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A combined technology for the production of dried vegetables: osmotic dehydration/freeze drying

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Introduction

Combined technology has gained attention in recent years in food processing industry for achieving high quality product. They consist in substituting a single process with a stage process obtained by the coupling of two or more unit operations, each of them fitted to operate in the near optimal range of conditions to minimize biological, chemical and phisical degradation of foods/1,2,3/. In the field of dehydration processes, a promising technology, is the osmotic drying that can be used as a preliminary stage of conventional drying processes in order to obtain intermediate or low moisture foods. Particularly attractive is the coupling of the osmotic process performed at low temperature/4,5,6/ with a soft low-temperature technique, as freeze-drying, respectfull of texture properties with the advantage of reducing process time and energy requirements in respect to freeze-drying process alone.

Osmotic dehydration is carried out immersing vegetables and fruit in a hypertonic sugar solution (ranging 10-60% and often with addition of salts) obtaining a considerable loss of water/7/. While water diffuses out from the products, there is a simultaneous uptake of solute. The gain in soluble solid, even if modifies the composition and nutritional characteristics of the final product, is sometimes desiderable having positive effect in/8/:

1. inhibiting the enzymatic and non-enzymatic browning;
2. preventing the loss of volatiles during successive drying stages.

Osmotic dehydration generally will not produce shelf stable dried product and consequentely the foodstuff should be further processed by a conventional drying method as air-, freeze-, vacuum-drying in order to obtain a chemical, biological and physical stability of the processed product/9,10/.

In order to obtain a product characterized by higher quality, can be attractive to perform the osmotic dehydration at low temperatures to preserve both organoleptic and structure characteristics of the product. Moreover low process temperatures limit the microorganism growth in the concentrated solution avoiding food contaminations.

The main objectives of the present work is to investigate the effect of low temperature osmotic preconcentration on freeze-drying kinetics in the case of apple and potato. The products was osmosed at the temperatures of 25, 4, -1 °C, using solutions of glucose (50%) in the case of apple and sucrose/sodium chloride (45/15%) for potato. Rehydratability of processed samples by the combined technology was compared to single stage freeze-dried apple and potato.

Material and Methods

Sample preparation

Stark delicious apple and bintjie potato were used in the present work. The specific varieties were chosen because apple and potato of these varieties can be readily available throughout the

entire year at fairly constant quality (hardness, turgor, maturity level).
After peeling , slabs of sizes of 1 x 1x 2 cm were cut.

Osmotic media

Glucose solution at 50% by weight and sucrose/sodium chloride at 45/15 % were used as osmotic agents in the case of apple and potato respectively.
The weight ratio of osmotic medium to apple and potato samples was at least 25:1, to avoid significant dilution of the solution during dehydration.
The osmotic solution was gently agitated by means a mechanical stirrer at 100 r.p.m. in order to improve mass transfer and to prevent formation of a dilute solution film around the sample, particularly important at low temperatures due to the increase of solution viscosity/11/.

Osmotic dehydration

Osmotic dehydration was run at three temperature 25 °C, 4 °C and -1 °C in the case of the two products. Each numbered sample was completely submerged in the osmotic solution using a plastic mesh. The apple and potato samples were treated 72 h and 24 respectively in order to reach the equilibrium period/12/ in which both solid and liquid mass transports are practically constant.
To determine the kinetic of the osmotic process, samples were taken from the solution each 30 min. After removal, samples were placed on blotting paper in order to remove excess solution.
The water loss, WL, (i.e. normalized moisture content X_w) and the solid uptake, SG, were determined by means of gravimetric method. Samples were weighed and placed in a vacuum oven at 60 °C for 24 h to evaluate the total solid content, necessary to determine SG. The initial solid content was determined according to standard method, using pieces of apple and potato cut from the same fruit or tuber from which samples were cut.
The evaluation of WL and SG is performed assuming that a minimal leaching of soluble and unsoluble solids from the samples occurs during osmotic process/5, 7, 11/.
Relevant expressions for SG, WL, moisture content X_w are listed below:

$$SG = \frac{W_s - W_{s0}}{W_{s0} + W_{w0}} \qquad WL = \frac{W_{w0} - (W_t - W_s)}{W_{s0} + W_{w0}} \qquad X_w = \frac{W_t - W_s}{W_{w0}}$$

with W_t, W_w,W_s, the total weight, water and solid weight in the sample (fresh conditions with subscript 0).
Triplicate dehydration runs were performed for the different experimental conditions.

Freeze-drying

To evaluate the effect of the osmotic pre-treatment on freeze-drying kinetics, the osmotic dehydration of the apple and potato was stopped before the equilibrium period, at 25 h and 3.5 h for apple and potato respectively.
Before undergoing to freeze-drying, each blotted samples were wrapped in a polyethylen film (to avoid freeze-dehydration) and frozen at -24 ° C for 24 h. Freeze-drying was performed in a Christ freeze-drier (model Alpha 1-4) at a residual pressure chamber of 0.2 mbar and at shelf temperature of 25 °C.
The drying kinetic was determined inserting into the chamber three samples at times. The drying time, for each batch, was increased by 30 min up to 350 min in the case of apple and to 800 min for the potato. At the end of each drying run, samples were weighed and completely dried in the vacuum oven in order to determine the solid uptake.

Rehydration kinetic

Rehydration was performed by immersion in water at 50 °C to constant drained weight. Samples of apple and potato, before undergoing to rehydration, was first pre-treated and after completely freeze-dried. Relevant rehydration kinetics were compared with those determined for fresh freeze-dried samples.

Results and Discussions

Osmotic pre-treatment

In figs.1 and 2 are shown the WL and SG of apple osmosed in 50 % glucose solution for the three temperature levels tested. The WL and SG curves can be divided in two distinct regimes: the dinamic period in the first stage in which mass transfer rates (WL and SG) are changed until the equilibrium period is reached, i.e. in which the net rate of mass transport is zero. The dehydration kinetic relative to the higher temperature is, as expected, faster than the others two temperatures. The equilibrium period begins, for all temperature levels, after the same soaking time, ≈ 1500 min. The moisture content, at the begin of the equilibrium period, has almost the same value of 0.4 for the three temperatures tested.

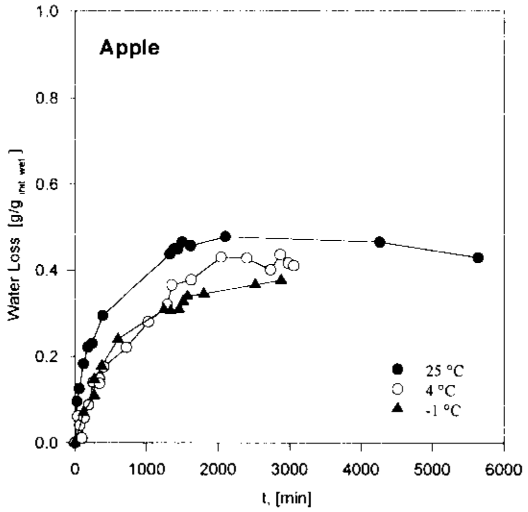

Fig. 1:Water loss of apple sample osmosed at 25 , 4 and -1 °C.

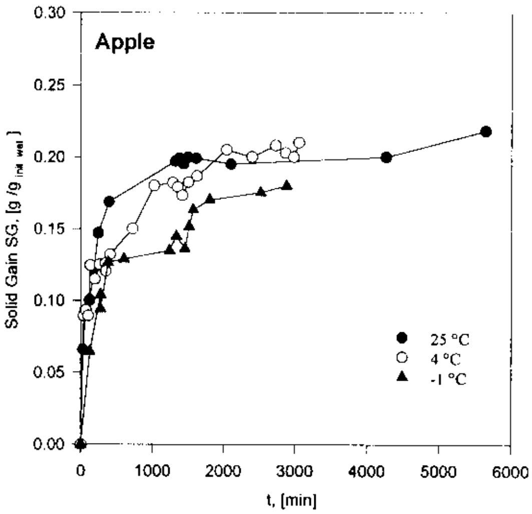

Fig. 2:Solid uptake of apple sample osmosed at 25 , 4 and -1 °C.

Also SG shows close values for long soaking times. The equilibrium value for SG is about 0.20. In the dinamic period, the osmotic dehydration performed at -1°C shows a lower solid uptake.

WL and SG in the case of potato are shown in figs 3 and 4. For short times, in the dynamic period, an effect of the temperature on the WL can be distinguished. For long times, the equilibrium moisture content attains the same value. In the case of SG there is a notable difference between the uptake at 25°C and the other temperature levels. The equilibrium solid uptake is about 0.10 for 4 °C and -1 °C and 0.15 for 25 °C.

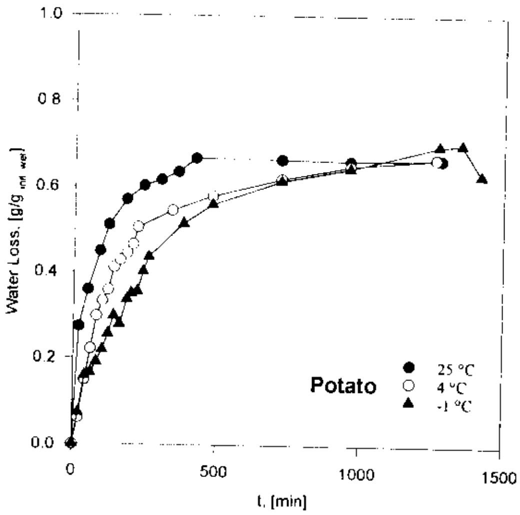

Fig. 3: Water loss of potato sample osmosed at 25 , 4 and -1 °C.

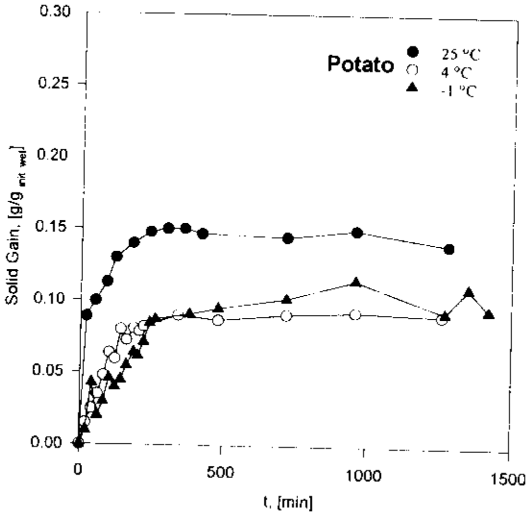

Fig.4: Solid uptake of potato osmosed at 25, 4 and -1 °C.

Freeze-drying

The effect of the osmotic pretreatment on the freeze-drying kinetics is shown in fig. 5. Typical drying curves for fresh and osmosed apple slabs are shown for different levels of osmoting temperature. The difference in initial moisture content reflects the different degree of water loss due to the osmotic pre-treatment. This difference has an effect on the drying time, with a considerable shortening of the freeze-drying cycle.

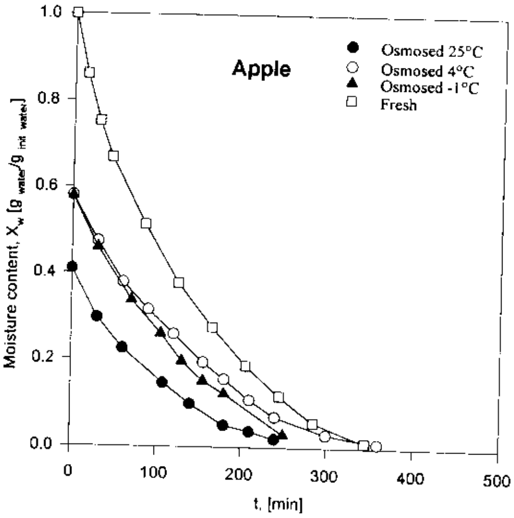

Fig.5: Freeze-drying curves for osmosed apple compared to fresh freeze-dried samples.

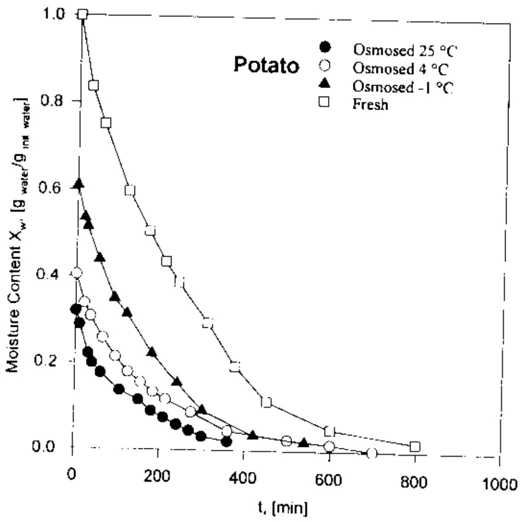

Fig.6: Freeze-drying curves for osmosed potato compared to fresh freeze-dried.samples

Fig. 6 shows drying curves for different pre-treatments in the case of potato. In this case too, relevant effect, on the freeze-drying time, can be observed due to the initial moisture content level.

Rehydration kinetic

The comparison of rehydration behaviour of the dried samples using single freeze-dried process and combined osmosis/freeze-drying can be observed in figs. 7 and 8 for apple and potato respectively. The water uptake, on a total solid basis, was measured as a function of time.

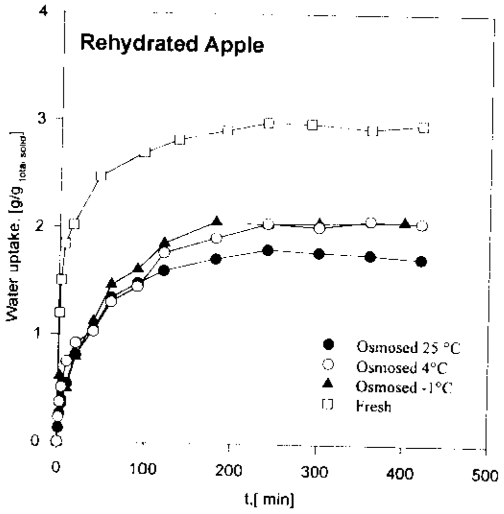

Fig. 7: Water uptake vs. time of freeze-dried pre-treated apple.

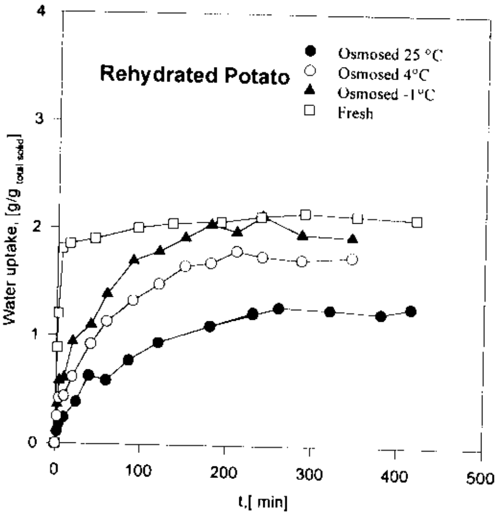

Fig. 8: Water uptake vs. time of freeze-dried pre-treated potato.

Samples dehydrated using the combined method show a lower rehydratability than those dried with single process. This can be due to the amount of solid gained during the osmotic process and to the shrinkage of the sample.

In the case of apple, dehydrated by the single process, the water level relative to long time is sensibly higher than in the other cases.

Conclusions

Osmotic dehydration, performed at low temperatures, can be used as an effective dehydration process leading to relatively high levels of water loss and solid gain with a moderate deterioration of chemical, physical and biological characteristic of the foods.

The effect of the osmotic pre-treatment on freeze-drying kinetics is related to water removal. The different levels of the initial water content, before undergoing to freeze-drying, lead to a sensibly shortening of the freeze-drying time.

The uptake of solid shows to have a direct influence on the rehydratability of the two vegetables.

References

1. Donsì G., Ferrari G. Nigro R. *"The use of combined processes in the preservation of vegetables"* paper presented at ICEF 7, Brighton, 11-13/04/1997
2. McKenna B.M. (1994) In: "Food Preservation by Combined Processes", eds. Leistener L. and Gorris L.G.M. Final Report of Flair Concerted action N° 7, Subgroup B, EUR 15776 EN, p7.
3. Leistener L.,(1992),"*Food Preservation by Combined Methods*" Food Research International, 25 ,151-158.
4. Saurel R., Raoult-Wack A.L. Rios G.M., Guilbert S.,(1995),"*Approches technologiques nouvelles de la déshydratation-impregnation par immersion(DII)*",IAA , 112.
5. Hawkes J., Flink J.M., (1978), "*Osmotic Concentration of Fruit Slices prior to Freeze Dehydration*", J. Food. Processing and Preservation, 2,265-284.
6. Yang A.P.P., Wills C., Yang T.C.S.,(1978),"*Use of Combination Process of Osmotic Dehydration and Freeze-Drying to Produce a Raisin-type Lowbush Blueberry Product*",J.Food Sci,52,6,1651.
7. Lenart A., (1996), "*Osmo-Convective Drying of Fruit and Vegetables: Technology and Application*", Drying Technology, 14(2),391-413.
8. Sankat C.K., Castaigne F. Maharaj R., (1996),"*The air drying behaviour of fresh and osmotically dehydrated banana slices*", Int, J. Food Sci. Technol. 31,123-135
9. Mazza G.,(1983), "*Dehydration of Carrots: Effect of pre-drying treatments on moisture transport and product quality*", J. FD. Technol., 18,113-123.
10. Monsalve-Gonzalez A., Barbosa-Canovas G.V., Cavalieri R.P., (1993),"*Mass Transfer and Textural Changes during Processing of Apple by Combined Methods*", J. Food Sci.,58(5),1118-1124.
11. Lazarides H.N.,Katsanidis E.,Nickolaidis A., (1995),"*Mass Transfer Kinetics during Osmotic Preconcentration Aiming at Minimal Solid Uptake*", J. Food Eng.,25,151-166.
12. Rahaman Shafiur P.M., Buckle K.A., Perera C.O.,(1996) "*Osmotic Dehydration of Pineapple Wedges using Palm Sugar*",Lebensm.-Wiss.u-Technol.,29,452-459.