Effect of Resistant Maltodextrin on Bioactive Compounds of Pasteurized Orange Juice †

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Abstract: Resistant maltodextrin (RMD) is a water-soluble fermentable functional fiber. RMD is a satiating prebiotic, a reducer of glucose and triglycerides in the blood and a promoter of good gut health. It is being incorporated into food more and more frequently. Therefore, it is necessary to study its possible effects on intrinsic bioactive compounds of food. The aim of this work was to evaluate the effect of RMD addition on the bioactive compounds of pasteurized orange juice with or without pulp. RMD was added in different concentrations: 0 (control sample), 2.5, 5 and 7.5%. This way, for a finished drink portion of 200 mL, 5, 10 or 15 g of RMD would be ingested, respectively; enough to display its prebiotic effect. Ascorbic acid and vitamin C were analyzed by HPLC, whereas total phenols, total carotenoids and antioxidant capacity were measured by spectrophotometry. Orange juice with pulp presented higher values of bioactive compounds and antioxidant capacity than orange juice without pulp. The addition of RMD before the juice pasteurization process protected phenols and carotenoids of the juice. The content of total phenols, total carotenoids, ascorbic acid and vitamin C after pasteurization were higher in samples with RMD, as was antioxidant capacity. Moreover, a higher protective effect of RMD was observed when its concentration in orange juice was higher.

Keywords: resistant maltodextrin; prebiotic; pasteurized orange juice; bioactive compounds

1. Introduction

Resistant maltodextrin (RMD) is a water-soluble fiber that is indigestible in the small intestine but could be fermented in the colon, resulting in enhanced short-chain fatty acid production [1]. RMD is attracting a lot of interest because of its potential functional and prebiotic effect. It has proved to exert a satiating effect [2], to reduce post-meal glucose [3] and triglyceride [4] levels in blood and to promote good gut health [5]. To date, most of the studies that have been conducted have mainly focused in the clinical area, and scarce information is available on what effects RMD displays in food matrices, which could be also beneficial for both the food science and health fields.

Fruit consumption is an essential part of human nutrition as fruits provide key nutrients. Orange juice, which is the most in-demand fruit juice worldwide [6], is associated with better diet quality and an increase of positive health outcomes [7]. Thermal pasteurization is the most common method to prolong shelf-life of commercial orange juice as it is the most cost-effective means to reduce microbial populations and enzyme activity [8]. However, heat treatments cause losses of bioactive compounds and antioxidant properties [9,10]. Bioactive compounds are associated with many health benefits [11], so their loss due to food processing is undesirable. Therefore, the aim of this work was to
evaluate the effect of RMD addition before the pasteurization process on the bioactive compounds of orange juice.

2. Materials and Methods

2.1. Sample Preparation and Pasteurization

Eight orange juice samples were prepared to conduct this study. Four of them had orange pulp added (orange juice with pulp, OJP) and four of them were without orange pulp (orange juice without pulp, OJWP). Increasing RMD concentrations (2.5, 5 and 7.5%) were added to both OJP and OJWP samples. Control samples without RMD addition were also prepared. All orange juices were pasteurized (Fruchtsaftdispenser, Mabo Steuerungselemente GmbH, Eppingen, Germany) at 85 °C for 10 s and hot-filled in 250 mL polyethylene terephthalate (PET) bottles.

2.2. Analytical Determinations

2.2.1. °Brix, Acidity and pH

Measurement of total soluble solids by refractometry (Abbemat 200, Anton Paar, Austria), acidity as grams of citric acid per 100 mL (gAC/100 mL) (DL53 acid titrator, Mettler Toledo, Switzerland) and pH (Basic 20 pHmeter, Crison, Spain) were performed as basic quality control parameters for the orange juices.

2.2.2. Total Phenols

The determination of total phenols (TF) was based on the Folin–Ciocalteu method. Absorbance was measured at 765 nm in a UV–visible spectrophotometer (Thermo Scientific, Helios Zeta UV-Vis, Loughborough, LE, UK). The total phenolic content was expressed as mg of gallic acid equivalents (GAE) (Sigma-Aldrich, Darmstadt, Germany) per 100 g of sample [12].

2.2.3. Total Carotenoids

The total carotenoids (TC) in the samples were extracted with a solvent hexane/acetone/ethanol mixture following the method of Olives et al. [13]. Sample absorbance was measured at 446 nm in an UV–visible spectrophotometer (Thermo Electron Corporation, Waltham, MA, USA). The TC content was expressed as mg of β-carotene (Sigma-Aldrich, Darmstadt, Germany) per 100 g of sample.

2.2.4. Ascorbic Acid and Vitamin C

Ascorbic acid (AA) and vitamin C (ascorbic acid + dehydroascorbic acid) were determined by a HPLC-UV detector (Jasco equipment, Cremella, Italy). The method proposed by Xu et al. [14] was used to determine the ascorbic acid with some modifications made by Igual et al. [12].

2.2.5. Antioxidant Capacity

Antioxidant capacity (AC) was assessed using the free radical scavenging activity of the samples evaluated with the stable radical 2,2-diphenyl-1-picryl-hydrazyl-hydrate (DPPH) following the methodology of Igual et al. [15]. A UV–visible spectrophotometer (Thermo Scientific, Helios Zeta UV-Vis, Loughborough, LE, UK) was used to the absorbance at 515 nm. The final results were expressed as milligram Trolox equivalents (TE) per 100 g (mg TE/100 g).

2.3. Statistical Analysis

Analysis of variance (ANOVA) was applied with a confidence level of 95% (p < 0.05) to evaluate the differences among samples. Furthermore, a correlation analysis among studied bioactive compounds and antioxidant capacity of juices with a 95% significance
level was carried out. Statgraphics (Centurion XVII Software, version 17.2.04) was used to this end.

### 3. Results and Discussion

°Brix, acidity and pH were evaluated as the basic control parameters, as they are related to the stability of bioactive compounds in plant-derived products [16]. The mean values (with standard deviation in brackets) of these parameters were 11.38 (0.03) °Brix, 3.683 (0.006) pH and 0.773 (0.004) (gAC/100 mL) for the OJP control sample and 11.47 (0.08) °Brix, 3.8 (0.03) pH and 0.691 (0.002) (gAC/100 mL) for the OJWP control sample. These values were in accordance with those obtained by Elez-Martínez [17]. RMD addition led to an increase in total soluble solids (°Brix) \( (p < 0.05) \) as a consequence of the completed RMD solubilization in aqueous matrices. Citric acid content significantly decreased \( (p < 0.05) \) with RMD, as its addition implied the replacement of raw orange juice in the finished beverage. Small but significant \( (p < 0.05) \) differences were found in terms of pH because of RMD addition. Thus, measurements for the OJP and OJWP samples with the highest RMD concentration (7.5%) were 17.99 (0.04) °Brix, 3.71 (0.02) pH and 0.711 (0.002) (gAC/100 mL), and 18.09 (0.02) °Brix, 3.823 (0.006) pH and 0.636 (0.002) (gAC/100 mL), respectively.

The mean values (with standard deviation in brackets) of the TF, TC, AA, vitamin C and AC in control OJP and OJWP were 94.9 (1.2) mg GAE/100 g, 6.78 (0.2) mg β-carotene/100 g, 5.53 (0.12) mg AA/100 g, 6.47 (0.04) mg vitamin C/100 g and 100.9 (0.5) mg TE/100 g; and 83.8 (0.6) mg GAE/100 g, 6.57 (0.2) mg β-carotene/100 g, 5.43 (0.07) mg AA/100 g, 6.28 (0.02) mg vitamin C/100 g and 96.3 (0.3) mg TE/100 g, respectively. Therefore, orange juice with pulp presented significantly \( (p < 0.05) \) higher values of bioactive compounds and antioxidant capacity than orange juice without pulp.

Variation of total phenolic compounds, total carotenoids, ascorbic acid, vitamin C and antioxidant capacity suffered in the samples after pasteurization in the presence of different concentrations of RMD in orange juice. The variation of each component \( (ΔM) \) referring to the control OJP and OJWP sample content, respectively, were calculated according to the following equation.

\[
ΔM_i^{RMD\%} = \frac{M_i^{RMD\%} - M_i^{Control}}{M_i^{Control}} \times 100
\]

where \( M_i \): mass of compound \( i \) in the sample obtained from 100 g of the pasteurized orange juice control (OJP or OJWP) and superscripts represent the following: RMD\%: percentage of RMD in the sample (2.5, 5 and 7.5%); control (OJP or OJWP).

Figure 1 shows that OJP samples contained significantly \( (p < 0.05) \) increased phenolics, while OJWP samples presented significantly \( (p < 0.05) \) higher variation in carotenoids \( (p < 0.05) \). This makes sense since orange pulp retains phenolic compounds [18] and orange juice is rich in carotenoids, as these pigments are responsible for the orange juice color [19]. Also, these variations were higher when higher RMD concentrations were applied \( (p < 0.05) \). Therefore, we found that RMD addition before orange juice pasteurization led to a protective effect in both total phenol and total carotenoid content, with this protective effect being more pronounced in OJP samples and OJWP samples, respectively.
Figure 1. (a) Mean values and standard deviation of total phenol variation (ΔM) of pasteurized orange juice (OJP and OJWP) with 2.5, 5 and 7.5% RMD. (b) Mean values and standard deviation of total carotenoid variation of pasteurized orange juice (OJP and OJWP) with 2.5, 5 and 7.5% RMD. Letters indicate homogeneous groups established by the ANOVA (p < 0.05) for each parameter analyzed. OJP, orange juice with pulp; OJWP, orange juice without pulp; RMD, resistant maltodextrin.

RMD addition before orange juice pasteurization had a protective effect on the ascorbic acid and vitamin C content (Figure 2). In the same way as for phenols and carotenoids, this protective effect was more intense when higher RMD concentrations were applied. Moreover, despite the fact that the protective effect of ascorbic acid was more noticeable in OJWP samples, orange pulp seemed to interact with RMD to increase dehydroascorbic acid protection from degradation in thermal pasteurization, as OJP samples obtained slightly higher variations of vitamin C.

Figure 2. (a) Mean values and standard deviation of ascorbic acid (AA) variation (ΔM) of pasteurized orange juice (OJP and OJWP) with 2.5, 5 and 7.5% RMD. (b) Mean values and standard deviation of vitamin C variation in pasteurized orange juice (OJP and OJWP) with 2.5, 5 and 7.5% RMD. Letters indicate homogeneous groups established by the ANOVA (p < 0.05) for each parameter analyzed. OJP, orange juice with pulp; OJWP, orange juice without pulp; RMD, resistant maltodextrin.

Figure 3 shows mean values and standard deviations of the antioxidant capacity variation of studied samples. As can be observed, higher RMD concentrations before orange juice pasteurization led to higher antioxidant capacity of orange juices, especially in OJWP samples. The highest antioxidant capacity variation was obtained for OJWP with RMD 7.5%, which was significant (p < 0.05).
In order to explain the relationships of the different compounds quantified in this study with the antioxidant capacity of the samples and the relationships among them, correlation statistical analyses were performed. The studied bioactive compounds showed a positive Pearson’s correlation coefficient with antioxidant capacity. Vitamin C and total phenols played a major role in the antioxidant capacity of orange juices, showing 0.8916 ($p < 0.05$) and 0.8647 ($p < 0.05$) values of the Pearson coefficient, respectively. This behavior has been observed by other authors in citric products [12,14]. Similar to the findings of Igual et al. [12], there was a significant correlation (0.8313, $p < 0.05$) between the ascorbic acid and total carotenoid content. This fact could be due to the stabilizing effect of ascorbic acid on carotenoids [20].

As a conclusion of this work, RMD addition before the juice pasteurization process protected all bioactive compounds, namely total phenols, total carotenoids, ascorbic acid and vitamin C, as well as the antioxidant capacity. We also found that this protective effect on the bioactive compounds of orange juice was higher when higher RMD concentrations were applied. Therefore, we demonstrated that RMD could have interesting applications in the food technology field, leading to health-related benefits.

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