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Functional foods enriched in Aloe vera. Effects of vacuum impregnation and temperature on the respiration rate and the respiratory quotient of some vegetables

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Abstract

This work is part of a study on the process of production of vegetables enriched in Aloe vera using the vacuum impregnation (VI) technique. The objectives of this work were: (i) to analyze the effects of VI with Aloe vera on some quality parameters of vegetables: water activity, water content, soluble solids content, real and apparent densities, and pH; (ii) to analyze the effects of the presence of Aloe vera in VI solutions and temperature on the respiration rates (carbon dioxide production and oxygen consumption) and the respiration quotient of some vegetables (endive, cauliflower, broccoli and carrots). VI made it possible to incorporate up to 7 g of Aloe vera in 100 g (dry matter) of broccoli, about 4 g in cauliflower and endive, and about 3 g in carrot. In almost all cases, respiration rate values were higher at 20ºC than at 5ºC. For vegetables submitted to VI using an isotonic sucrose solution, and in comparison with fresh samples, respiration rates at 5ºC were higher for broccoli, endive and carrot, but lower for cauliflower. At 20ºC, they were higher in the case of broccoli, endive and cauliflower, but lower for carrots. As compared with fresh samples, and at 5ºC, respiration rates were lower for all vegetables impregnated using a solution with 30 g/L of Aloe vera powder; at 20ºC, they were lower for cauliflower, but higher for broccoli, endive and carrots. The presence of Aloe vera in sufficient concentration seemed to compensate the metabolic stress caused by the application of vacuum.

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Keywords: functional foods; vacuum impregnation; aloe vera; vegetables; endive, cauliflower, broccoli, carrot, physicochemical properties; respiration data.

1. Introduction

Food provides essential nutrients for normal function of body, but unbalanced diet over a long time increases the risk of developing nutritional diseases and involves expensive medical treatments. The

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inclusion of physiologically active natural components with beneficial effects on health strengthens the nutritional value of fresh vegetables. Scientists have discovered potential health benefits of natural components of Aloe vera. Aloe is a tropical and subtropical plant characterized by lance-shaped leaves with jagged edges and sharp points. It is a perennial plant; its leaves joined at the stem in a rosette pattern. The actual value of Aloe vera in helping to improve pathologic conditions, relieve complaints and restore health has been debated from antiquity to the present. Many studies have been made about Aloe vera and its physiologically active substances; they confirm its potential value [1, 2, 3, 4, 5]. The vacuum impregnation (VI) technique [6, 7, 8] makes it possible to produce functional foods from fruits and vegetables, keeping their "fresh" physical and sensorial characteristics, and fortifying their nutritional value by introducing liquids, with dissolved or suspended substances, directly into the vegetable porous structure, in a controlled way, allowing fast compositional changes. Aside from transpiration, respiration is undoubtedly the most important factor contributing to the deterioration of vegetables after harvest. Information on respiration rates is needed for the solution of practical problems concerned with storage and transportation of fresh or minimally processed vegetables. This work is part of a study on the process of production of vegetables enriched in Aloe vera using the VI technique [9]. The objectives of this work were: (i) to analyze the effects of VI with aloe vera on some quality parameters of vegetables: water activity (a_w), humidity (water mass fraction, X_w), soluble solids content (Brix), real and apparent densities (ρ_r, ρ_a), and pH; (ii) to analyze the effects of the presence of aloe vera in VI solutions and of temperature on the respiration rates (carbon dioxide production and oxygen consumption) and the respiration quotient of some vegetables (endive, cauliflower, broccoli and carrots).

2. Materials & Methods

The vegetables used in the experiments were endives (Cichorium intybus L.), cauliflower (Brassica oleracea var. Italica), broccoli (Brassica oleracea var. Botrytis L.) and carrots (Daucus carota L. var. Nantesa), with the aim to study inflorescences (cauliflower and broccoli), leaves (endive) and roots (carrots). They were obtained from the local market (Valencia, Spain), taking into account homogeneity in size, shape and apparent ripeness. Vacuum impregnation (VI) experiments were carried out in a specially designed equipment [7]. The vacuum period of the VI process was performed at 50 mbar during 10 minutes, and samples remained immersed into the solution of impregnation (SI) during 10 minutes at atmospheric pressure. Prior to analysis, the SI in excess on samples surface was eliminated using a manual centrifuge. Three types of SI were prepared: SucSI, used as VI reference SI, were aqueous sucrose solutions of the same a_w than each of the four raw materials; AV5SI and AV30SI were Aloe vera aqueous dispersions prepared with, respectively, 5 g/L and 30 g/L of Aloe vera powder (Aloe barbadensis, Terry laboratories, Melbourne, Fl, USA). AV5SI has a similar concentration than the gel of the Aloe vera plant, and pH . CO_2 production and O_2 consumption were determined, and respiration quotient calculated, at 5 and 20ºC, for fresh and impregnated vegetables, using a static procedure [10]. Four groups of samples from each vegetable were obtained and their respiration rates determined and compared: F (fresh, not submitted to any VI), VISuc (VI with SucSI), VIAV5 and VIAV30 (VI with AV5SI and AV30SI, respectively). Analytical determinations and calculus were performed as described in previous papers [7, 8, 10, 11].

3. Results & Discussion

Table 1 shows some physicochemical properties of fresh (F) and impregnated (VIAV5 and VIAV30) samples of the studied vegetables. Broccoli is the only vegetable with some detectable natural porosity, that is, a fraction of his volume is occupied by an internal gaseous atmosphere. This fraction is very low for endive, cauliflower and carrot, but it is enough for VI: its expansion is effective in replacing internal liquid with external SI. The amounts of AV5SI and AV30SI retained by the vegetables, expressed as % of samples initial volume, were 46 and 37% for broccoli, 17 and 7% for cauliflower, 17 and 17% for endive, and 14 and 10% for carrot [9]. When using AVSI5, these volumetric impregnations allowed to obtain the following amounts of Aloe vera in the products, referred to 100 g dry matter: broccoli, more than 1 g; cauliflower, endive and carrot, more than 700 mg. In the case of AVSI30: broccoli, 7 g; cauliflower and endive, about 4 g; carrot, about 3g. Because of the partial replacement of the internal native liquid with the external more concentrated SI (AV30SI), VIAV30 samples showed greater soluble solid content (Brix) than fresh and VIAV5 samples, lower a_w and X_w values, and suffered a slight reduction of the pH value, due to the acid nature of the used SI: AV5SI pH is 4.1±0.1, AV30SI pH is 3.7±0.1.

Table 1. Some physicochemical properties of fresh (F) or impregnated (VI) vegetables.

Vegetable	Treatment (Sample)	X_w (% water mass fraction)	a_w (water activity)	pH	Brix	ρ_r (kg/m^3) (real density)	ρ_a (kg/m^3) (apparent density)	ε (%) (porosity)
	F	96.1±0.2	0.995±0.003	5.85±0.02	3.93±0.06	1015±7	1011±3	n.d.
Endive	VIAV5	94.3±0.2	0.992±0.003	5.88±0.02	3.87±0.06	1022±5	1007±5	n.d.
	VIAV30	93.7±0.2	0.985±0.003	5.2±0.	4.2±0.2	1016±2	1009±5	n.d.
	F	90.3±0.3	0.990±0.003	6.50±0.09	9.1±0.5	1037±4	866±2	16±2
Broccoli	VIAV5	90±2	0.992±0.003	6.25±0.08	8.9±0.6	1040±4	959±2	8±4
	VIAV30	86±2	0.979±0.003	6.1±0.2	9.5±0.5	1056±6	970±4	8±4
	F	90.4±0.3	0.993±0.003	6.56±0.03	9.0±0.13	1037±5	995±5	n.d.
Cauliflower	VIAV5	92.8±0.9	0.992±0.003	6.64±0.04	8.53±0.06	1007±4	946±5	n.d.
	VIAV30	89.1±0.3	0.981±0.003	5.85±0.04	9.17±0.06	1000±4	989±7	n.d.
	F	88.7±0.3	0.993±0.003	6.31±0.04	8.6±0.3	1044±7	1030±2	n.d.
Carrot	VIAV5	90±2	0.990±0.003	6.2±0.2	8.7±0.4	1039±7	1031±4	n.d.
	VIAV30	87.8±0.2	0.987±0.003	5.7±0.2	8.81±0.05	1024±8	1023±4	n.d.

n.d. not detectable

Respiration rates (O_2 consumption and CO_2 production) are good indicators of the metabolic activity of vegetables. Process operations (e.g. VI) can cause them some stress, which results in metabolic activation, becoming apparent with increased respiration rate [10]. Tables 2, 3, 4 and 5 present the results of the determinations of respiration rates and the values of the respiration quotients, for broccoli, cauliflower, endive and carrot, respectively. Figure 1 and Figure 2 help to analyze the results.

The controlled factors (VI, presence/concentration of Aloe vera, and temperature) had significant effects on the respiration rate and the respiratory quotient of the studied vegetables. In almost all cases, respiration rate values were higher at 20ºC than at 5ºC. VI (with SucSI) affected vegetables respiration, in a greater way on those who lost a bigger amount of native liquid, probably due to the stress/hurt that the cellular structure experiences in the course of the operation. For vegetables submitted to VI using the isotonic sucrose SI (VISuc samples), and in comparison with fresh samples (F), respiration rates at 5ºC were higher for broccoli, endive and carrots, but lower for cauliflower. At 20ºC, they were higher in the case of broccoli, endive and cauliflower, but lower for carrots.

The presence/concentration of Aloe vera in the SI also affected significantly vegetables respiration, but in an opposite way. As compared with fresh samples (F), and at 5ºC, respiration rates were lower for all vegetables impregnated using the SI with 30 g/L of Aloe vera powder (VIAV30); at 20ºC, they were lower for cauliflower, but higher for broccoli, endives and carrots. Apparently, the presence of Aloe vera components (mucopolysaccharides) in a sufficient concentration was capable, in some extent, of compensating the metabolic stress caused by the application of vacuum. The values obtained for the respiration quotient were near 1, though the VIAV30 samples exceeded this value, both to 5 and to 20ºC.

Table 2. Respiration data for broccoli

Treatment	O_2 consumption mL O_2 kg^{-1} h^{-1}		CO_2 production mL CO_2 kg^{-1} h^{-1}		Respiratory Quotient	
	5ºC	20ºC	5ºC	20ºC	5ºC	20ºC
F	82 ± 20	82 ± 20	71 ± 17	172 ± 51	0.90 ± 0.05	0.99 ± 0.08
VISuc	148 ± 28	148 ± 28	149 ± 30	258 ± 62	1.00 ± 0.02	1.07 ± 0.06
VIAV5	152 ± 18	152 ± 18	153 ± 13	128 ± 15	1.00 ± 0.02	1.0 ± 0.2
VIAV30	106 ± 5	106 ± 5	105 ± 4	318 ± 40	1.00 ± 0.02	1.03 ± 0.06

Table 3. Respiration data for cauliflower

Treatment	O_2 consumption mL O_2 kg^{-1} h^{-1}		CO_2 production mL CO_2 kg^{-1} h^{-1}		Respiratory Quotient	
	5ºC	20ºC	5ºC	20ºC	5ºC	20ºC
F	71 ± 31	124 ± 4	67 ± 28	137 ± 20	0.98 ± 0.04	1.1 ± 0.2
VISuc	45 ± 5	213 ± 8	42 ± 6	240 ± 32	0.93 ± 0.06	1.1 ± 0.11
VIAV5	62 ± 13	103 ± 21	67 ± 23	127 ± 40	1.1 ± 0.11	1.2 ± 0.2
VIAV30	37 ± 3	120 ± 24	42 ± 5	151 ± 29	1.13 ± 0.062	1.27 ± 0.06

Table 4. Respiration data for endive

Treatment	O_2 consumption mL O_2 kg^{-1} h^{-1}		CO_2 production mL CO_2 kg^{-1} h^{-1}		Respiratory Quotient	
	5ºC	20ºC	5ºC	20ºC	5ºC	20ºC
F	19 ± 7	44 ± 18	18 ± 6	43 ± 19	0.93 ± 0.05	1.0 ± 0.11
VISuc	57 ± 12	77 ± 7	53 ± 10	82 ± 2	0.90 ± 0.02	1.07 ± 0.06
VIAV5	17 ± 2	50 ± 7	17 ± 4	45 ± 15	1.0 ± 0.11	0.9 ± 0.11
VIAV30	32 ± 20	57 ± 20	37 ±25	92 ± 9	1.13 ± 0.06	1.2 ± 0.11

Table 5. Respiration data for carrot

Treatment	O_2 consumption mL O_2 kg^{-1} h^{-1}		CO_2 production mL CO_2 kg^{-1} h^{-1}		Respiratory Quotient	
	5ºC	20ºC	5ºC	20ºC	5ºC	20ºC
F	41 ± 21	78 ± 22	38 ± 22	74 ± 26	0.90 ± 0.08	0.95 ± 0.08
VISuc	47 ± 5	66 ± 6	47 ± 5	66 ± 8	1.00 ± 0.02	1.0 ± 0.2
VIAV5	16 ± 3	63 ± 12	18 ± 3	73 ± 21	1.2 ± 0.11	1.2 ± 0.10
VIAV30	37 ± 52	108 ± 10	47 ± 2	156 ± 20	1.13 ± 0.06	1.43 ± 0.06

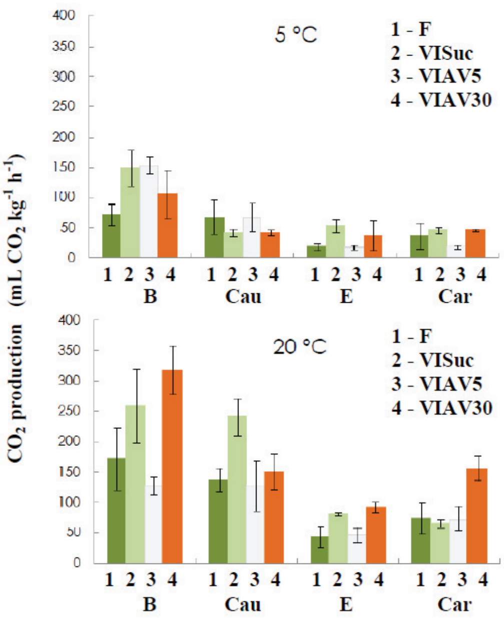

Fig. 1. CO_2 production of broccoli (B), cauliflower (Cau), endive (E) and carrot (Car), for fresh (F) and impregnated (VISuc, VIAV5, VIAV30) samples, at 5 and 20ºC

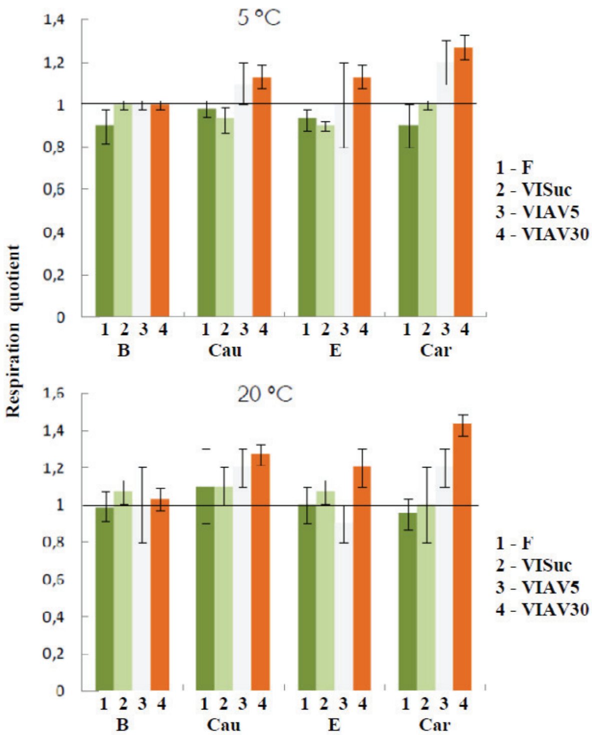

Fig. 2. Respiration Quotient (RQ) of broccoli (B), cauliflower (Cau), endive (E) and carrot (Car), for fresh (F) and impregnated (VISuc, VIAV5, VIAV30) samples, at 5 and 20ºC

4. Conclusion

VI made it possible to incorporate up to 7 g of Aloe vera in 100 g (dry matter) of broccoli, about 4 g with cauliflower and endive, and about 3 g with carrots. In almost all cases, respiration rate values were higher at 20ºC than at 5ºC. For vegetables submitted to VI using an isotonic sucrose solution, and in comparison with fresh samples, respiration rates at 5ºC were higher for broccoli, endive and carrots, but lower for cauliflower. At 20ºC, they were higher in the case of broccoli, endive and cauliflower, but lower for carrots. As compared with fresh samples, and at 5ºC, respiration rates were lower for all vegetables impregnated using a solution with 30 g/L of Aloe vera powder; at 20ºC, they were lower for cauliflower, but higher for broccoli, endive and carrots. The presence of Aloe vera in sufficient concentration seemed to compensate the metabolic stress caused by the application of vacuum. Vacuum impregnation and the presence of Aloe vera in vacuum impregnation solutions affected differently the respiration rate and the respiration quotient of the different studied vegetables. This must be taken into account regarding the design of industrial processes of production.

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