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The effect of different osmotic agents on the sensory perception of osmo-treated dried fruit

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SUMMARY
To increase the attractiveness of dried fruit, the osmotic dehydration method (DIS) was used to fortify the structural matrix of fruit tissues with health-promoting compounds. The aim of these studies was to determine the impact of different osmotic agents on the sensory perception and acceptability of osmo-dried and osmo-freeze-dried sour cherries, blackcurrants, and apples. The osmo-dried fruits, thus manufactured, were subjected to profile sensory analysis. With the exception of basic fruit taste, all the sensory attributes investigated were influenced significantly by the osmotic agent used for fruit impregnation before drying. We proved that the osmotic solution significantly influenced the taste and/or texture profile of the dehydrated fruit and affected their sensory acceptability, but the changes depended on species and drying method. In general, dried fruit pre-treated with sucrose (S), inverted sugar (IS), or de-acidified fruit juice (DeAFJ) were characterised by having a predominantly sweet taste, while those treated with concentrated apple juice (JF) had high acidity. Oligofructose (OF) applied to freeze-dried fruit created a high level of crispness in the final product. Polyols such as galactosorbitol (GALSOR) and sorbitol (SOR) could not be recommended for osmotic impregnation of fruit due to a sensation of increasing hardness that lowered consumer acceptability of the product.

Osmotic dehydration is a method of preservation in which the food is dipped in concentrated salt or sugar solutions. Partially dehydrated fruits and vegetables prepared in this way can be added to foods such as desserts, yogurt, ice-cream, confectionery, and bakery products. After additional drying, they can also be used as components of cereals or snacks for direct consumption (Lenart, 1996; Torreggiani and Bertolo, 2001). The quality traits and nutritional value of osmo-dried fruits and vegetables can be modified depending on the parameters of the dehydration process and osmotic agent used (Mandala *et al*., 2005; Chiralt and Talens, 2005). Although dehydration leads to serious losses of nutrients such as minerals or phytochemicals (Stojanovic and Silva, 2007), the dehydrated material becomes impregnated with the osmotic agent that enhances not only its sensory properties, but also has an impact on its dietary value (Torreggiani and Bertolo, 2001). For example, Betoret *et al*. (2003) successfully developed probiotic-enriched, dried apple pieces.

Dried fruits are beneficial to human health because they are a rich source of vitamins, minerals, anti-oxidants, and especially fibre (including soluble fibres) due to their concentration during processing. These products are also a rich source of energy, particularly if produced by osmo-convective dehydration using concentrated sucrose solutions. However, this may limit the attractiveness of such dried fruit to weight-conscious consumers. Different osmotic substances have been investigated as potential substitutes for sucrose, including glucose, trehalose, polyols, concentrated fruit juices, or mixtures of various carbohydrates, among others (Ferrando and Spiess, 2001; Rastogi *et al*., 2002; El-Aouar *et al*., 2006; Rodrigues and Fernandes, 2007; Moreira *et al*., 2008; Konopacka *et al*., 2008). Most of these were shown to be effective osmotic agents; but, generally, there was little information on their impact on the eating quality of osmo-dried fruit and their sensory attractiveness.

As a contribution to the ISAFRUIT Integrated Research Project, seeking a healthier diet for Europe, an effort was undertaken to develop novel dried fruit products that could appeal to consumers to increase the consumption of processed fruit. To increase the attractiveness of dried fruit the dehydration-impregnation by soaking (DIS) method was chosen as it offers simultaneous enhancement of the sensory quality and opportunities to fortify the structural matrix of fruit tissues with health-promoting compounds. The aims of the present studies were to determine the nature of the impact of eight different soaking solutions on sensory perceptions, and on the acceptability of osmo-dried and osmo-freeze-dried sour cherries, blackcurrants, and apples.

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MATERIALS AND METHODS

Osmo-dried fruit production

Raw material: Sour cherry ('English Morelo'), blackcurrant ('Tiben'), and apple ('Idared') were chosen as the experimental material. Fruits were picked at commercial harvest maturity in 2006 at the Experimental Orchard of the Research Institute of Pomology and Floriculture, Dąbrowice, Poland. Fresh sour cherries were washed, pitted, and frozen at –25°C until processing. Blackcurrants were frozen without pre-treatment; but, on the day of processing, frozen berries were grazed in the carborundum drum of a kitchen food processor (Talent 881.0; Zelmer, Rzeszów, Poland). Fruits were abraded in 200 g portions at the lowest machine speed for 60 s. Apples were stored in a cold room (0°C; 90% RH; normal atmosphere) up to the time of processing.

Dehydration-impregation by soaking (DIS): Eight osmotic agents were selected as dehydration solutions. These were expected to increase the nutritional and/or sensory properties of the processed fruit (Table I). Prior to dehydration, a water solution of each osmotic agent (at 60 °Brix) was prepared and equilibrated to 40°C. Before processing, the sour cherries and blackcurrants were moved from –25°C to –5°C, and equilibrated. Fresh apples were warmed to 20°C and cut into 1 cm cubes. The proportion of each fruit and each osmotic solution was 1:4 (w/w), and dehydration was performed for 1 h in beakers placed in a shaking water bath (Julabo SW 22; Julabo Labortechnik GmbH., Seelbach, Germany) at a frequency of 140 rpm, an amplitude of 20 mm, and 40°C. After osmotic dehydration, the fruits were drained, rinsed with cold distilled water, and blotted on filter paper. Dehydrated fruits were weighed and checked for their soluble solids content (SSC), titratable acidity (TA), and dry matter (DM) content. The kinetic parameters for DIS were calculated according to the following equations:

WL (water loss, in g H_2O g^{-1} initial DM) =

$$\frac{(1 - s_o) \times m_o - (1 - s_\tau) \times m_\tau}{s_o \times m_o}$$

SG (solids gain, in g DW g^{-1} initial DM) =

$$\frac{s_\tau \times m_\tau - s_o \times m_o}{s_o \times m_o}$$

where m was the sample mass in (g), s was the dry solids mass of the material in (g), and the subscripts 0 = initial and τ = time in (min).

Drying: Osmo-dehydrated (DIS-treated) fruits collected from four successive batches were pooled and split into two samples. The first sample was subjected to convective drying (DIS - CD). The fruit were spread in a monolayer on stainless sieves and dried in a convective drier with a horizontal air flow (2.2 m s^{-1}) at 60°C (sour cherries for 8 h, blackcurrants for 10 h, and apples for 4 h. The other sample of DIS fruit was freeze-dried (DIS - FD) at –30°C for 24 h followed by 50°C for 2 h.

Sensory assessment

The quality of the dried products was evaluated by profiling methods. An expert panel consisting of 14 trained people were recruited from staff of the Research Institute of Pomology and Floriculture, each having had extensive experience in performing sensory assessments of dried horticultural products. The panellists took part in a special training session, where particular attribute definitions were discussed and clarified. Ten panellists were invited for each session. The products were presented in individual booths, illuminated with white 6,500 K daylight bulbs, in transparent vessels with tight lids to avoid any loss of aroma or cross-contamination, and to protect the samples from humidification. Each expert assessed several qualitative traits using an unstructured 100-mm linear scale. The results were transposed into a 0 – 10-point scale, where "0" denoted the absence of a given trait or an unacceptable level, while "10" indicated an intensive sensation or high quality. The following attributes were evaluated: fruit aroma (typical for each species), crispness (only for osmo-freeze dried samples), hardness, overall texture, typical fruit taste for each species, sweet taste, sour taste, and overall quality, defined as the sensory impression of the balance and harmony of all attributes and their interactions.

Statistical analysis

The sensory profiling data were analysed by multivariate Principal Component Analysis (PCA) using standardised mean data calculated for groups of products pretreated with particular osmotic agents. To determine the effect of each osmotic agent (and drying method) on the sensory attributes investigated, a two-way analysis of

Table I
Specifications of the osmotic agents used in these experiments

Osmotic agent (abbrev.)	Expected added value; form; supplier
Sucrose (S)	Texture and flavour improvement; powder; commercially available sugar.
Fructo-oligosaccharide (FOS)	Pre-biotic properties, polysaccharides expected to strengthen good *Bifidobacterium* microflora; water solution (70 °Brix); 'Polfarmex', Kutno, Poland.
Concentrated fruit (apple) juice (FJ)	Build-up sweetness with natural fruit sugar, increases of fruit aroma sensation; concentrate (68 °Brix); 'Ogród Polski'; Hortex Holding S.A., Skierniewice, Poland.
De-acidified and desalted concentrated fruit (apple) juice (DeAFJ)	Build-up sweetness with natural fruit sugars; concentrate (68 °Brix); 'Polfarmex', Kutno, Poland.
Sorbitol (SOR)	Pre-biotic properties, polyols inhibit tooth decay; water solution (70 °Brix); 'Polfarmex', Kutno, Poland.
Galactosylosorbitol (GALSOR), (lactose hydrolysate with gal-sorbitol)	Pre-biotic properties, water solution (60 °Brix); enzymatic synthesis on a laboratory scale; TU Lodz, Poland.
Oligofructose (OF) [an 80:20 (w/w) mixture of FOS and maltodextrin]	Pre-biotic properties, crystallisation prevention and water holding; dry powder; 'Polfarmex', Kutno, Poland.
Inverted sugar (IS)	Sweet tasting, texture and flavour improvement, inhibition of sugar crystallisation; water solution (70 °Brix); 'Biovet', Pulawy, Poland.

variance (ANOVA) was applied. All statistical calculations were performed using the STATISTICA 8.0 software package (StatSoft Inc., Tulsa, OK, USA).

RESULTS AND DISCUSSION

Osmotic treatment

The effect of osmotic dehydration (DIS) achieved using different osmotic treatments is summarised in Table II. In all cases, a 60-min treatment resulted in a significant increase in dry matter (DM) content for all fruit species investigated. The lowest increase in DM was found for fruits dehydrated with oligofructose [OF; mean for all species = 6.5% (w/w)] while, for other agents, values were in the range of 13.7 – 17.4% (w/w). Generally, osmotic treatment led to a lowering of the acidity of sour fruits (up to a 40% decline in sour cherries, and a 30% decline in blackcurrants), while for low-acid fruit (apple), a slight increase in acididity was noted. The exception was DIS treatments with concentrated apple juice (FJ), which caused a 25.4% increase in TA for sour cherries, and > 100% for apples, due to the high content of natural organic acids in FJ. For all fruit species, the DIS procedure caused a significant increase in the sugar:acid ratio (Table II). For sour cherries, the ratio increased from 9.3 (for untreated fruit) to 15.5 (for FJ) and 31.8 (for DeAFJ). In the case of blackcurrant, it rose from 4.1 to 7.2 (OF) and to 12.2 – 12.3 (S and GALSOR), and from 30.1 to 28.9 (FJ) and to 60.0 (DeAFJ) for apples.

Analyses of the mass transfer indices [i.e., water loss (WL) and solids gain (SG)] indicated that both osmotic agent and fruit species had a significant influence on the loss of water and on DM uptake ($P < 0.05$; Table II). In the case of sour cherries, all the osmotic agents investigated had a similar ability to dehydrate fruit tissue, while OF had a significantly lower ability to impregnate fruit tissues. For blackcurrants and apples, the removal of water was slowed significantly when OF was applied. Considering the WL:SG ratio, in blackcurrants SG was found to be dominant over WL (i.e., a WL:SG ratio < 1), while in sour cherries and apples, the WL:SG ratio was between 1.4 – 1.8, with the exception of sour cherries dehydrated in OF, for which the ratio was significantly higher (2.9).

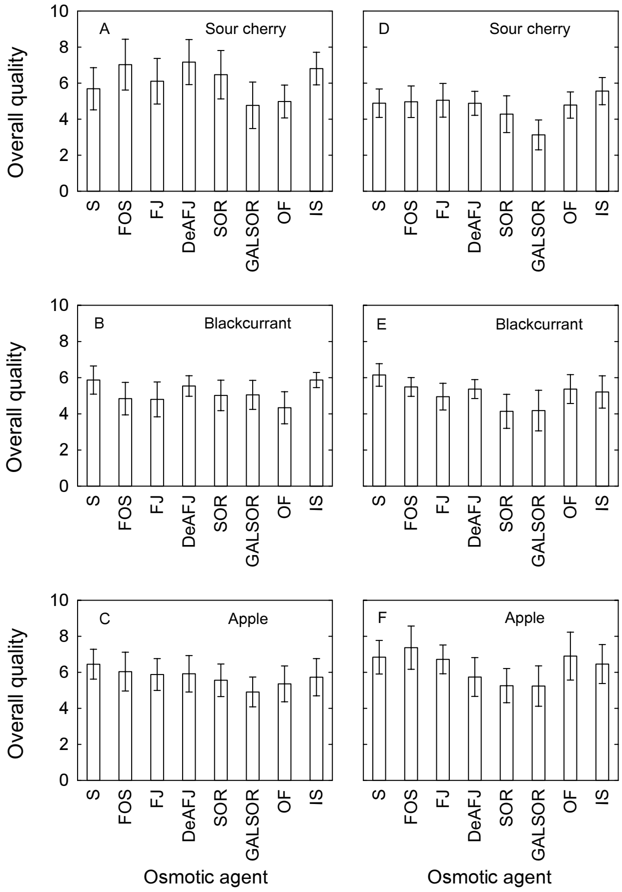

FIG. 1
Sensory assessments of mean overall qualities (10-point scale; 0 = bad; 10 = very good, well-harmonised) of osmo-convectively dried (Panels A–C) or freeze-dried (Panels, D–F) sour cherries (Panels A, D), blackcurrants (Panels B, E), and apples (Panels C, F) pre-treated with eight different osmotic agents (see Table I). All values are means ± SD (n = 10).

Sensory appreciation

The overall quality assessments of all the fruit samples produced in these experiments are presented in Figure 1. It was clear that using different osmotic agents (e.g., sucrose, concentrated fruit juice, or oligofructose) for a given species, dried using a particular technology (i.e., convectively-dried or freeze-dried), resulted in final products of significantly different quality. The differences

TABLE II
Impact of different osmotic agents on dry matter (DM) content, titratable acidity (TA), sugar:acid ratio (S:A), water loss (WL), and solids gain (SG) for sour cherries (SC), blackcurrants (BC), and apples (AP) dehydrated in various 60 °Brix solutions for 60 min at 40°C

Parameter	Fruit	Untreated	Osmotic agent (see Table I)							
			S	FOS	FJ	DeAFJ	SOR	GALSOR	OF	IS
Dry matter (DM) content (%)	SC	17.6	31.1	33.3	34.8	38.4	38.0	35.6	25.7	35.2
	BC	20.9	37.2	35.6	36.2	37.0	34.8	36.7	28.5	37.7
	AP	15.2	26.6	26.0	28.4	30.4	31.0	28.7	19.1	29.9
Mean increase			13.7	13.7	15.2	17.4	16.7	15.8	6.5	16.4
Acidity as citric acid (%)	SC	1.69	1.34	1.19	2.12	1.14	1.20	1.03	1.34	1.27
	BC	3.73	2.58	2.89	3.47	2.82	2.96	2.56	3.17	2.84
	AP	0.44	0.52	0.49	0.91	0.47	0.51	0.46	0.44	0.48
S:A ratio	SC	9.3	21.3	25.8	15.5	31.8	29.5	32.7	17.5	25.4
	BC	4.1	12.2	10.2	9.0	11.2	9.9	12.3	7.2	11.2
	AP	30.1	49.5	48.2	28.9	60.0	56.8	57.9	39.0	56.2
Water loss (WL) (g g^{-1} DM_o)	SC		2.07	2.21	2.17	2.29	2.18	2.25	2.36	2.30
	BC		1.18	1.12	1.20	1.12	1.02	1.15	0.91	1.20
	AP		1.92	1.79	2.22	2.33	2.43	2.33	1.40	2.25
Solids gain (SG) (g g^{-1} DM_o)	SC		1.18	1.23	1.34	1.49	1.53	1.35	0.80	1.29
	BC		1.54	1.47	1.47	1.56	1.47	1.53	1.15	1.56
	AP		1.33	1.33	1.33	1.42	1.42	1.39	0.99	1.34

TABLE III

Probability values of the analyses of variance for the effects of osmotic agent (OA) and drying technology (T) used on the sensory attributes of osmo-dried fruits

Fruit species	Source of variation	Sensory attribute: Fruit aroma	Hardness	Crispness[1]	Overall texture	Fruit taste	Sweet taste	Sour taste	Overall quality
Sour cherry	OA	0.310	0.000*	0.000*	0.000*	0.910	0.000*	0.006*	0.001*
	T	0.000*	0.000*	–	0.006*	0.509	0.001*	0.006*	0.000*
	OA × T	0.514	0.001*	–	0.008*	0.993	0.388	0.826	0.406
Blackcurrant	OA	0.200	0.003*	0.000*	0.000*	0.600	0.002*	0.398	0.005*
	T	0.000*	0.000*	–	0.002*	0.461	0.319	0.390	0.772
	OA × T	0.964	0.033	–	0.027*	0.898	0.875	0.977	0.154
Apple	OA	0.092	0.006*	0.000*	0.000*	0.083	0.000*	0.015*	0.023*
	T	0.107	0.564	–	0.000*	0.871	0.200	0.493	0.025*
	OA × T	0.387	0.000*	–	0.000*	0.771	0.744	0.995	0.580

[1]Attribute investigated only for osmo-freeze dried fruit.
*Probability values marked with an asterisk denote statistically significant effects ($P \leq 0.05$).

observed within a species dried using particular technology (see Panels in Figure 1) were usually ≤ 2 points on the 10-point scale. On the other hand, impregnation with the same compound did not guarantee a product of the same quality, for example sour cherries soaked in inverted sugar (IS) and convectively-dried judged to be 6.8, while after IS and being freeze-dried they scored only 5.7. Even greater differences were noticed for fruits treated with FOS. Here, convectively-dried cherries scored 7.7 points, while blackcurrants scored only 4.8. Furthermore, in the case of apples and blackcurrants infused with FOS, freeze-dried fruit were scored more highly than those convectively-dried; but, for sour cherries, the relationship was the reverse. The variations observed may be linked to the nature of the raw material, its chemical composition, and/or its structure that influences the intensity of the mass transfer phenomena and other reactions leading to the formation of compounds involved in texture and flavour perception (Torregani and Bertolo, 2001).

The relationships between the raw material, the osmotic treatment, and the drying method were studied by analyses of variance conducted separately for each species. For each sensory attribute, the effect of osmotic agent (OA) and drying technology (T) was determined (Table III). The results confirmed the complexity of the interactions between sensory perception and the factors investigated. The majority of the sensory attributes investigated turned out to be significantly influenced by the osmotic agent used for impregnation of the fruit before drying. Only traits connected with the taste and aroma characteristics of a particular fruit species were independent of this factor.

The results from the sensory profile analyses are shown in Figure 2 in the form of a "quality map". The space created by the first two main components (PC1 and PC2), taken together, accounted for 88.2% of the total variation in the sensory perception of all osmo-dried fruits. Crispness, sweetness, and sour taste were identified as those traits which differentiated osmo-dried fruit quality most significantly (i.e., they had the longest vectors among the attributes investigated).

The relationships between the orientations of the vectors of a particular sensory attribute, and the points, characterised each dried fruit impregnated with the various osmotic agents, and allowed us to anticipate which of the osmotic solutions we investigated could significantly influence the taste or texture profile of the dehydrated fruit and thereby affect its quality appreciation. For example, points that characterised dried fruit infused with sucrose (S), FOS, or inverted sugar (IS) were located near the vectors of sweetness and overall quality. This means that those components affected the sweetness profile that was highly appreciated by the expert panel. In contrast, fruits pre-treated with GALSOR were predominantly characterised by having a high "hardness" sensation, which explained their poor acceptance (i.e., point placed far from the overall quality vector). Similar products, but slightly sweeter, were produced using sorbitol (SOR). The "crispness" sensation was highest for fruits dehydrated with OF. Unfortunately, however, the predominance of their sour taste sensation resulted in them having a low quality rating. A relatively low overall quality score was indicated for fruit products infused with FJ; however, this agent can clearly increase the intensity of the sour taste, and also favours the fruit aroma sensation reported for osmo-dried sour cherries by Konopacka *et al.* (2008).

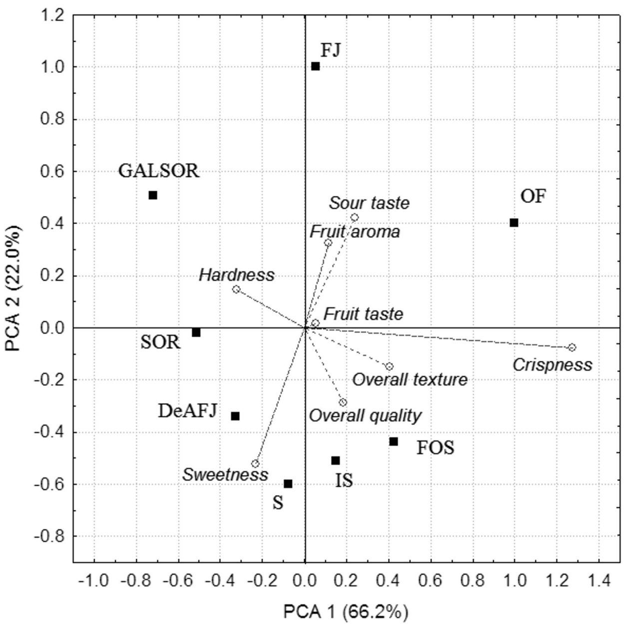

FIG. 2
Principal component analysis (PCA) projection profile of sensory analyses (traits = fruit taste, sour taste, sweetness, crispness, hardness, overall texture, and overall quality) of dried fruits impregnated before drying with different osmotic agents (see Table I for definitions).

The most promising results were obtained using FOS. Dried fruits impregnated with FOS were characterised by having good texture properties as well as an acceptable sweetness intensity that resulted in high quality acceptance. This finding is especially valuable due to the well-documented pre-biotic properties of FOS. These oligo-saccharides can stimulate a selective increase in the faecal *Bifidobacterium* count (Biedrzycka and Bielecka, 2004) and *Bifidobacteria* are known for their health-promoting properties (Makras and De Vuyst, 2006).

CONCLUSIONS

1. With the exception of basic fruit taste, the sensory attributes investigated here were significantly influenced by the osmotic agent used for impregnation before fruit drying.
2. Each of the osmotic solutions we investigated significantly influenced the taste and/or texture profile of the dehydrated fruit, and affected their sensory acceptability; but, the changes depended on the fruit species and on the drying method used.
3. In general, dried fruits pre-treated with sucrose (S), inverted sugar (IS), or de-acidified fruit juice (DeAFJ) had a predominantly sweet taste, while those treated with concentrated apple juice had high acidity. Oligofructose (OF) applied to freeze-dried fruits created a high level of crispness in the final products. The polyols, galactosorbitol (GALSOR) and sorbitol (SOR), are not recommended for osmotic impregnation of fruits due to the fact that they intensify the sensation of hardness and thus lower the acceptability of the product.
4. A quality map of the sensory perceptions of dried fruits impregnated with a particular osmotic agent can be useful during novel product development, especially for the optimisation of sensory quality.

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