf golden apple (*Spondias cytherea* Sonn.). Tropical Fruits Newsletter **36**/**37**:12-14.

[8]Ramsundar, D., Comissiong, E., Badrie, N., Baccus-Taylor, G. and Spence, J. 2002. Processing and quality evaluation of whole canned 'dwarf' golden apples *(Spondias cytherea*). Journal of Food Quality **25**(1): 13-25.

[9]Daulmerie, S. 1994b. Investigations on Golden Apple (*Spondias cytherea*). Production with Particular Reference to Post-harvest Technology and Processing. Inter-American Institute for Cooperation on Agriculture, Port-of-Spain, Trinidad, West Indies, pp. 1-53.

[10]Oliveira, F.A.R., Lino, I.B.M. and Oliveira, J.C. 1999. Process optimization and minimal processing of foods: an international approach in the framework of the EU Copernicus program. In Oliveira, F.A.R. and Oliveira, J.C. (eds). Processing Foods: Quality Optimization and Process Assessment. CRC Press, Boca Raton, pp. 1-11.

[11]Lazarides, H.N., Fito, P., Chiral, A., Gekas, V. and Lenart, A. 1999. Advances in osmotic dehydration. In Oliveira, F.A.R. and Oliveira, J.C. (eds). Processing Foods. Quality Optimization and Process Assessment. CRC Press LLC, New York, pp. 175-199.

[12]Moyano, P.C. and Zúñiga, R.N. 2003. Kinetic analysis of osmotic dehydration carried out with reused sucrose syrup. Journal of Food Science **68**(9):2701-2704.

[13]Lenart, A. and Flink, J. M. 1984a. Osmotic concentration of potato. 1. Criteria for end point of osmosis process. Journal of Food Technology **19**:45-63.

[14]Lenart, A. and Flink, J.M. 1984b. Osmotic concentration of potato 11. Spatial distribution of the osmotic effect. Journal of Food Technology **19**:65-89.

[15]Torreggiani, D. 1993. Osmotic dehydration in fruit and vegetable processing. Food Research International **26**:59-68.

[16]Salvatori, D. and Alzamora, S.M. 2000. Structural changes and mass transfer during glucose infusion of apples as affected by blanching and process variable. Drying Technology **18**:361-382.

[17]Talens, P., Escriche, I., Martinez-Navarrete, N. and Chiralt, A. 2002. Study of the influence of osmotic dehydration and freezing on the volatile profile of strawberries. Journal of Food Science **67**(5):1648-1653.

[18]Dixon, G.M. and Jen, J.J. 1977. Changes of sugars and acids of osmovac-dried apple slices. Journal of Food Science **42**:1126-1127.

[19]Riva, M., Campolong, Leva, A.A., Maestrelli, A. and Torreggiani, D. 2005. Structure-property relationships in osmo-air-dehydrated apricot cubes. Food Research International **38**(4):533-542.

[20]St.Louis, C. and Badrie, N. 2002. Production of a fruit based hot sauce using golden apples *(Spondias cytherea*) in the Caribbean: Effects of peel addition, brining and storage on quality of sauces. Journal of Food Quality **25**(6):519-532.

[21]Katerson, A. and Badrie, N. 2002. Sensory and physico-chemical quality of 'reduced sodium' hot sauces from 'dwarf' golden apples (*Spondias cytherea*, Sonn.). Journal of Food Science **67**(9): 3476-3483.

[22]Lawless, H.T. and Heymann, H. 1998. Acceptance and preference testing. Sensory Evaluation of Foods: Principles and Practices. Chapman and Hall, New York, pp. 430-479.

[23]Chambers, E. IV. and Smith, E.A. 1991. The uses of qualitative research in product research and development. In Lawless, H.T. and Klein, B.P. (eds). Sensory Science Theory and Applications in Foods. Marcel Dekker, New York, pp. 395-412.

[24]Fuller, G.W. 1994. New Food Product Development from Concepts to Marketplace. CRC Press, Boca Raton, Florida, pp. 69-124.

[25]Meilgaard, M., Civille, G.V. and Carr, B.T. 1991. Sensory Evaluation Techniques. CRC Press, Boca Raton, Florida, pp. 209-210.

[26]Francis, E.J. 1989. Food colourants: Anthocyanins. Critical Reviews in Food Science and Nutrition **28**(4):273-314.

[27]Francis, E. J. 1998. Colour analysis. In Nielsen, S.S. (ed.). Food Analysis. An Aspen Publisher Inc., Gaithersburg, Maryland, pp. 599-612.

[28]Gould, W.A. 1978. Food Quality Assurance. The AVI Publishing Company, Westport, Connecticut, pp. 270-282.

[29]AOAC 1997. Moisture in fruits. Association of Official Analytical Chemists. 16th ed. Association of Analytical Chemists International (AOAC), Gaithersburg, MD.

[30]Benson, H.J. 1990. Microbiological Applications: A Laboratory Manual in General Microbiology. Wm.C. Brown Publishers, Dubuque, pp. 70-92.

[31]IFT/SED 1981. Sensory evaluation guideleine for testing food and beverage products. Food Technology **35**:50-59.

[32]Peryam, D.R. and Pilgrim, F.J. 1957. Hedonic scale method of measuring food preferences. Food Technology **11**(9): 9-14.

[33]Bidaisee, G. and Badrie, N. 2001. Osmotic dehydration of cashew apples (*Ancardium occidentales*): quality evaluation of candied cashew apples. International Journal of Food Science and Technology **36**(1): 71-78.

[34]Brenndorfer, B., Kennedy, L., Bateman-Oswin, C.O., Trim, D.S., Mrema, G.C. and Brobby-Wereko, C. 1987. Solar Dryers: their Role in Post-harvest Processing. The Commonwealth Secretariat, London, pp. 8–12, 16-18.

[35]Ponting, J.D. 1973. Osmotic dehydration of fruits – recent modifications and applications. Process Biochemistry **8**(12):8-20.

[36]Spiess, W.E.L., Behsnilian, D., Ferrando, M., Gaiser, M., Gartner, U., Hasch, M., Mayer-Miebach, E., Rathjen, A. and Waltz, E. 2002. Mass transfer and related phenomena in plant tissues during heat treatment and osmotic stress. In Welti-Chanes, J., Barbosa-Cánovas, G.V. and Aguilera, J.M. (eds). Engineering and Food for the 21st Century. CRC Press LLC, Boca Raton, Florida, pp. 177-191.

[37]Barbosa-Cánovas, G.V. and Vega-Mercado, H. 1996. Dehydration of Foods. Chapman and Hall, New York, US, pp. 265-288.

[38]Lazarides, H.N., Nicolaides, A. and Katsanidis, E. 1995. Sorption behaviour changes induced by osmotic preconcentration of apple slices in different osmotic media. Journal of Food Science **60**(2):348-350, 359.

[39]Tregunno, N.B. and Goff, H.D. 1996. Osmodehydrofreezing of apple, structural and textural effect. Food Research International **29**(5-6):471-479.

[40]Torreggiani, D. and Bertolo, G. 2001. High quality fruit and vegetable products using combined processes. In Fito, P. and Chiralt, A. (eds). Osmotic Dehydration and Vacuum Impregnation. Technomic Publishing Co. Inc., Pensylvania, pp. 3-9.

[41]Ponting, J.D., Watters, G.G., Forrey, R.R., Jackson, R. and Stanley, W.L. 1966. Osmotic dehydration of fruits. Food Technology **29**(10):125-128.

[42]Farkes, D.F. and Lazar, M.E. 1969. Osmotic dehydration of apple pieces. Effect of temperature and syrup concentrations on rates. Food Technology **23**:688-690.

[43]Heng, K., Guilbert, S. and Cuq, J. 1990. Osmotic dehydration of papaya: Influence of process variables on the product quality. Sci. Aliment. **10**: 831-848.

[44]Leistner, L. 1995. Use of hurdle technology in food processing. Recent advances. In Barbosa-Cánovas, G. V. and Welti-Chanes, J. (eds). Food Preservation by Moisture Control. Fundamentals and Applications. Isopow Practical 11, Technomic Publication, Lancaster, Pa, pp. 377-396.

[45]Wiley, C.R. 1994. Minimally processed refrigerated fruits and vegetables. In Barbosa-Cánovas, G.V. and Welti-Chanes, J. (eds). Food Preservation by Moisture Control. Fundamentals and Applications. Isopow Practical 11, Technomic Publishing Company, Lancaster, Pennsylvania, pp. 66-127.

[46]Konkel, P.J. 2001. Confectionary products. In Pouch, F. and Dowles, K.T.O. (eds). Microbiological Examination of Food. Public Examination of Food, Washington, D.C., pp. 555-588.

[47]Lenart, A. 1991. Sorption properties of apples and carrot preserved by osmo-convection method. Food Technology and Nutrition **19**:27–35.