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Effect of vacuum impregnation treatments to improve quality and texture of zucchini (*Cucurbita pepo,* L)

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Abstract

Vacuum Impregnation (VI) is a non-destructive technology, used to introduce external liquids, in the porous structures of food matrices favored by the action of hydrodynamic mechanism as promoted by pressure changes.
Previous studies evidenced the potentiality to apply VI to zucchini [2] but no systematic studies have been carried out yet. Aim of this study was to investigate the effect of VI by using mixed solutions containing structuring ability components (maltodextrins, salt and $CaCl_2$) with on quality and microstructural properties of zucchini. Slices of zucchini (0.5-cm thick) (*Cucurbita pepo,* L.) were subjected to VI treatments. VI solutions with different solutes composition were investigated: maltodextrines, NaCl and $CaCl_2$ were used to prepare single (1 solute) or mixed (2 and 3 solutes) VI solutions Samples were analysed for total solids, soluble solids, salt and [Ca] content, textural properties (shear force, relaxation test), sensory and microstructure (Cryo-SEM). Mass balance (Solute Gain/Loss, Water Gain/Loss) was also computed. The composition of the VI solution affected mass transfer. A significant change in the textural properties was observed in zucchini processed with VI solutions containing NaCl and MD; the presence of $CaCl_2$ in the VI solution in combination with the other solutes, was able limit the hardness loss and when alone even to determine an hardening effect. Cryo-SEM analysis highlighted a different effect on microstructure of the vegetable tissue due the use of the single or mixed VI solutions. The use of VI mixed solutions made with MD, NaCl and $CaCl_2$ to process zucchini allows to favour solute and water gain while limiting textural and microstructural changes

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Keywords: Vacuum Impregnation; zucchini; texture; Cryo-SEM; quality.

1. Introduction

Vacuum Impregnation (VI) is a non-destructive technology, used to introduce external liquids, in the porous structures of food matrices favoured by the action of hydrodynamic mechanism as promoted by

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pressure changes. The substitution of internal gases by a liquid phase of adjustable composition allows formulation of a food by expeditious compositional modifications of the solid matrix. Thus, while a change in the product composition occur, the VI impregnated product could exert improved quality (nutritional, sensory, textural, health) properties depending on the functionality of the components of the VI solution. Widely explored is the use of solutions made with sugars alone or in combinations with salt to impregnate food matrices; in recent times the addition of solutes other than sugars such as biologically active compounds and microorganisms is under investigation [1] for the potentiality to obtain innovative food products.

Texture is an important quality property of both fresh and processed vegetables. To this regards, the enrichment of fruits and vegetables with calcium salts has been investigated in both atmospheric and vacuum conditions thanks to the structuring ability of Ca^{2+}. Its interactions with the plant cellular tissue could, in fact, positively affect the mechanical properties of processed products and their acceptability by consumers [2, 3]. In more recent times, the fortification of vegetables matrices with minerals, included calcium, has been considered also an interesting method to produce foods with higher nutritional impact suitable for consumers with inadequate diets or specific health needs [3, 4].

Zucchini (*Cucurbita pepo,* L.) is a widely known vegetable of the Mediterranean area; it is characterised by high water and low solutes (sugars, fibers and polysaccharides) content as well as a mild flavour. Its texture is typically firm in the ripened fruit but tend to soften meaningfully during storage but in particular when the vegetable undergoes to cooking for dishes preparation and this behaviour is limiting its use for processed products.

Previous studies evidenced the potentiality to apply VI to zucchini [2] but neither systematic studies nor investigations to evaluate the use of structuring solutes to improve quality and texture of this vegetable have been carried out to our knowledge.

Aim of this study was, thus, to investigate the effect of VI by using mixed solutions containing structuring ability components (maltodextrins, salt and $CaCl_2$) on quality and microstructural properties of zucchini. To evaluate the specific technological effect of each solute, VI was also carried out on zucchini by using binary solutions at different solute concentrations.

Nomenclature

MD	Maltodextrins
VI	Vacuum Impregnation

2. Materials and Methods

Slices of zucchini (0.5-cm thick) (*Cucurbita pepo,* L.) were subjected to VI treatments by using a Rotavapor equipment (*Rotavapor LABOROTA4000, Heidolph Instruments,* Schwabach, Germany) connected to a vacuum pump (*CVC2I, Buchi,* Postfach, Switzerland) and the following process conditions: VI solution temperature: 20°C; P: 25 mbar, vacuum time (t_v): 10 min; post-vacuum or relaxation time (t_{pv}): 30 min; ratio product:solution = 1:3.3.

VI solutions with different solutes composition (type, concentration and solutes combination) were investigated. In particular maltodextrines (MD, DE 7.5-9, 10%), NaCl (0-5%) and $CaCl_2$ (0-1000 mM) were used to prepare simple (1 solute) or mixed (2 and 3 solutes) VI solutions. As reference a VI process with distilled water was also carried out. After the relaxation time, samples were drained for 2 min on a steel net and thereafter analysed for total solids, soluble solids (expressed as °Bx), salt and [Ca] content according to AOAC methods, textural properties (Instron Universal Texting Machine, shear test), sensory and microstructure using Cryo-SEM technique [5]. To limit the effect of the variability of the raw material, results of each parameter are expressed as Δ%, computed as the difference (%) of the parameter value in respect to that of no-impregnated product. Mass balance (Solute Gain/Loss, Water Gain/Loss) was also computed according to [6].

3. Results and Discussion

The mean values of dry matter (%) and solute (° Brix) content of the fresh raw zucchini resulted equal to 6.17 ±0.36 and 5.14±0.17, respectively.

In this study VI solutions were prepared with different solute type and concentration and complexity (up to three solutes) to obtain isotonic up to hypertonic solutions in respect to the water phase of the vegetable; with this approach mechanisms other than the Hydrodynamic Mechanism (HDM) was expected to occur during the processing, in particular the osmotic ones during the after vacuum step.

Under the applied experimental conditions, the composition of the VI solution greatly affected the mass transfer in the product (Table 1). When only water was used, a meaningful water uptake in the impregnated zucchini occurred as a consequence of the hydrodynamic mechanism and the deformation phenomena induced by the pressure drop that depend also on the viscoelastic properties of the cellular network; solids loss is due to the losses of native liquid carried away by the gas expansion and flow out from the pores as well as diffusional phenomena during the relaxation time after VI [7].

VI solutions with NaCl (alone or in combination with MD and $CaCl_2$) led to a significant water loss while it did not occur when solutions prepared with MD and $CaCl_2$, as single component or mixed were used (Table 1) due to its effects on the osmolarity of the VI solutions that favoured a water transfer from the vegetable to the solution.

Interesting are the effects of the $CaCl_2$-VI solution alone. In fact, even if hypotonic in respect to the water phase of the vegetable, they determined a reduced water uptake and solute loss in respect to the water-VI process. The calcium interaction with the plant cellular matrix leading to a more interconnected structure that limited water and solids exchange related to the deformation phenomena during the VI process could be implied in these results [4].

Solute gain occurred in VI zucchini especially when processed with MD solutions; based on salt concentration in the impregnated product competitive phenomena seem to occur when two or more solutes are present in the VI solution limiting the final solutes uptake by the vegetable (data not shown).

A significant change in the textural properties (shear force and energy) was observed in VI processed zucchini even when water alone was used as process media (Figure 1). VI solutions containing NaCl and MD alone determined a significant reduction of both shear and energy force while the opposite occurred when 100 mM $CaCl_2$ solution was used. Furthermore the presence of CaCl2 in the VI solution in combination with the other solutes, due to its structuring effect was able limit the hardness loss and when alone even to determine an hardening effect (Figure 1).

Zucchini tissue is characterised by a non uniform, anisotropic porous structure showing a more compact external part with small intercellular spaces and an open central zone containing seeds and larger lysigeneous intercellular spaces and remains of cellular walls (void degraded cells) that can be available for HDM action [3]. For the purposes of this study, cryo-SEM analysis was carried out on the tissues of the external region of fresh and the differently VI processed zucchini (Figure 2 and 3).

Fresh zucchini micrographs show densely packed and turgid parenchyma cells not continuously interconnected with intercellular spaces originating pores in the vegetable tissue that confirm the feasibility of zucchini to Vi processing.

Table 1. Water Gain/Loss (WG/L, g/g), Solid Gain/Loss (SG/L, g/g), dry matter variation (% in respect to the fresh no-impregnated product) of VI zucchini

VI solution	WG/L (g/g)	SG/L (g/g)	Dry matter (Δ%)
H2O	0.325	-0.030	-28.08
10 % MD	0.144	0.018	10.86
2.5 % NaCl	-0.107	0.004	18.12
5.0 % NaCl	-0.091	0.011	28.11
10 mM $CaCl_2$	0.170	0.012	0.59
100 mM $CaCl_2$	0.176	0.019	8.88
10% MD+2.5% NaCl	-0.169	0.018	52.91
10% MD+2.5% NaCl + 100 mM CaCl2	-0.210	0.033	87.95

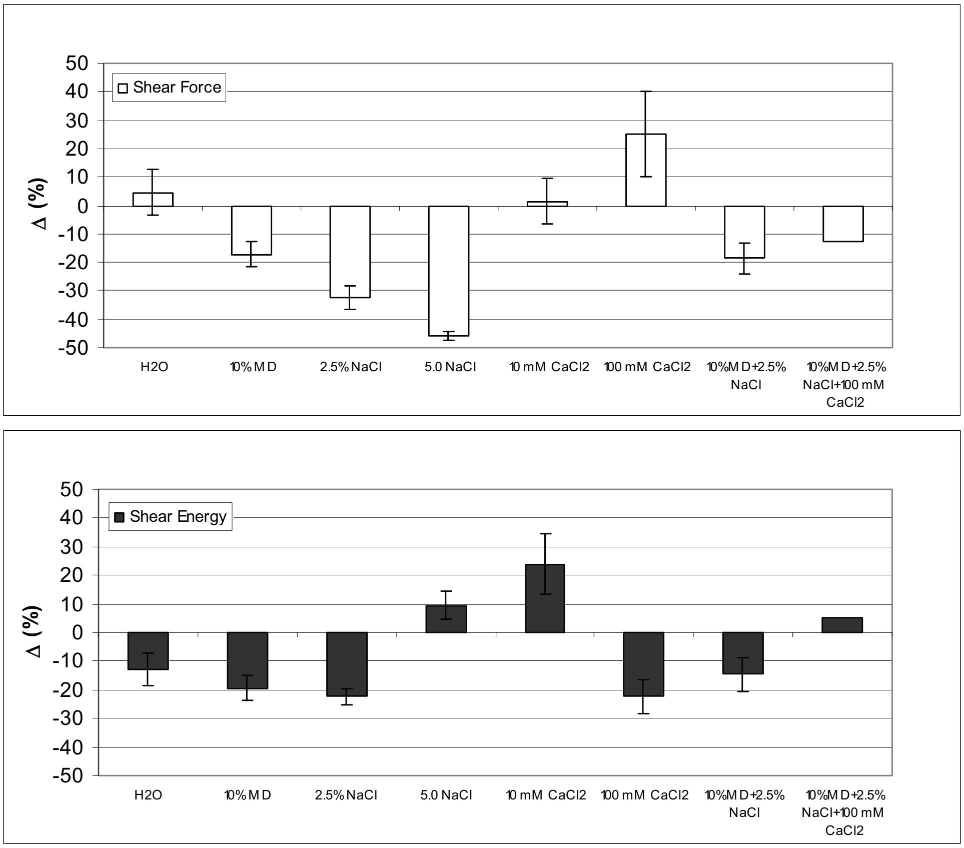

Fig. 1. Shear Force (a) and Energy (b) change (Δ%, in respect to the , no-impregnated product) of zucchini processed by using VI solutions with different solutes composition

Larger cells with a more irregular shape in respect to the ones noticed in the fresh vegetable, could be observed in the case of water-impregnated zucchini where the water penetrated into the cell provokes its swelling and the crushing of the plasmatic membrane towards the cell wall [8] (Figure 2). VI solutions exerted different effects on the vegetable tissue depending on solute type and complexity. A marked damage on the vegetable tissue due to a dehydration effect was observed when NaCl and, to a more limited extent, MD were used alone in the VI solution (data not shown) while on the contrary the structuring effect of the $CaCl_2$ is implied in more thick cell walls and turgid cells in the CaCl2-VI processed zucchini (Figure 2).

In the mixed solutions, the presence of MD limited the damages induced by NaCl and $CaCl_2$; intercellular spaces rich of solutes, turgid cells and thick walls were in this case observed (Figure 2).

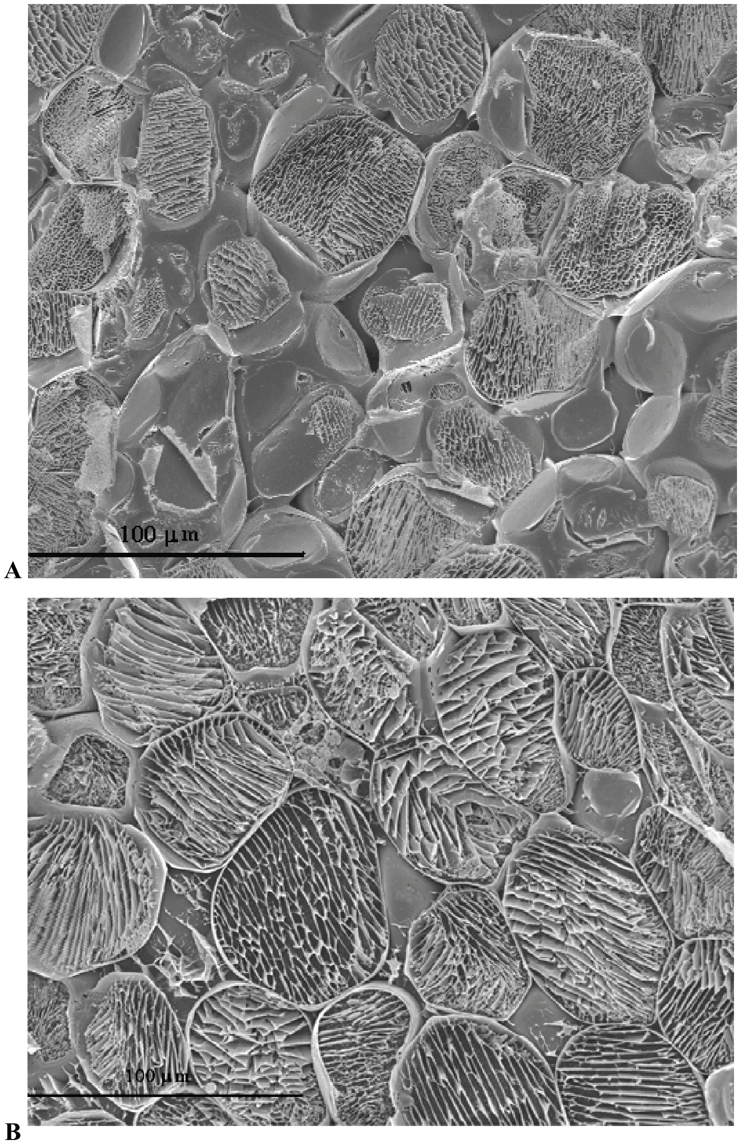

Fig. 2. Micrographs of zucchini fresh (A), vacuum impregnated with H_2O (B), obtained by cryo-SEM analysis

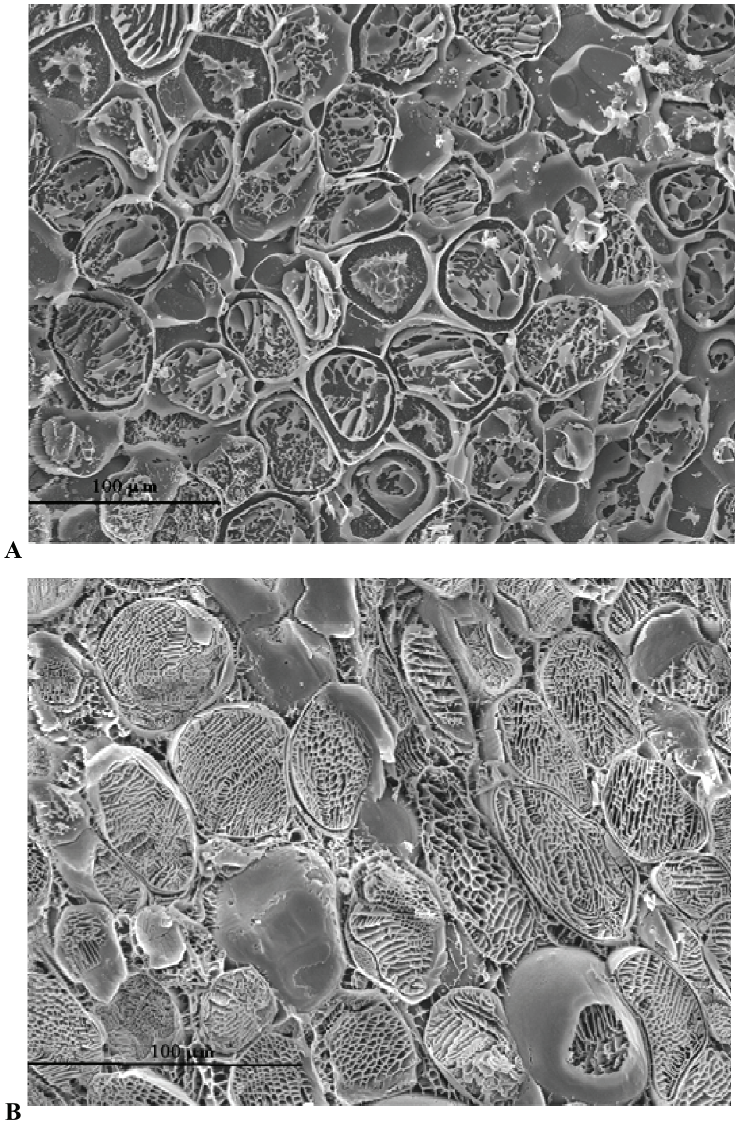

Fig. 3. Micrographs of zucchini vacuum impregnated with solution of 100 mM $CaCl_2$, (A) 10% MD + 2,5% NaCl + 100 mM $CaCl_2$ (B), obtained by cryo-SEM analysis

4. Conclusions

The use of VI mixed solutions made with MD, NaCl and $CaCl_2$ to process zucchini allows to favour solute and water gain while limiting textural and microstructural changes.

Furthermore, these results confirm the feasibility of VI to process this vegetable and to obtain minimally processed products with improved quality properties. The potentiality to use impregnated zucchini for further stabilisation processes need to be investigated.

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