SciVerse ScienceDirect

Procedia Food Science 1 (2011) 1848 – 1853

Procedia Food Science

11th International Congress on Engineering and Food (ICEF11)

# New prospects for high quality ingredients obtained from citrus fruit peel

Giovanna Cortellino*, Serena Gobbi, Danila Torreggiani

*Research Unit of Food Technology - Council of Agricultural Research, Via Venezian 26, 20133 Milan, Italy*

**Abstract**

Vacuum infusion is used to facilitate the peeling of citrus fruit for the fresh-cut market, giving, as a by-product, a peel soaked with water but quite undamaged. Osmotic dehydration, commonly used to remove part of the water content of fruit before further drying, could increase the stability of the colour pigment and minimize the shrinkage phenomenon. The aim of this research is to apply to orange peels the osmodehydration followed by air-drying in order to obtain a high quality food ingredient both from a nutritional and sensorial aspect. Peels from vacuum infused organic oranges, cv Tarocco and cv Navel, were cut into slices (1x2 cm) and then osmodehydrated at 20°C in sucrose solution (60% w/w) for different times (1-2-3-4-5-6-24 h), followed by air drying at 80°C up to a constant weight. Solid gain and water loss of the osmotic process were assessed. Changes of colour and shape, due to processing, were evaluated by image analysis technique. The bitterness sensorial characteristic of powders, obtained from grinding the dried peel, was judged by a panel test. The high solid gain of peels, due to the osmotic step, was attributed to the particular structure of pith, which was able to absorb an elevated amount of sugar solution thanks to its wide intercellular spaces and not turgid cells. The solid gain allowed colour attributes of slices after air dehydration to be maintained. The air drying without pre-treatment, caused a structural collapse of peels which looked wrinkled. This effect was noticeably reduced in pre-osmodehydrated slices with a positive progressive trend in function of osmosis time. Furthermore the solid-liquid exchanges and the consequent sucrose intake had a positive effect on sensorial quality of the dried product, decreasing the characteristic bitter perception.



*Keywords*: peel; orange; osmodehydration; air-drying; bitterness.

## 1. Introduction

The large scale retail and the catering industry dedicate more and more refrigerated space to fresh-cut fruit and vegetables. In expectation of a further increase in the fresh-cut field, which is having a higher annual growth than any other food sector, it's opportune to think about the recovery and the exploitation

* Corresponding author. Tel.: +39-02-239557209; fax: +39-02-2365377.
*E-mail address*: giovanna.cortellino@entecra.it


doi:10.1016/j.profoo.2011.09.271

of this industry's by-products, which are rich in high nutritional and healthy compounds. Orange peel contains a high amount of pectins, flavonoids, carotenoids and limonene [1] making it completely usable, in addition to single compound extraction. Currently citrus fruits are not much present on the fresh-cut market, this is mainly due to the problems of the peeling step, which is still handmade or by mechanical blade instrument resulting in low yield. An experimental peeling technique, which involves the water vacuum infusion of fruits [2], represents an alternative. Using this method the peel is easily detached without damaging the fruit, giving, as a by-product, a peel soaked with water but quite undamaged. This could be converted into an ingredient to improve taste and nutritional quality of different food. The drying technique allows the peel to be stabilized, but the dehydration of vegetable tissues involves undesirable phenomenons such as: cells structure damage linked to the water migration from inside to outside of product, shrinkage like wrinkling and contraction due to microstructural stress [3], browning and pigment denaturation. In many vegetable products the chemical-physical alterations due to the common processing technique may be reduced by a osmodehydration pre-treatment, which consists of soaking the foods in a hypertonic salt or sugar or combined solution. The difference in osmotic pressure between the fruit and the hypertonic solution is the driving force to reduce the water content while increasing the soluble solid content. Shrinkage and structural collapse during drying decrease while the solid content increases when fruit is impregnated with sugars prior to air drying [4]. Moreover osmotic dehydration, used before further drying, could increase the stability of the colour pigment and minimize browning phenomenon [4].

The aim of this research is to apply osmodehydration followed by air-drying, to orange peels, obtained from fruits peeled by vacuum infusion, in order to obtain a high nutritional and sensory quality food ingredient. The final dried peel, could be added to baked products, snacks, yogurts, dessert, preserves and such. The effect of water loss and solid gain of citrus peels was evaluated over a period of 1 to 24 h. The influence of the osmotic step on maintaining the colour and shape attributes and on improving sensorial characteristic of peels after drying was also studied.

## 2. Materials & methods

Organic oranges, cv Tarocco and cv Navel, were hand peeled after water vacuum infusion. Peels were cut into slices (1x2 cm): a part was kept as control and the others were osmodehydrated at 20°C at atmospheric pressure in sucrose solution (60% w/w) for different times (1-2-3-4-5-6-24 h). At each time a sample (~ 120 g) was taken from the osmotic solution. Peels, pre-treated and not, were dehydrated at 80°C (dry bulb) up to a constant weight. Air dehydration was performed using an alternate upward-downward air-circulated pilot dryer (Thermo-Lab. Codogno, LO) operating at an air velocity of 1.5 m/s. Each trial was repeated twice.

Dry matter of raw and osmodehydrated product was measured [5]. Solid gain (SG) and water loss (WL) of the osmotic process were assessed and expressed as g/100 g of initial fresh peels [6]. After air-drying the colour (CIE-Lab system) and the shape index "area/box" ("rectangularity"), given by the ratio between the slice area and the area of the minimum rectangle which contains the slice, were evaluated by Image Analysis technique. To this aim full colour images of 18 orange peel slices (raw and air dehydrated) were acquired by digitalisation with a CanonScan N650U flat-bed scanner (Canon Inc., Tokio, Japan) at 300 dpi resolution and were stored as JPG files. The acquisition was made putting the slices with the flavedo placed on scan flat and imposing a black box over them to guarantee constant light conditions. Thirteen colour tests of a reference chromatic scale were put on the scan flat in order to standardize the colour analysis. The acquired images were analyzed, for colour and shape, by a specific software (Software Image Pro Plus 5.0 Media Cybernetics, Silver Spring MD, USA). The dried peels were ground in order to make the sensorial analysis easier for the panel test, which consisted of 10 trained tasters, who were asked to evaluate the bitterness characteristic of powders [7]. The dried sample without pre-treatment was used as reference, as it had the maximum bitter intensity, established as 10. The taste boxes were illuminated by a red light to eliminate the influence of the sample colour on the panel judgement.

Analysis of variance (ANOVA) and Tukey multiple range test were used to determine statistically significant difference ($P < 0.05$). Different letters corresponded to a significant difference.

## 3. Results & discussion

The peels, obtained by peeling oranges previously infused under vacuum, resulted strongly soaked with water, due to the peculiar microstructure of albedo. The peels presented initial dry matter not significantly different (Table 1), and during the osmotic process this parameter increased, as a consequence of both water loss (WL) and solid gain (SG).

Table 1. Dry matter (%) of raw (Raw) and osmodehydrated peels for 1, 2, 3, 4, 5, 6, 24 h (O1, O2, O3, O4, O5, O6, O24). Different letters (small: among the different pre-treatments for a single cultivar; capital: between the two cultivars for the same pre-treatment) indicate significant differences (P<0.05%, Tukey's test).

| Cultivar | Raw | O1 | O2 | O3 | O4 | O5 | O6 | O24 |
|---|---|---|---|---|---|---|---|---|
| Tarocco | 12,4 g A | 21,1 f B | 26,2 e B | 29,5 d B | 32,4 c B | 34,9 bc B | 35,8 b B | 44,9 a B |
| Navel | 13,6 g A | 27,7 f A | 33,3 e A | 37,5 d A | 39,8 cd A | 42,6 bc A | 45,0 b A | 56,4 a A |

WL and SG increased gradually during the course of osmosis (Figure 1) and tended to stabilize only after 3 h in the case of Navel peels (WL = 33,4% and SG = 20,8%) and after 4 h for Tarocco peels (WL = 27,7% and SG = 16,4%). By prolonging the treatment till 24 h a further significant increase of both parameters occurred. As highlighted in Figure 1, osmosis exchanges were higher in the Navel orange peels than in Tarocco ones; the difference, already visible after 1 hour of processing, was maintained till the end of the osmosis. Navel peels reached final values of water loss and solid gain of 51,2% and 32,7%, while Tarocco showed final values of 39,7% and 26,6 % respectively. The high solid gain of peels, superior to values reported for other vegetables [4], was attributed to the particular structure of pith, which was able to absorb an elevated amount of osmotic solution thanks to its wide intercellular spaces and not turgid cells [8].

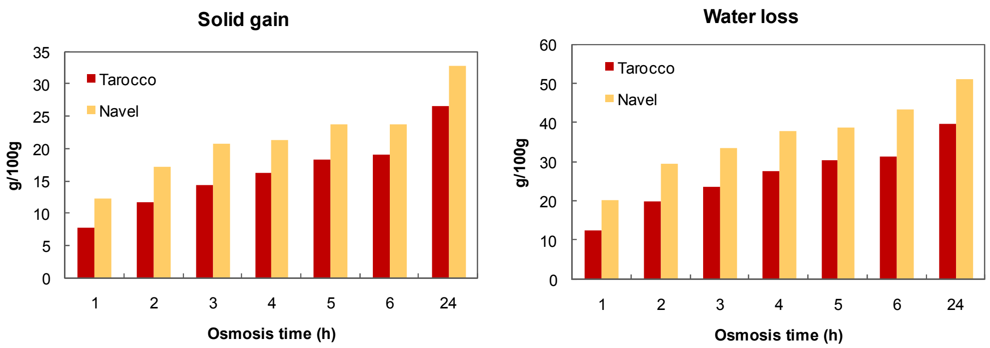


Fig. 1. Water loss (WL) and solid gain (SG) of orange peels of both cultivar after 1, 2, 3, 4, 5, 6, 24 h of osmosis. Results expressed as g/100 g of initial fresh peels.

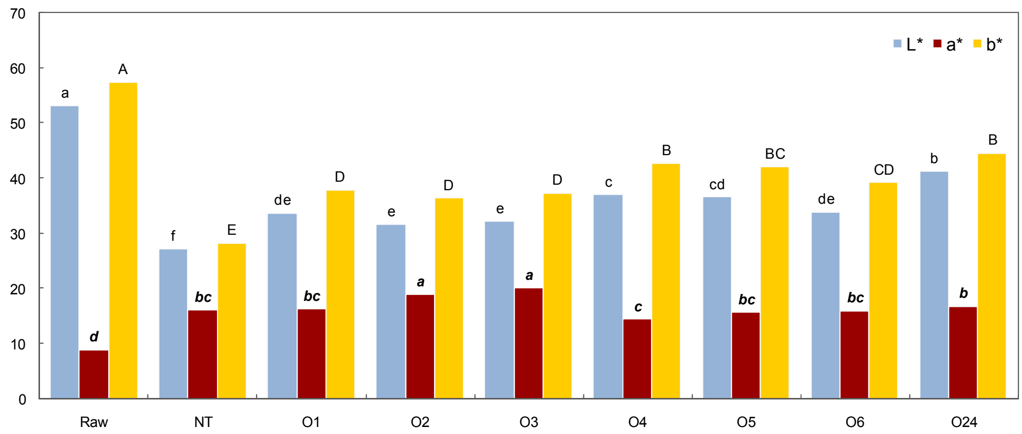


Fig. 2. L*, a* and b* values of cv Tarocco peels after drying: raw (Raw), non-treated (NT) and osmodehydrated for 1, 2, 3, 4, 5, 6, 24 h (O1, O2, O3, O4, O5, O6, O24).

The drying of peels at 80°C determined a stressed browning of flavedo for both cv (Figure 2-3) highlighted by a decreasing of L* (lightness) and b* (yellow) values. Concerning the L* parameter, the two cultivar presented similar raw values: 53.0 for Tarocco and 51.8 for Navel, which decreased respectively to 27.0 and 28.5 for non-treated dried peels. The b* parameter showed a similar trend: the raw values were about 57.4 and decreased to 34.1 for non-treated dried Navel peels and to 28.1 for Tarocco ones. The raw peel colour of the two cultivar were characterised by different a* values: 26.7 for Navel and 8.8 for Tarocco, the former decreased to 24.9 and the latter increased to 15.9 through drying. The osmosis process limited the negative influence of air-drying on L* parameter in quite a marked way after 24 h of pre-treatment for both cultivar, the values being kept over 40. The best result in the control of modification of b* parameter was reached after 24 h treatment for Navel and after only 4 h for Tarocco. The slight but significant decrease of Navel peels a* value, due to drying, was efficiently contrasted by the sucrose intake, as shown in Figure 3, with best results after 3 h. On the contrary the enrichment of sucrose of Tarocco peels didn't succeed in preventing the increase of a* value and in some cases (O2 and O3) the phenomenon was promoted, as previously demonstrated for other fruits [4].

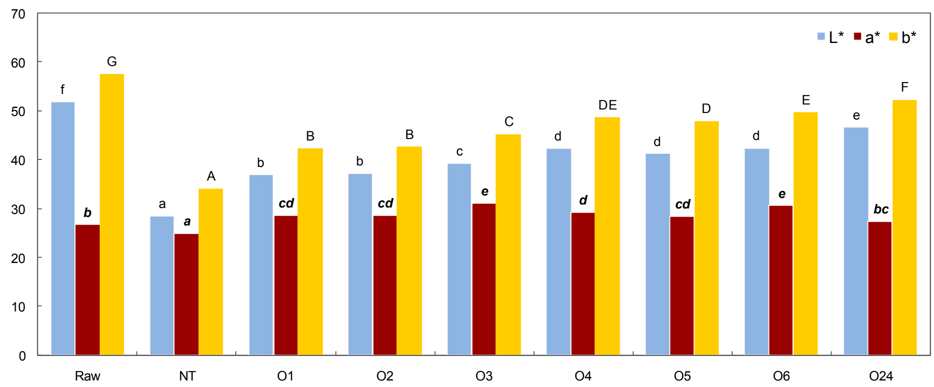


Fig. 3. L*, a* and b* values of cv Navel peels after drying: raw (Raw), non-treated (NT) and osmodehydrated for 1, 2, 3, 4, 5, 6, 24 h (O1, O2, O3, O4, O5, O6, O24).

Besides the chromatic alterations, air drying without pre-treatment (NT), caused a structural collapse of peels which looked evidently wrinkled, as can be observed in Figure 4. This effect was noticeably reduced in pre-osmodehydrated slices, which maintained a regular geometry, with a positive progressive trend in function of osmosis time. This was confirmed also by the shape index “area/box”, whose values were higher for pre-treated peels than those of not pre-treated ones (Table 2).

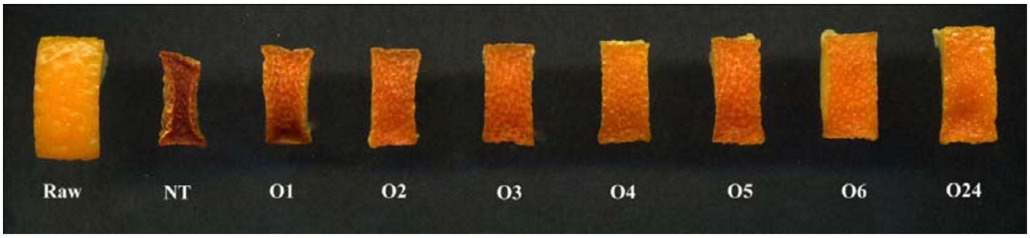


Fig. 4. Image of Navel peels after drying: raw (Raw), non-treated (NT) and osmodehydrated for 1, 2, 3, 4, 5, 6, 24 h (O1, O2, O3, O4, O5, O6, O24).

Table 2: Shape index of orange peels after drying: raw (Raw), non-treated (NT) and osmodehydrated ones for 1, 2, 3, 4, 5, 6, 24 h (O1, O2, O3, O4, O5, O6, O24).

| Cultivar | Raw | NT | O1 | O2 | O3 | O4 | O5 | O6 | O24 |
|---|---|---|---|---|---|---|---|---|---|
| Tarocco | 0.72 c | 0.57 a | 0.63 ab | 0.67 bc | 0.64 abc | 0.72 c | 0.67 bc | 0.70 bc | 0.69 bc |
| Navel | 0.85 de | 0.69 a | 0.81 b | 0.83 bc | 0.84 cd | 0.84 cd | 0.85 de | 0.86 de | 0.87 e |

As regards the sensorial analysis of powder, obtained by the peels dried after osmosis, the intensity of “bitter” attribute was always judged lower than 10 (Figure 5). This result can be explained by the solid-liquid exchanges and the consequent sucrose intake, which has a positive effect on sensorial quality of dried product decreasing the characteristic bitter perception. In particular the bitterness of both cultivar peels, dried after a pre-treatment of only 1 hour, were perceived with a valued intensity as 6; this value tended to decrease more quickly for cv Navel than for cv Tarocco by lengthening the pre-treatment. After 6 h of osmosis Navel reached the intensity value of 4.0 while Tarocco 4.5. The perceived intensity became significantly lower after 24 h of osmo-dehydration: 3.3 for Tarocco and 3.0 for Navel.

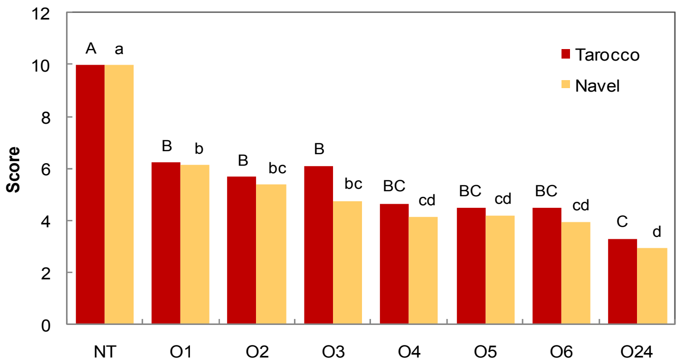


Fig. 5. Intensity of bitter attribute in both cultivar peels: non-treated (NT) and osmodehydrated for 1, 2, 3, 4, 5, 6, 24 (O1, O2, O3, O4, O5, O5, O6, O24) after drying.

Chromatographic analysis, carried out on osmotic solution after the 24 hour treatment, attested the presence of limonene, the triterpene compound responsible for the bitterness of the peel and located mainly in the albedo (data not reported). Comparing the concentration of limonene found in osmotic solution and in the raw peel indicated that the peels lost on average 50% of the initial content through the 24 h pre-treatment. Concerning limonene concentration in peels osmodehydrated for different times, further research is needed to evaluate whether the lower bitter intensity of osmodehydrated peels could be attributed, not only to the sugars enrichment, but also to the decrease of limonene content.

## 4. Conclusion

The extent of water loss and solid gain of the osmotic step, ascertained in this study, confirms the general principle stating that the "dehydration" effect is always superior to the sugars penetration (WL > SG) till when the membrane is intact [4]. At the same time, the low ratio WL/SG (~ 1.6), not found for other vegetables, confirmed that the tissutal structure of raw material is an essential variable of the process highlighting the fact that citrus peel is highly suitable for osmotic impregnation. In agreement with literature [9], the enrichment in soluble solids improved significantly the retention of chromatic and structural characteristics during the successive air drying, as confirmed by the results of image analysis concerning the colour and the shape. Moreover, the solid-liquid exchange and the consequent sucrose intake had repercussions on sensorial quality of dried product, decreasing the characteristic bitter perception. In addition the limonen loss due to osmosis, attested by the presence of this bitter compound in the osmotic solution after 24 h of process, could help to increase tasters' acceptance.

The recovery and the exploitation of these peels could contribute towards increasing the economic convenience of vacuum infusion to produce fresh-cut oranges on a wide scale, as the peels, obtained with this peeling technique, are perfectly undamaged.

## References

[1] Manthey J.A. & Grohmann K. Phenols in citrus peel byproducts. Concentrations of hydroxycinnamates and polymethoxylated flavones in citrus peel molasses. *J. Agric. Food Chem.* 2001; 49: 3268-3273.

[2] Pinnavaia S. & Senesi E. Innovazione tecnologica nella frutta di IV gamma. *Ingredienti Alimentari*, 2006; V: 6-10.

[3] Aguilera J.M. & Karel M. Preservation of biological materials under dessication. *Critical Reviews of Food Science and Nutrition*. 1997; 37: 287-309.

[4] Torreggiani D. & Bertolo G. Present and future in process control and optimization of osmotic dehydration. In: *Advances in food and nutrition research*. San Diego (CA): Elsevier Academic Press. 2004; 48: 173-238.

[5] AOAC, Official Methods of Analysis, 15th ed. Association of Analytical Chemists, Washington DC, USA. 1990; 912.

[6] Giangiacomo R., Torreggiani D., Abbo E. Osmotic dehydration of fruit. Part 1: Sugar exchange between fruit and extracting syrups. *J. of Food Processing and Preservation*, 1987; 11: 183-195.

[7] Pagliarini E. 2002. Metodi descrittivi. In: *Valutazione sensoriale*, Milano: U. Hoepli, 59-65.

[8] Chafer M., Gonzalez-Martinez C., Chiralt A., Fito P. Microstructure and vacuum impregnation response of citrus peels. *Food Research International*. 2003; 36: 35-41.

[9] Campolongo S., Avitabile Leva A., Riva M., Maestrelli A., Torreggiani D. Analisi dell'immagine: un nuovo strumento per lo studio delle relazioni proprietà-struttura nella frutta disidratata. In *Ricerche e innovazioni nell'industria alimentare*. Pinerolo (TO): Chiriotti ed., 2005; VII: 552-557.

Presented at ICEF11 (May 22-26, 2011 – Athens, Greece) as paper FEW478.