Natural Product Research

Formerly Natural Product Letters

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/gnpl20

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NATURAL PRODUCT RESEARCH
https://doi.org/10.1080/14786419.2020.1824224

SHORT COMMUNICATION

Gelatin-based coating enriched with blueberry juice preserves the nutraceutical quality and reduces the microbial contamination of tomato fruit

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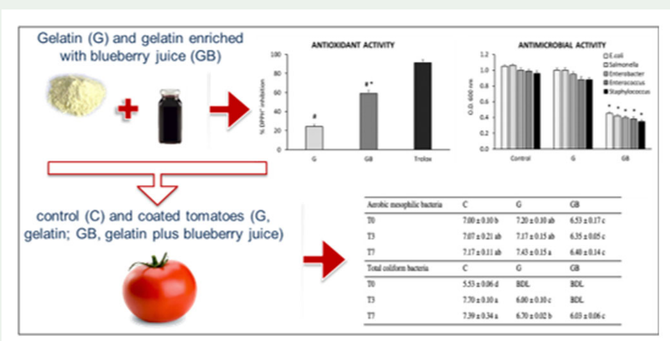
ABSTRACT

To preserve quality and extend the shelf life of tomato, a bioactive edible coating was prepared using gelatin wastes from pharmaceutical industry and lyophilised blueberry juice (BJ). The effectiveness of gelatin-coating (G) and G enriched with blueberry juice (GB) was tested, monitoring carotenoids, polyphenols and flavonoids content, the antioxidant activity and the antimicrobial efficiency of coating against the native microflora.

After 7 d of storage, coated fruit showed higher phenolic and flavonoids content and increased antioxidant activity, while carotenoids were unaffected by the treatments. The growth of mesophilic bacteria of GB, and the growth of coliform bacteria of G and GB were significantly reduced during the entire period. The results indicate that GB preserved the nutritional quality of tomatoes and that BJ was able to increase the antimicrobial activity of the coating. This paves the way for a possible use of this biodegradable waste polymer as an eco-friendly coating material.



ARTICLE HISTORY
Received 8 June 2020
Accepted 11 September 2020

KEYWORDS
Edible coatings; carotenoids; phenolic compounds; fruit storage; microbial contamination

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/14786419.2020.1824224.

1. Introduction

Fresh fruit as tomato (*Solanum lycopersicum* L.), a key component of the Mediterranean diet and one of the most consumed fruit in the world, may undergo quantitative and qualitative losses and microbial spoilage after harvest (Maringgal et al. 2020). Edible coatings (ECs) made by biopolymers as proteins, lipids and polysaccharides, pure or enriched with antioxidant and antimicrobial substances, are promising tools to extend shelf life and preserve nutritional quality of different fruit, among which tomato, as recently reviewed by Maringgal et al. (2020).

Waste recover is one of the main targets of both the circular economy and environmental protection. The residues deriving from the production of pharmaceutical softgel capsules are usually disposed with environmental and economic costs, while their composition (gelatin, glycerol and water) would allow their use as food coatings. Gelatin-based coatings can indeed extend fruit shelf life (Soradech et al. 2017) and deliver antimicrobial and antioxidant molecules (Etxabide et al. 2017). Recently, the physico-chemical and antioxidant properties of films produced with this waste added with blueberry pomace were analyzed (de Moraes Crizel et al. 2016). However, the effectiveness of this waste material in combination with fruit juices as bioactive coating for fruit was not studied so far. Therefore, the present research aimed to evaluate whether a coating made with the residues of softgel capsules production, pure or enriched with blueberry juice (BJ), chosen because of its high levels of bioactive compounds, among which anthocyanins, a flavonoid subclass with high antioxidant and antimicrobial activity (Diaconeasa et al. 2015), could preserve the nutraceutical quality of tomato fruit and reduce the microbial growth during a domestic-like conservation.

2. Results and discussion

2.1. Properties of BJ extract and pure and BJ-enriched gelatin

The concentration of phenols, flavonoids and anthocyanins of BJ (Table S1 in Supplementary material) is similar or even higher than that reported for juices extracted from fresh blueberries (Mohideen et al. 2015; Zhang et al. 2019). BJ inhibited 49% of the DPPH radical, probably thanks to the recognised action of anthocyanins and other flavonoids as free radical scavengers (Nicoletti et al. 2015).

BJ was highly efficient against all Gram-positive and Gram-negative bacteria strains (Figure S1 in Supplementary material), in accordance with the effectiveness of phenolic compounds against *Listeria monocytogenes, Salmonella enteritidis* (Shen et al. 2014), *S. aureus, Salmonella typhimurium and E. coli* (Yang et al. 2014).

Antioxidant activity of pure gelatin (G) was scarce. The addition of 1 g L^{-1} of BJ significantly increased it (Figure S2 in Supplementary material), while lower and higher BJ concentrations were not very effective or not fully soluble, respectively (data not shown). Similarly, inclusion of blueberry pomace in gelatin-based film enhanced its antioxidants potential (de Moraes Crizel et al. 2016).

G was ineffective against any microorganisms tested, while GB, thanks to the antimicrobial properties of BJ, hampered the growth of both Gram-positive and Gram-negative strains (Figure S3 in Supplementary material), confirming the reported ability of gelatin to reduce the growth of *E. coli* and *S. aureus* only when mixed with natural compounds (Bodini et al. 2013; Bonilla and Sobral 2016).

2.2. Gelatin coating influence the quality of tomato fruit during storage

Coated fruit generally contained more phenolics and flavonoids than controls, and BJ enrichment did not allow a further increase (Figure 4S in Supplementary material). In the same tomato cv (Naomi), Raffo et al. (2002) reported a phenolic concentration (derived as the sum of individual compounds) about 75% higher than that measured in our research, probably due to different environmental factors during growth and postharvest storage.

During storage phenolic concentration decreased less in coated fruit, indicating a positive effect of gelatin in preserving the nutraceutical value of tomato fruit. A lower decrease of phenolics during storage was observed in mango fruit coated with 10% gelatin (Gol and Rao 2014). To the best of our knowledge, no data is published on the influence of gelatin on flavonoids while, in tomato, a positive effect was played by chitosan coating (Pagno et al. 2018).

Differently from phenolics, lycopene, lutein and β-carotene were unaffected by storage time and coating (Figure 5S in Supplementary material). Lycopene and β-carotene were more and less concentrated, respectively, than in Naomi tomatoes studied by Raffo et al. (2002). These results were expressed on dry weight basis but, thanks to reported dry matter percentage, a comparison with our data was possible. This difference suggests that fruit studied by Raffo et al. (2002) were less ripened than ours, as also suggested by phenolics content (75% higher than in our fruit) since, according to the same Authors, phenolics decreased with ripening.

Antioxidant activity underwent a storage-dependent decrease, that, in agreement with the behaviour of phenolics and flavonoids, was less pronounced in coated fruit at any storage time (Figure 6S in Supplementary material). GB was slightly less efficient than G in preserving the antioxidant activity. Despite the antioxidant potential of gelatin films incorporated with essential oils (Ramos et al. 2016) or several bioactive compounds (Bonilla and Sobral 2016; de Moraes Crizel et al. 2016) was assessed, no data are available on the impact of gelatin-based coatings on the antioxidant activity of fruit.

2.3. Influence of gelatin coating on native microbial population of tomato fruit

2.3.1. Total mesophilic aerobic bacteria

Gelatin was unable to reduce the microbial count unless BJ was added (Table S1 in Supplementary material), indicating the effectiveness of BJ bioactive compounds. Since the bacterial growth was inhibited but not completely prevented, GB coating revealed a bacteriostatic rather than bactericidal property. This effect could be due to the gradual release of the bioactive compounds from the gelatin matrix that, though reduces the antimicrobial effect, ensures a long-lasting effect as compared to the application of pure antimicrobial compounds.

In accordance with our findings, gelatin coating inhibited microbial proliferation on fresh-cut melon (Poveronov et al. 2014) or fresh-cut oranges (Radi et al. 2017) only after the addition of chitosan or *Aloe vera* and green tea extracts. Similarly, enrichment of pullulan-coating with extracts of *Bergenia crassifolia* leaves reduced *S. aureus* contamination on peppers by 1 log CFU/g after 14 days (Kraśniewska et al. 2015).

2.3.2. Total coliform bacteria

Very few papers deal with the effects of gelatin on coliform growth and, to the best of our knowledge, they did not study the fruit contamination, but the antimicrobial properties of natural additives added to gelatin-based films (reviewed by Ramos et al. 2016).

In the present research coliforms seem to be more sensitive than mesophilic aerobic bacteria to pure gelatin. Total coliforms increased significantly during storage also in coated fruit, although bacteria population was always higher in control samples (Table S2 in Supplementary material). Addition of BJ prevented coliform growth at T3 and reduced it at T7 as compared to G, confirming the good antibacterial properties of BJ extract.

3. Conclusions

Gelatin coating may preserve the nutritional quality of tomatoes, as indicated by the trend of phenolic compounds and antioxidant potential during storage. The enrichment with BJ did not increase the health-promoting compounds further but it markedly improved the antimicrobial effect of the coating.

If properly enriched with bioactive molecules, gelatin represents a promising tool to preserve nutraceutical quality and to reduce spoilage during fruit conservation and marketing. Being produced starting from wastes of the pharmaceutical industry, the gelatin used in this study has an additional ecological value. Moreover, saving of disposal costs of this waste material could compensate the operating costs for coating application, potentially making this treatment a zero-cost method.

Acknowledgements

Research supported by University of Pisa, Italy and by CNR, Consiglio Nazionale delle Ricerche, Italy. We thank Prof. Alessandro de Oliveira Rios and Dr. Carlos H. Pagno (Departamento de Ciência dos Alimentos, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brasil) for providing the gelatin used in this research.

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