proceedings

MDPI

Proceedings

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

Elías Arilla, Javier Martínez-Monzó, Purificación García-Segovia and Marta Igual *

Food Investigation and Innovation Group, Food Technology Department, Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain; elarco@upv.es (E.A.); xmartine@tal.upv.es (J.M.-M.); pugarse@tal.upv.es (P.G.-S.)

* Correspondence: marigra@upvnet.upv.es; Tel.: +34-96-3879694

† Presented at the 1st International Electronic Conference on Food Science and Functional Foods, 10–25 November 2020; Available online: https://foods_2020.sciforum.net/.

Submitted: date; Accepted: date; Published: date

Abstract: Resistant maltodextrin (RMD) is a water-soluble fermentable functional fiber. RMD is a satiating prebiotic, reducer of glucose and triglycerides in the blood, and promoter of good gut health. Its incorporation into food is more and more frequent. 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 orange pasteurized 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 and 15 g of RDM would be ingested, 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 pasteurization juice process protected phenols and carotenoids of juice. The content of total phenols, total carotenoids, ascorbic acid, and vitamin C after pasteurization were higher in samples with RMD, just as antioxidant capacity. Moreover, it was observed a higher protective effect of RMD when its concentration in orange juice was higher.

Keywords: resistant maltodextrin; prebiotic; orange pasteurized 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 its potential functional and prebiotic effect. It has proved to exert a satiating effect [2], to reduce post-meal glucose [3] and triglycerides [4] levels in blood and to promote good gut health [5]. Up to date, most of the studies that have been conducted have mainly focused in the clinical area, but scarce information is available on what effects RMD displays in food matrices, which could be also beneficial for both food science and health fields.

Fruit consumption is an essential part of human nutrition as they provide key nutrients. Orange juice, which is the most demanded 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 mean 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 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 were 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, Germany) at 85 ºC 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 (g_{AC}/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 Electron Corporation, USA). The total phenolic content was expressed as mg of gallic acid equivalents (GAE) (Sigma-Aldrich, 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 Olives et al. [13] method. Sample absorbance was measured at 446 nm in an UV-visible spectrophotometer (Thermo Electron Corporation, USA). The TC content was expressed as mg of β-carotene (Fluka-Biochemika) 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 HPLC-UV detector (Jasco equipment, 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 Igual et al. [15] methodology. UV-visible spectrophotometer (Thermo Electron Corporation, USA) was used to the absorbance at 515 nm. The final results were expressed as miligram 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 (Table 1) were evaluated as basic control parameters as they are related with 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 OJP control sample and 11.47 (0.08) °Brix, 3.8 (0.03) pH and 0.691 (0.002) (gAC/100 mL) for OJWP control sample. This 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 ($p < 0.05$) by 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 RMD addition. Thus, OJP and OJWP samples with the highest RMD concentration (7.5%) marked 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.

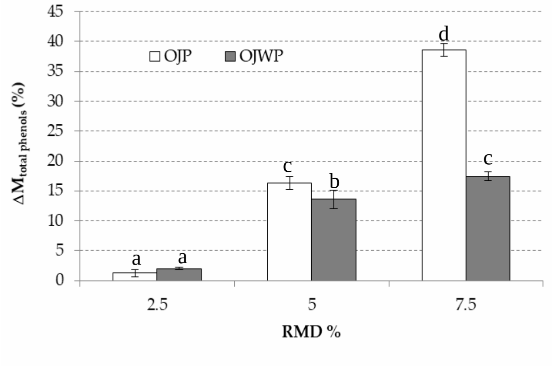
The mean values (with standard deviation in brackets) of TF, TC, AA, vitamin C and AC of control OJP and OJWP were 94.9 (1.2) mgGAE/100 g, 678 (2) mgβ-carotene/100 g, 5.53 (0.12) mgAA/100 g, 6.47 (0.04) mgvitamin C/100 g and 100.9 (0.5) mgTE/100 g, and 83.8 (0.6) mgGAE/100 g, 657 (2) mgβ-carotene/100 g, 5.43 (0.07) mgAA/100 g, 6.28 (0.02) mgvitamin C/100 g and 96.3 (0.3) mgTE/100 g, respectively. Therefore, orange juice with pulp presented significant ($p < 0.05$) 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 by the samples after pasteurization in presence of different concentration of RMD in orange juice. Variation of each component (ΔM_i) referred to control OJP and OJWP sample content, respectively, were calculated according follow equation.

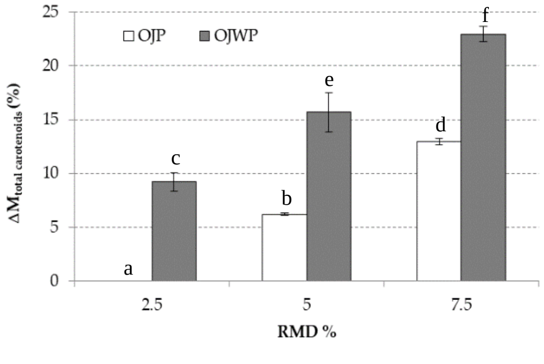
$$\Delta M_i^{RMD\%} = \frac{M_i^{RMD\%} - M_i^{Control}}{M_i^{Control}} \times 100 \quad (1)$$

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

Figure 1 shows that OJP samples marked significant ($p < 0.05$) higher phenolic increase while OJWP samples presented significant ($p < 0.05$) higher carotenoids variations ($p < 0.05$). 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 phenols and total carotenoids content, being this protective effect more pronounced in OJP samples and OJWP samples, respectively.



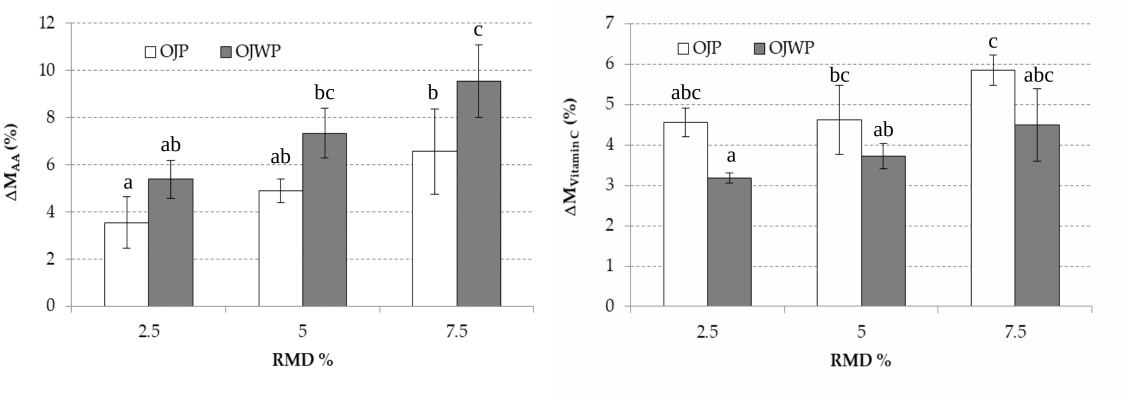
(**a**)



(**b**)

Figure 1. (**a**) Mean values and standard deviation of total phenols variation of pasteurized orange juice (OJP and OJWP) with 2.5, 5 and 7.5 RMD %. (**b**) Mean values and standard deviation of total carotenoids 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 addition before orange juice pasteurization had a protective effect on the ascorbic acid and vitamin C content (Figure 2). In the same way as 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 seems to interact with RMD to increase dehydroascorbic acid protection to degradation in thermal pasteurization, as OJP samples obtained slightly higher variations of vitamin C.



(**a**) (**b**)

Figure 2. (**a**) Mean values and standard deviation of ascorbic acid variation 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 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.

Figure 3 shows mean values and standard deviation of antioxidant capacity variation of studied samples. As it can be observed, higher RMD concentrations before orange juice pasteurization led to higher antioxidant capacity of orange juices, especially in OJWP samples. The significant ($p < 0.05$) highest antioxidant capacity variation was obtained for OJWP with RMD 7.5%.

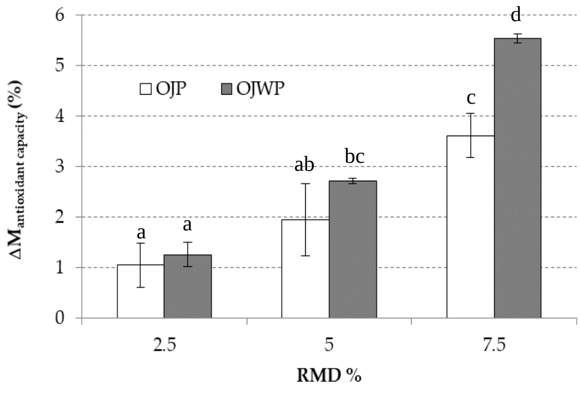


Figure 3. Mean values and standard deviation of antioxidant capacity variation of pasteurized orange juice (OJP and OJWP) with 2.5, 5 and 7.5 RMD %. Letters indicate homogeneous groups established by the ANOVA ($p < 0.05$) for each parameter analyzed. OJP, orange juice with pulp; OJWP, orange juice without pulp.

In order to explain the relationship of the different compounds quantified in this study with the antioxidant capacity of the samples and among them, correlation statistical analyses were performed. 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 Pearson coefficient, respectively. This behaviour was observed by other authors in citric products [12,14]. In the same was as Igual et al. [12], there was a significant correlation (0.8313, $p < 0.05$) between ascorbic acid and total carotenoids 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 pasteurization juice 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 for 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.

Author Contributions: Conceptualisation, E.A., J.M.-M., P.G.-S. and M.I.; methodology, E.A. and M.I.; formal analysis, E.A.; investigation, E.A. and M.I.; resources, J.M.-M., and P.G.-S.; data curation, E.A., M.I. and P.G.-S.; writing—original draft preparation and editing, E.A.; writing—review, M.I., P.G.-S. and J.M.-M; supervision, M.I. and P.G.-S.; project administration, J.M.-M.; funding acquisition, P.G.-S. and J.M.-M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by Agència Valenciana de la Innovació (Generalitat Valenciana) (research grant ref. INNTAL31/19/002).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Lockyer, S.; Nugent, A.P. Health effects of resistant starch. *Nutr. Bull.* **2017**, *42*, 10–41, doi:10.1111/nbu.12244.
2. Ye, Z.; Arumugam, V.; Haugabrooks, E.; Williamson, P.; Hendrich, S. Soluble dietary fiber (Fibersol-2) decreased hunger and increased satiety hormones in humans when ingested with a meal. *Nutr. Res.* **2015**, *35*, 393–400, doi:10.1016/j.nutres.2015.03.004.
3. Livesey, G.; Tagami, H. Interventions to lower the glycemic response to carbohydrate foods with a low-viscosity fiber (resistant maltodextrin): Meta-analysis of randomized controlled trials. *Am. J. Clin. Nutr.* **2009**, *89*, 114–125, doi:10.3945/ajcn.2008.26842.
4. Kishimoto, Y.; Oga, H.; Hayashi, N.; Yamada, T.; Tagami, H. Suppressive effect of resistant maltodextrin on postprandial blood triacylglycerol elevation. *Eur. J. Nutr.* **2007**, *46*, 133–138, doi:10.1007/s00394-007-0643-1.
5. Baer, D.J.; Stote, K.S.; Henderson, T.; Paul, D.R.; Okuma, K.; Tagami, H.; Kanahori, S.; Gordon, D.T.; Rumpler, W.V.; Ukhanova, M.; et al. The metabolizable energy of dietary resistant maltodextrin is variable and alters fecal microbiota composition in adult men. *J. Nutr.* **2014**, *144*, 1023–1029, doi:10.3945/jn.113.185298.
6. Priyadarshini, A.; Priyadarshini, A. Market dimensions of the fruit juice industry. In *Fruit Juices: Extraction, Composition, Quality and Analysis*, 1st ed.; Rajauria, G., Tiwari, B.K., Eds.; Elsevier: London, UK, 2018; pp. 15–32, doi:10.1016/B978-0-12-802230-6.00002-3.
7. O'Neil, C.E.; Nicklas, T.A.; Rampersaud, G.C.; Fulgoni, V.L. 3rd. 100% orange juice consumption is associated with better diet quality, improved nutrient adequacy, decreased risk for obesity, and improved biomarkers of health in adults: National Health and Nutrition Examination Survey, 2003–2006. *Nutr. J.* **2012**, *11*, 107, doi:10.1186/1475-2891-11-107.
8. Perez-Cacho, P.R.; Rouseff, R. Processing and storage effects on orange juice aroma: A review. *J. Agric. Food. Chem.* **2008**, *56*, 9785–9796, doi:10.1021/jf801244j.
9. Velázquez-Estrada, R.M.; Hernández-Herrero, M.M.; Rüfer, C.E.; Guamis-López, B.; Roig-Sagués, A.X. Influence of ultra high pressure homogenization processing on bioactive compounds and antioxidant activity of orange juice. *Innov. Food Sci. Emerg. Technol.* **2013**, *18*, 89–94, doi:10.1016/j.ifset.2013.02.005.

10. Lu, Q.; Peng, Y.; Zhu, C.; Pan, S. Effect of thermal treatment on carotenoids, flavonoids and ascorbic acid in juice of orange cv. Cara Cara. *Food Chem.* **2018**, *265*, 39–48.
11. Liu, R.H. Dietary bioactive compounds and their health implications. *J. Food Sci.* **2013**, *78* (Suppl. 1), A18–A25, doi:10.1111/1750-3841.12101.
12. Igual, M.; García-Martínez, E.; Camacho, M.M.; Martínez-Navarrete, N. Stability of micronutrients and phytochemicals of grapefruit jam as affected by the obtention process. *Food Sci. Technol. Int.* **2016**, *22*, 203–212, doi:10.1177/1082013215585417.
13. Olives Barba, A.I.; Cámara Hurtado, M.; Sánchez Mata, M.C.; Fernández Ruiz, V.; López Saenz de Tejada, M. Aplication of UV-vis detection-HPLC method for a rapid determination of lycopene and b-carotene. *Food Chem.* **2006**, *95*, 328–336, doi:10.1016/j.foodchem.2005.02.028.
14. Xu, G.; Liu, D.; Chen, J.; Ye, X.; Ma, Y.; Shi, J. Juice components and antioxidant capacity of citrus varieties cultivated in China. *Food Chem.* **2008**, *106*, 545–551, doi:10.1016/j.foodchem.2007.06.046.
15. Igual, M.; Cebadera, L.; Cámara, R.M.; Agudelo, C.; Martínez-Navarrete, N.; Cámara, M. Novel ingredients based on grapefruit freeze-dried formulations: Nutritional and bioactive value. *Foods* **2019**, *8*, 506, doi:10.3390/foods8100506.
16. Sánchez-Moreno, C.; Plaza, L.; de Ancos, B.; Cano, M.P. Quantitative bioactive compounds assessment and their relative contribution to the antioxidant capacity of commercial orange juices. *J. Sci. Food Agric.* **2003**, *83*, 430–439, doi:10.1002/jsfa.1392.
17. Elez-Martínez, P.; Soliva-Fortuny, R.C.; Martín-Belloso, O. Comparative study on shelf life of orange juice processed by high intensity pulsed electric fields or heat treatment. *Eur. Food Res. Technol.* **2006**, *222*, 321, doi:10.1007/s00217-005-0073-3.
18. Iglesias-Carres, L.; Mas-Capdevila, A.; Bravo, F.I.; Aragonès, G.; Muguerza, B.; Arola-Arnal, A. Optimization of a polyphenol extraction method for sweet orange pulp (*Citrus sinensis* L.) to identify phenolic compounds consumed from sweet oranges. *PLoS ONE* **2019**, *14*, e0211267, doi:10.1371/journal.pone.0211267.
19. Meléndez-Martínez, A.J.; Vicario, I.M.; Heredia, F.J. Review: Analysis of carotenoids in orange juice. *J. Food Compos. Anal.* **2007**, *20*, 638–649, doi:10.1016/j.jfca.2007.04.006.
20. Choi, M.H.; Kim, G.H.; Lee, H.S. Effects of ascorbic acid retention on juice color and pigment stability in blood orange (*Citrus sinensis*) juice during refrigerated storage. *Food Res. Int.* **2002**, *35*, 753–759, doi:10.1016/S0963-9969(02)00071-6.