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Influence of sugar composition and air dehydration levels on the chemical–physical characteristics of osmodehydrofrozen fruit

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Osmodehydrofreezing, a 'combined' process where osmotic dehydration is followed by air dehydration and freezing, has been proposed to prepare reduced-moisture fruit ingredients, free of preservatives, with a natural and agreeable flavour, colour and texture, and with functional properties suitable for different applications. The influences of syrup composition and air dehydration level on the chemical–physical properties of osmodehydrofrozen apricot and clingstone peach were studied. The presence in the syrup of sorbitol, known as a humectant, produced a lower solid gain, a higher weight reduction and a lower consistency in osmodehydrated apricot and peach cubes. The use of this sugar-alcohol, in addition to other sugars as osmotic agents, could lead to fruit products with good rehydratability properties to be used as ingredients in bakery products, ice cream or yoghurt.

INTRODUCTION

Osmodehydrofreezing is a 'combined' process where a limited air-dehydration step is preceded by an osmotic treatment in sugar solution to obtain fruit products, at reduced water activity, to be stored at freezing temperature (Torreggiani *et al.*, 1988). These products are then free of preservatives, maintain their natural flavour and colour and have an agreeable texture. Osmodehydrofreezing has been proposed for the preparation of fruit ingredients at reduced moisture with functional properties suitable for different applications. Maltini *et al.*, (1992) found, for reduced-moisture fruit, a correlation between the square of the percentage of insoluble solids and the consistency: owing to the soluble solids intake during osmosis, the percentage of insoluble solids decreases leading to products that, at the same water activity as air-dehydrated fruit, are softer.

As recently reported by Torreggiani *et al.*, (1991), osmodehydrofrozen apricot and clingstone peach cubes were used in the production of fruit yoghurt to avoid whey separation through a controlled rate of moisture uptake by the partially dehydrated fruit pieces.

The chemical composition of osmodehydrated fruit, influenced by the nature of sugars as osmotic solute (Maltini *et al.*, 1990), could modify their functional properties. The use of sorbitol, which is of growing interest in drying processes for antibrowning (Labuza & Warren, 1976) and as a humectant (Zimmermann, 1989), could give dried products with higher humidity but with the same water activity.

The aim of the present work is to study the influence of syrup composition and air-dehydration levels on the chemical—physical characteristics of osmodehydrofrozen apricot and clingstone peach.

MATERIALS AND METHODS

Raw material

Apricots (*Prunus armeniaca* L., cv. Tonda di Costigliole) and clingstone peaches (*Prunus persica* L., cv. Baby Gold 6) were used.

Apricots were halved and stoned, clingstone peaches were lye-peeled (7% NaOH at 80°C for 40 s), halved and stoned. The fruits were then cut into 10 mm cubes (Dicer, Bertuzzi, Brugherio, Milan, Italy).

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Processing

Osmotic dehydration
Fruit cubes were osmodehydrated in a fructose (Cerestar, Ferrara, Italy) syrup or in a fructose–sorbitol, ratio 2 : 1 (Merck), syrup. Both syrups were at 70°Bx and contained 1% ascorbic and 0·2% citric acid as antioxidants. Osmodehydration was conducted at 45°C for 30 min, the fruit to syrup ratio was 1 : 3 and the syrup was continuously recirculated using a peristaltic pump.

Air dehydration
Osmodehydrated fruit cubes were dried in an upward air-circulated drier (Simplicior mod. BABCOCK-BSH, Badhersfeld, D) at a dry-bulb temperature of 65°C and at an air speed of 1·5 m/s. Three levels of solids content were obtained, corresponding to water activity values of 0·90 (DI), 0·82 (DII) and 0·75 (DIII).

Freezing and storing
Freezing was carried out by an air-blast tunnel at −40°C and 4 m/s air speed. The frozen products were packaged in sealed polyethylene plastic bags and stored at −20°C.

Analysis

Dry matter, pH and total titrable acidity (meq/100 g DM) were determined in accordance with AOAC (1980).

Refractometric index (°Bx) were measured with a Refractometer RFM 81 (BS-Instruments, UK).

Water activity (a_w) as equilibrium vapour pressure/100 was measured by using a Termocostanter Hygrometer (NovaSina, Zurich, Switzerland).

Sugars were quantified by HPLC on a Polyspher CHCA (Merck) column (0·65 × 30 cm) at 90°C eluting with deionised water, with a Jasco 830 RI refractometric detector (Forni *et al.*, 1992).

Alcohol-insoluble solids (AIS) were determined according to Barbier and Thibault (1982).

Texture was measured using an Instron model 1140 Universal Testing Machine measuring the maximum force (kg) with a standard Shear Press Cell Model CS1, with a crosshead spead of 20 cm/min, on 30 g of fruit cubes. The data reported are the averages of five determinations.

Colour measurements were made by means of a Minolta Chroma Meter CR 2000. Reported data are the means of 25 determinations. From *L*, *a*, *b*, values the colour attributes of hue (a/b) and saturation ($\sqrt{a^2 + b^2}$) were calculated (Hunter, 1975). Analysis of variance and Duncan's multiple range test were used to determine statistically significant differences ($P \leq 0{\cdot}05$) (Larmond, 1977).

The analysis were conducted on fresh fruits, and on fruit cubes, both after osmodehydration and air-dehydration.

Osmotic dehydration Parameters

Following Hawkes and Flink (1978), solids gain (SG), water loss (WL) and material balance (Cp) were calculated by the following formulas:

$$SG = \frac{WS + WS_0}{WS_0 + WW_0} \times 100$$

$$WL = \frac{WW_0 - (TW - WS)}{WS_0 + WW_0} \times 100$$

where WW_0 is the weight of the water initially present, WS_0 the initial weight of solids, TW the weight of the fruit and WS the weight of solids in the fruit at the end of the process.

$$Cp = \frac{Ct - Co}{P_0} \times 100$$

where Co and Ct are the concentrations of the component C in the fruit cubes before and after the osmodehydration process, respectively.

RESULTS AND DISCUSSION

The compositions of raw apricot and clingstone peach are in Table 1. Apricot have a higher total titrable acidity and a higher sucrose and glucose content than peach. The fruit compositions are in the range of the values previously observed in raw apricot and peach processed by osmodehydration (Giangiacomo *et al.*, 1987; Senesi *et al.*, 1991).

Water loss, solids gain, and weight reduction of the fruits after osmodehydration in fructose (F) and in fructose–sorbitol (FS) syrups are shown in Table 2. Water loss is not influenced by the syrup composition, while lower solids gains were obtained for apricot and peach when osmodehydrated in FS syrup. As shown in Table 3, where the exchanges of the components between fruit and extracting syrup are reported, the lower solids gain is due to a lower intake of fructose not totally replaced by the sorbitol intake. Because of this, total sugars uptake is higher for both types of fruit osmodehydrated in fructose syrup. It can therefore be concluded that the use of sorbitol as an osmotic substance, together with fructose, does not influence the dehydration power of the syrup but reduces the solids gain of the fruit so achieving a higher weight loss.

Table 1. Raw fruit composition (% fresh weight)

	Apricot	Clingstone peach
Dry matter	13·75	12·90
°Bx	12·08	10·48
Titrable acidity[a]	22·0	6·62
Sucrose	3·66	3·48
Glucose	1·77	1·25
Fructose	0·92	0·92
Sorbitol	0·29	0·29
Total sugars	6·64	5·94

[a] meq/100g.

Table 2. Water loss (WL), solids gain (SG) and weight reduction (WR) of fruits after osmodehydration[a]

	Apricot		Clingstone peach	
	F	FS	F	FS
WL	32·1	32·9	37·7	37·0
SG	7·7	5·8	8·8	7·8
WR	24·4	25·5	29·4	31·1

[a] F, osmodehydration in fructose syrup; FS, osmodehydration in fructose/sorbitol syrup.

Table 3. Material balance (Δ Cp) during osmodehydration[a]

	Apricot		Clingstone peach	
	F	FS	F	FS
Titrable acidity	−0·34	−0·44	−0·06	−0·03
Total sugars	6·90	5·98	6·03	5·08
Sucrose	−0·57	−0·25	−0·98	−0·55
Glucose	−0·01	−0·12	−0·27	−0·28
Fructose	7·50	4·39	7·38	4·15
Sorbitol	−0·02	1·96	−0·10	1·76

[a] F, osmodehydration in fructose syrup; FS, osmodehydration in fructose/sorbitol syrup.

Water loss (WL) and solid gain (SG) are slightly higher in the clingstone peach than in the apricot cubes, leading to a higher weight reduction (WR).

Total titrable acidity decreases in both fruits (Table 3) during the osmosis. Apricot and peach contain, on average, 0·66 and 0·34% of citric acid, respectively, while the ascorbic acid is 0·016 and 0·011%, respectively (Wills, 1987). So, since the syrup contains 1% ascorbic acid and 0·22% citric acid, the loss of acidity could be due to a balance between the loss of malic and citric acids and the intake of ascorbic acid (Forni *et al.*, 1990). The decrease of acidity of apricot, already observed by Dixon and Jen (1977) and by Torreggiani *et al.* (1986), is higher than in peach: apricot cubes show a decrease of 0·34–0·44% on the initial fruit weight, (25–30% of the initial acidic content), while peach has a decrease of 7–14% of the initial acidic content.

Water activity (a_w), dry matter percentage and total titrable acidity of the fruit after osmodehydration and after air-drying are shown in Table 4. The fructose/sorbitol-osmodehydrated peach shows a lower dry matter at the same a_w, when compared with the fructose peach. Zimmermann (1989) observed that, because of the interaction between sugars-alcohols and water, the presence of sorbitol in the fruit gives products with a higher humidity but with the same a_w. In apricot, the presence of sorbitol did not influence the a_w after osmodehydration, but only after air-dehydration. To compare dried fruit cubes with and without sorbitol, the curves calculated from the a_w data as a function of dry matter for apricot and peach were calculated ($a_w = K\,RS^n$). For both apricot and peach air-dehydrated after osmosis in fructose–sorbitol syrup an upward-sloping curve is exhibited meaning that in the presence of sorbitol small variations of dry matter are accompanied by higher modifications of a_w. The values of K and n are, respectively: apricot F, 5·85 and −0·47; apricot FS, 8·87 and −0·57; peach F, 4·09 and −0·38; peach FS, 5·94 and −0·47.

As shown in Table 5, for apricot and Table 6 for clingstone peach, neither the sugar content or dry weight, nor the relative sugar ratios are modified by the air-dehydration.

Table 4. Water activity (aw), dry matter (% DM) and titrable acidity (AC, meq/100 g dry wt)[a]

	Apricot						C. peach					
	F			FS			F			FS		
	a_w	DM	AC	a_w	DM	AC	a_w	DM	AC	a_w	DM	AC
Osmodehydrated	0·97	28·4	77·8	0·97	28·3	71·5	0·96	30·2	26·6	0·96	27·3	32·8
Air-dehydrated												
DI	0·91	54·1	106	0·93	51·2	113	0·91	50·7	32·9	0·90	54·9	40·1
DII	0·84	62·3	105	0·84	63·8	111	0·85	63·4	40·5	0·84	66·2	39·8
DIII	0·80	71·3	110	0·75	74·2	92·5	0·80	70·1	32·1	0·79	71·5	39·0

[a] F, osmodehydration in fructose syrup; FS, osmodehydration in fructose/sorbitol syrup; DI, DII, DIII, different dehydration levels.

Table 5. Sugar composition (on a dry weight basis) of apricot after osmodehydration and after air-drying[a]

	F				FS			
	O	Di	DII	DIII	O	DI	DII	DIII
Sucrose	21·8	23·3	23·2	22·3	20·3	22·1	21·6	21·6
Glucose	9·04	9·10	9·00	10·5	8·72	9·00	9·43	9·05
Fructose	43·4	40·0	39·4	41·5	28·0	26·6	29·0	29·3
Sorbitol	1·63	1·20	1·37	1·45	11·9	12·1	12·1	12·0
Total sugars	75·9	73·6	73·0	75·8	69·0	69·8	72·1	72·0

[a] F, osmodehydration in fructose syrup; FS, osmodehydration in fructose/sorbitol syrup; O, osmodehydrated apricot; DI, DII, DIII, different dehydration levels.

Table 6. Sugar composition (on a dry weight basis) of clingstone peach after osmodehydration and after air-drying[a]

	F				FS			
	O	Di	DII	DIII	O	DI	DII	DIII
Sucrose	26·5	22·2	23·4	24·1	27·5	22·9	24·5	25·6
Glucose	5·04	8·57	8·95	8·67	5·31	7·42	7·55	7·57
Fructose	43·2	50·7	49·3	49·4	27·8	30·3	28·2	30·2
Sorbitol	0·97	0·10	0·10	0·10	11·3	12·3	11·5	11·5
Total sugar	75·7	81·65	81·8	82·3	71·9	72·9	71·8	74·9

[a] F, osmodehydration in fructose syrup; FS, osmodehydration in fructose/sorbitol syrup; O, osmodehydrated apricot; DI, DII, DIII, different dehydration levels.

Table 7. Consistency (kg) and AIS (%) data of raw and processed fruit[a]

	Apricot		Peach	
	Consistency	AIS	Consistency	AIS
Raw fruit	46·5 c	2·70 a	40·1 c	2·02 a
F	56·6 a	3·57 b	59·0 a	2·83 b
FS	48·5 b	3·62 b	48·4 b	2·90 b

[a] F, osmodehydrated in fructose syrup; FS, osmodehydrated in fructose/sorbitol syrup.
Mean values in the same column followed by different letter are significantly different ($P \leq 0{\cdot}05$).

The consistency of apricot and clingstone peach increased after the osmotic treatments (Table 7). Even if a_w and dry matter of the apricot after F and FS osmodehydration were similar, fructose–sorbitol apricots were softer. Maltini *et al.* (1992) observed, in osmodehydrated fruit, a linear correlation between the insoluble matter, expressed as % AIS, and the consistency. From our data, because F and FS osmodehydrated fruit have a different texture even if the % AIS contents are similar, a specific influence of the sorbitol on the consistency could be hypothesised. For peach, the lower consistency of FS osmodehydrated fruit could also be due to a lower dry matter content.

These phenomena could confirm the importance of sorbitol in dried products as a humectant; the role of this sugar-alcohol in the rehydratability of dried fruit and in the definition of consistency must be further ascertained.

Colour data, lightness (*L*), hue and saturation are shown in Table 8 for apricot and Table 9 for peach. During processing the behaviour is similar between apricot osmodehydrated in fructose or in fructose–sorbitol. Lightness decreases throughout processing while saturation increases after osmotic dehydration and diminishes during air-drying. Hue increases during processing because the yellow component increases (a, data not reported) leading to a deeper orange colour. Hue values of apricot treated in fructose–sorbitol are lower than the values of apricot treated in fructose. For both F and FS peach products, osmodehydration produces an increase of lightness and saturation. Air-dehydration produces an increase of the lightness but saturation and hue diminish because of the increase of the yellow component.

CONCLUSION

The presence of the sorbitol in the syrup leads to a lower solid gain and a higher weight reduction in both apricot and peach. Even though apricot and clingstone peach treated with syrup with or without sorbitol have the same ratio between soluble and insoluble solids, the fruits osmodehydrated in fructose—sorbitol syrup are softer than the fruits osmodehydrated in fructose. The proposed process, in which a limited dehydration step is

Table 8. Colour attributes of apricot[a]

	L	Hue	Saturation
Raw fruit	46.2 a	029 f	30.4 c
F	43·4 b	0·34 f	38·5 c
DI	40·2 cd	0·45 d	20·1 e
DII	40·1 cd	0·50 bc	20·9 de
DIII	39·4 d	0·53 b	19·4 e
FS	47·0 a	0·30 g	36·3 b
DI	41·4 c	0·40 e	22·7 e
DII	40·54 cd	0·46 cd	20·6 e
DIII	37·2 e	0·55 a	15·6 f

[a] F, osmodehydrated fruit in fructose syrup; FS, osmodehydrated fruit in fructose/sorbitol syrup.
Mean values in the same column followed by different letter are significantly different ($P \leq 0{\cdot}05$).

Table 9. Colour attributes of peach[a]

	L	Hue	Saturation
Raw fruit	36·7 e	10·1 f	64·7 c
F	41·1 d	4·60 b	70·7 a
DI	48·7 c	0·37 c	32·4 d
DII	49·3 c	0·35 c	33·6 d
DIII	49·4 c	0·31 c	33·2 d
FS	41·0 d	3·82 b	71·9 a
DI	52·2 a	0·28 c	36·8 c
DII	49·6 bc	0·33 c	33·0 d
DIII	51·1 ab	0·31 c	37·0 c

[a] F, osmodehydrated fruit in fructose syrup; FS, osmodehydrated fruit in fructose/sorbitol syrup.
Mean values in the same column followed by different letter are significantly different ($P \leq 0{\cdot}05$).

preceeded by an osmotic treatment in sugar solutions, could be improved by using sorbitol; softer dried products could be obtained, more pleasant to eat by hand as a snack item or to incorporate in such products as pastry, ice cream etc. There may be a specific effect of the sorbitol on the consistency of fruit products that should be more fully understood and applied.

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