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Gum Arabic and Tricalcium Phosphate as Encapsulating Agents during kiwifruit Drying

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Abstract

The current interest in the healthfulness of fruits may be linked to its antioxidant capacity, related to the presence of bioactive compounds. Freeze-drying opens up new alternatives for fruit processing, mainly due to the scarce heat damage to the product. Nevertheless, the high cost of this process may recommend some pre-drying treatment. In this study, the effect that using pre-microwaves or hot air partial drying prior to freeze-drying has on the vitamin A, C and E content and antioxidant capacity of kiwifruit puree, with or without the presence of gum Arabic and tricalcium phosphate, was studied. Powders obtained from kiwifruit purees with solutes added showed a significant (p<0.05) higher content of vitamins and greater antioxidant capacity. Gum Arabic and tricalcium phosphate protect against loss caused by any studied drying treatments. Nevertheless, microwaves and especially hot air partial drying treatments prior to freeze-drying caused significant vitamin and antioxidant capacity loss.

Keywords: microwaves; hot air; freeze-drying; antioxidant capacity; vitamins A, E and C

Introduction

Every day, our body is subjected to attack by many reactive oxygen species (ROS), formed not only during the physiological metabolism of energetic nutrients but also under infection, smoking, and pollution threaten [1, 2]. When the normal antioxidant defences are overwhelmed, ROS bring about a condition of oxidative stress [3], which means that ROS attack and oxidize portions of lipids, nucleic acids, and proteins, with the consequent impairment of physiological functions and the appearance of pathologies [1]. The contribution of antioxidant nutrients becomes of vital importance to rescuing the body from oxidative stress conditions [4]. Fresh vegetables are relevant reservoirs of vitamins and phenol compounds [5]. If introduced into the body at every meal, those nutrients provide consistent protection to physiological macromolecules by increasing the antioxidant capacity of the plasma [6, 7]. The kiwifruit is the edible berry of a cultivar group of the woody vines of several Actinidia species. The most common commercially available, green-fleshed kiwifruit is the ‘Hayward’ cultivar, which belongs to the Actinidia delicosa species [8]. Kiwifruit are often promoted for their high vitamin C content, which probably contributes to the health benefits that include antioxidant, antiatherogenic and anticarcinogenic activities, as well as immunomodulation [9]. However, kiwifruit also contain other vitamins and minerals that may contribute to possible health benefits, including folate, potassium and magnesium, dietary fibre and phytochemicals [10]. The effects of kiwifruit consumption on hypertension and dyslipidemia have been tested in human trials. [11] found that the consumption of green kiwifruit resulted in a small but significant reduction in diastolic and systolic blood pressure in male smokers, the effect being strongest in those with hypertension.

On the other hand, in subjects that were hypercholesterolemic, kiwifruit consumption did have a favourable effect on plasma high-density lipoprotein cholesterol (HDL-C) concentrations and the total cholesterol (TC): HDL-C ratio [12]. These results support the earlier findings that kiwifruit consumption increased HDL-C and decreased the TC: HDL-C ratio and also decreased the plasma triglyceride concentrations [13, 14].

In addition to the "mainstream" health targets commonly used to define the benefits from functional food, a small number of studies demonstrate more novel bioactive effects of kiwifruit, such as "natural" sleep aid or wound healing. The consumption of "Hayward" kiwifruit in the evening has been shown to improve sleep onset, duration, and efficiency in adults with self-reported sleep disturbances [15]. In addition, the application of kiwifruit fresh slices to burns has been shown to improve the healing process [16].

However, many people are not able to consume fresh fruit every day, due to their work conditions, distance from the markets of fresh products, or having very little time for shopping and cooking [17]. Therefore, they buy processed fruit and consume them every day. Powdered fruit products may be an alternative means of increasing fruit consumption in response to the increased demand for ready-to-eat foodstuffs. The benefits of handling, packaging and transporting fruit powder, the great stability of the product and the ease of final consumption could contribute to this end. Freeze-drying (FD) emerged as a drying method which generates high quality products with very low moisture content, good sensory and nutritional properties and a good capacity for rehydration. However, long processing times and high operation costs are necessary to obtain freeze-dried products with an adequate level of quality [18]. Different studies have been...
carried out into how to reduce processing costs, for example abolishing the cost of vacuum generation, combining technologies prior to or during FD operation or enhancing heat transfer [19–21]. On the other hand, freeze-dried fruit products are highly hygroscopic and are prone to suffering changes in their physical properties brought about by the environment and time. Therefore, adding biopolymers and other solutes has been shown to be necessary in order to increase the product stability by acting as a barrier to water adsorption [22, 23]. The aim of this study was to evaluate the impact of both the use of microwave (MW) or hot-air drying (HA) as pre-drying treatments prior to freeze-drying and the presence of gum Arabic (GA) and tricalcium phosphate (TCP) on both the vitamins and antioxidant capacity of kiwifruit powders.

Materials and Methods

Sample preparation and treatments

Kiwifruit (Actinidadeliciosa var. Hayward) was purchased in a local market in Valencia (Spain). The mean values (with standard deviation in brackets) of pH, °Brix and water content of the kiwifruit used were 3.32 (0.09), 13.6 (0.7) and 84.0 (0.8) g/100g, respectively. The fruit pieces were peeled, washed with distilled water and triturated in a Thermomix (TM 21, Vorwerk, Spain). The obtained puree was divided into two parts and GA (Sigma CAS: 9000-01-5, Spain) along with TCP (Sigma CAS: 7758-87-04, Spain) were added to one of them. The quantities employed were: 1 kg GA/kg soluble solids of the liquid phase of the product [24] and 0.02 kg TCP/kg soluble solids of the liquid phase of the product [25, 26]. As a result, two different samples were obtained: kiwifruit and kiwifruit with solutes. A part of each sample was freeze-dried. To this end, a layer (5 mm thickness) of each sample was placed in a standardised aluminium plate (15 cm diameter and 5 cm height). Consecutively, samples were stored in a CVF 525/86 cryo freezer (-86 ºC) (Ing. Climas, Spain) for the 24 h before being freeze-dried in a Lioalfa-6 Lyophyliser (Telstar, Spain) at 0.026 mbar and -56.6 ºC at condenser for 24 h. The obtained cakes were crushed (Thermomix TM 21, Vorwerk, Spain) to obtain kiwifruit powders, with and without solutes, which were named KS and K, respectively.

The rest of the samples of kiwifruit and kiwifruit with solutes was submitted to two different pre-drying methods, prior to FD, in order to reduce the initial water content: MW and HA. According to preliminary experiments (data not shown), the final water content for samples, moisture of grapefruit's own solutes (GS) to total sample solutes, m_cw, m_cmc, and mₙ are the mass of gum Arabic, carboxymethyl cellulose and liquidized grapefruit, respectively, in the sample and xₚ is the water content of the liquidized grapefruit (w/w). The mass fraction of water of was obtained by vacuum drying the samples in a vacuum oven (Vaciomet, J.P. Selecta, Spain) at 60 ± 1 ºC under a pressure of < 100 mm Hg until constant weight. To determine the total solute content (TS) of the freeze-dried samples, the methodology described by [27] was followed. In turn, 1.5 g of each powder were rehydrated, in triplicate, and the TS of the bulk powder was determined by oven drying (Vaciomet, J.P. Selecta, Spain) at 60 ºC until constant weight.

Vitamins A, C and E

The vitamins were determined by HPLC (Jasco equipment, Italy). The procedure employed to determine vitamin C was the reduction of dehydroascorbic acid to ascorbic acid, using DL-dithiothreitol as reductant reagent according to Igual et al., 2016. The HPLC method and instrumentation were: Ultrabase-C18, 5 μm (4.6x250 mm) column (AnalísVinicos, Spain); mobile phase 0.1 % oxalic acid, volume injection 20 μL, flow rate 1mL/min, detection at 243 nm and at 25 ºC. AA standard solution (Panreac, Spain) was prepared.

Vitamins A and E were extracted twice in the hexane phase and the collected extract was dried under a stream of liquid nitrogen [28]. The dried extract was solubilized in 0.2 mL methanol. The HPLC method and instrumentation were: Ultrabase-C18, 5 μm (4.6 x 250 mm) column (Spain); mobile phase methanol/acetonitrile/chloroform (47:42:11, v/v/v), volume injection 20 μL, flow rate 1 mL/min, detection at 326 and 296 for vitamins A and E, respectively at 25 ºC. Standard curves of each reference compound (Fluka-Biochemika, USA) were used for quantification purposes.
Antioxidant capacity

Antioxidant capacity (AOC) was assessed using the free radical scavenging activity of the samples evaluated with the stable radical 2, 2-diphenyl-1-picryl-hydrazyl-hydrate (DPPH). Briefly, the samples were diluted in methanol, homogenized and centrifuged (Selecta Medifriger-BL, Spain) at 400 x g for 10 min at 4 °C. 0.1 mL of supernatant was added to 3.9 mL of DPPH (Sigma-Aldrich, Germany) diluted in methanol (0.030 g/L). At 30 s intervals, a UV-visible spectrophotometer was used to measure the absorbance at 25 ºC and 515 nm until the reaction reached the steady state. The percentage of DPPH was calculated following Eq. (3).

\[
\% \text{DPPH} = \frac{(A_{\text{control}} - A_{\text{sample}})}{A_{\text{control}}} \times 100
\]  

where \(A_{\text{control}}\) is the absorbance of the control (initial time) and \(A_{\text{sample}}\) the absorbance of the sample at the steady state.

The final results were expressed as mmol trolox equivalents (TE) per 100 g sample using a trolox calibration curve in the range of 6.25–150 mM (Sigma-Aldrich, Germany).

Statistical analysis

An analysis of variance (ANOVA) was carried out to evaluate the differences among samples. When the p value was lower than 0.05, significant differences between samples were assumed. Furthermore, an analysis of the correlation between AOC and all the studied vitamins, with a 95 % significance level, was carried out. All statistical analyses were performed using Stat graphics Centurion XVI.II for Windows.

Results and discussion

Kiwifruit characterization

The vitamin A content (0.029 (0.002) mg/100 g) was lower than that of the rest of the quantified bioactive compounds. The vitamin E content was 2.10 (0.13) mg/100 g, similar to the values of this vitamin shown by [29] (2.5 mg /100g). In general, citric fruit are considered a good source of vitamin C. However, the amount of vitamin C in kiwifruit (105 (5) mg/100 g) is about three times more than that present in 100 g of grapefruit [30] or twice more than orange [31]. The obtained results coincide with the values shown for kiwifruit var. Hayward by other authors [32–35]. One of the predominant mechanisms of the protective action of bioactive compounds is their antioxidant activity and the capacity to scavenge free radicals [36]. Kiwifruit showed 15.63 (0.15) mmol TE/100g of AOC.

The effect of solute addition and pre-drying on bioactive compound variation of freeze-dried kiwifruit powder

The losses of vitamins and AOC suffered by the samples as a consequence of each drying step have been plotted in Fig. 1 – 4. The loss of each component (\(\Delta M_i\)), referred to the fresh kiwifruit content, were calculated according to equations 4 and 5.

\[
\Delta M_{p}^i = \frac{(M_{FK}^i - M_{P}^i)}{M_{FK}^i} \times 100
\]
\[
\Delta M_{FD}^i = \frac{(M_{FK}^i - M_{FD}^i)}{M_{FK}^i} \times 100
\]

where: \(M_i\): mass of compound i in the sample referred to the kiwifruit’s own solutes and superscripts: FK: fresh kiwifruit, P: pre-treated (mixed with the solutes and/or pre-dried by MW or HAD), FD: freeze-dried.
vitamins studied throughout FD. As regards pre-drying treatments, the loss of vitamins A or C due to MW or HAD pre-treatments was of the same order, while the loss of vitamin E was greater when HAD was used. In fact both the KMW and KHAD samples even lost the entire amount of vitamin A present in the fresh kiwi. In these KMW and KHAD samples, the additional loss of the remaining vitamin C brought about by the freeze-drying process was almost negligible, while the loss of vitamin E was also promoted in sample KMW. When comparing these samples with KSMW and KSHAD, the loss of vitamins was reduced in the samples with solutes added, so that for vitamins A and C the loss was reduced in the range of 30 and 20 %, respectively and for vitamin E from 15 % to 40%, depending on whether the HAD or the MW pre-treatment was applied, respectively. As regards AOC (Fig. 4), a loss of about 5 % was observed caused by FD (sample K) or simply by sample formulation (sample KS). A 50–60 % loss of AOC was observed in pre-treated KMW and KHAD samples, due just to FD or to HAD and FD, respectively. This loss was reduced to 20–25 % when solutes were present (KSMW and KSHAD samples). Added solutes help the retention of nutritive properties of kiwifruit during pre-treatments and FD. Maltodextrins and gums are added during the production of food powders in order to act as encapsulating or wall materials, contributing to keeping the desired functional properties in the finished product, such as stability against oxidation, ease of handling, improved solubility, controlled release and extended shelf-life [37]. GA is the gum most often used as a flavour encapsulating material, mainly due to its solubility, low viscosity, emulsification characteristics and its good retention of volatile compounds [38–40].

Conclusions

An encapsulating effect of GA+TCP was observed both for the mixing with solutes and/or the pre-drying treatment and for the freeze-drying process. When solutes are present, a pre-drying treatment
with MW may be recommended instead of HAD for the purposes of obtaining a freeze-dried product, as vitamin E and AOC are better preserved. Nevertheless, despite the fact that the pre-treatment will shorten the subsequent freeze-drying time and so reduce the energy costs, if the maximum preservation of the vitamin content and AOC is desired, the use of microwave or hot air drying pre-treatment should be avoided.

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References


Citation: