International Journal of Biomedicine 11(2) (2021) 173-176
http://dx.doi.org/10.21103/Article11(2)_OA10

ORIGINAL ARTICLE

Biotechnology

INTERNATIONAL JOURNAL OF BIOMEDICINE

Production, Properties and Swelling of Composite Pectic-Gel Particles in an Artificial Gastric Environment

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Abstract

The purpose of the present work was to obtain and study the properties of composite calcium-pectic gel particles (CaPGPs) obtained from aqueous solutions of apple pectin (AP) in the concentration of 2% and pectin heracleuman (HS) in the concentration of 3% in the presence of Ca^{2+} ions (0.34 M). The swelling of the obtained CaPGPs in an artificial gastric environment was also investigated.

***Methods and Results*:** We used commercial AP AU701 (AP, Herbstreith & Fox KG, Germany) and HS isolated from the aerial part of the Sosnovskyi hogweed *Heracleum sosnowskyi* Manden. Composite CaPGPs were obtained from aqueous solutions of AP (2%) and HS (3%) in the presence of Ca^{2+} ions (0.34 M) by the method of ionotropic gelation. The diameter and density of CaPGPs were determined. Dry gel particles from 2% AP were larger (1.18±0.19 mm) than dry gel particles from 3% HS (1.04±0.07 mm) and dry composite gel particles (1.01±0.06 mm). However, dry composite gel particles and dry gel particles from HS were approximately 3 times denser than dry gel particles from AP. Composite CaPGPs swelled by 74.2% in simulated gastric fluid (SGF). The degree of swelling in SGF of CaPGPs formed from HS was 15.6% lower, and CaPGPs formed from AP –52.2%. **(International Journal of Biomedicine. 2021;11(2):173-176.)**

Key Words: apple pectin • heracleuman • calcium ions • gel particles • artificial gastric environment

For citation: Shubakov AA, Mikhailova EA. Production, Properties and Swelling of Composite Pectic-Gel Particles in an Artificial Gastric Environment. International Journal of Biomedicine. 2021;11(2):173-176. doi:10.21103/Article11(2)_OA10

Abbreviations

AP, apple pectin; **CaPGPs**, calcium-pectic gel particles; **HS**, heracleuman; **SGF**, simulated gastric fluid.

Introduction

Pectin is a methylated ester of polygalacturonic acid.[1] Pectins are soluble dietary fibers, unique in their ability to hydrate (swell and retain water) and to form gels. As a source of nutrition for the intestinal microflora, pectins have a prebiotic effect, contributing to an increase in the number and activity of the obligate bacteria populations of the gastrointestinal tract of humans and animals.[2]

The properties of pectic-gel particles largely depend on the chemical composition and macromolecular structure of pectin polysaccharides.[3] Swelling and degradation of pectic-gel particles in the gastrointestinal tract depend on the structural and mechanical characteristics of pectin, the concentration of pectin and the type of metal ion as a cross-linking agent in the composition of pectic-gel particles, concentration of pectinases in the large intestine, pH, and temperature.[1,4,5]

Prolongation of the gastric transit time provides therapeutic benefits for orally delivered drugs by reducing the waste of the drug and the improving the bioavailability and solubility of drugs that are less soluble in high pH environments. Viscous and gel-forming dietary fibers are considered to delay gastric emptying, thus prolonging gastric

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transit time. However, even viscous meals undergo rapid dilution in the stomach, leading to a reduction of the initial viscosity. An alternative approach for the enhancement of gastric digesta viscosity would be to use a solution that forms a gel in the acidic media of the stomach, as pectin was found to do in the acidic conditions of the rat stomach; therefore, the use of pectin as a biopolymer gelling in the stomach appears reasonable. The rheological properties of gastric digesta after the consumption of gel-forming pectin appeared to determine the gastric transit time.[6]

Composite gels based on natural polymers allow the development of new biomaterials with new physicochemical properties that will improve their functionality. Different physicochemical characteristics of composite gel particles based on different pectins can influence their stability and swelling properties in the simulated gastric environment, the environment of the small and large intestines. Composite gel particles based on the different pectins exhibit potential applications as carrier materials in controlled release systems and particularly serve as promising systems for colon-targeted drug delivery.[7]

Previously, the properties of composite gel particles based on pectin and chitosan,[8] pectin and alginate,[7] pectin, and k-carrageenan[9] were obtained and studied. However, there is practically no data on the preparation and properties of composite gel particles formed from 2 different pectins.

The purpose of the present work was to obtain and study the properties of composite CaPGPs obtained from aqueous solutions of AP in the concentration of 2% and heracleuman pectin (HS) in the concentration of 3% in the presence of Ca^{2+} ions (0.34 M). The swelling of the obtained CaPGPs in an artificial gastric environment was also investigated.

Materials and Methods

We used commercial AP AU701 (AP, Herbstreith & Fox KG, Germany) and HS isolated from the aerial part of the Sosnovskyi hogweed *Heracleum sosnowskyi* Manden.[10]

Gel particles were obtained from aqueous solutions of pectins by the method of ionotropic gelation.[11] Composite pectin gels (2% AP+3% HS) were obtained by slowly stirring a mixture of AP (20 mg) and HS (30 mg) in distilled water (1 ml) with a magnetic stirrer MM-5 at heating (45°C) for 4 hours until complete dissolution. Composite CaPGPs were obtained from aqueous solutions of AP (2%) and HS (3%) in the presence of Ca^{2+} ions (0.34 M) by the method of ionotropic gelation.

For comparison, pectin gels were prepared from 2% AP and from 3% HS by dissolving 20 mg of AP or 30 mg of HS on a heated magnetic stirrer (45°C) for 2 or 3.5 hours, respectively, until complete dissolution.

Gel particles of spherical form were prepared by drop-by-drop injection of corresponding pectin solutions from a syringe through a needle with a hole diameter of 0.6 mm on the distance of 4-5 cm in the slowly stirred calcium chloride solution (0.34 M) and further stirring for 30 min at room temperature. The resulting gel particles were then washed three times in distilled water with stirring for 5 minutes and dried for 10-14 h at 37°C.

The diameter and density of CaPGPs were determined using an optical microscope (Altami, Russia) with a camera and an image analysis program (ImageJ 1.46r program, National Institutes of Health, USA). For calibration, a linear scale was used; one pixel corresponded to 0.024 mm.

To determine swelling, dry CaPGPs (1–2 mg) were placed in Petri dishes (diameter 3.5 cm) and incubated in 3 ml of SGF (2 h) with shaking in a shaker (Titramax 1000, Heidolph, Germany) at 100 rpm and at 37°C. SGF was prepared as described previously.[1,12] After 2h, the diameter and density of 100 randomly selected gel particles were measured as described above. The experiments were performed in triplicate. The degree of gel swelling (SD,%) was determined by the formula[8]: $SD = (D_1 - D_0)/D_0 \times 100\%$, where D_1 – diameter of the particles (mm) after 2 h incubation in the medium, D_0 – initial particle diameter of the particles (mm).

The statistical analysis was performed using the statistical software BioStat (version 4.03) and Microsoft Office Excel 2007.

Results and Discussion

The morphological (size, shape) and structural-mechanical (density) characteristics of the obtained wet and dry CaPGPs were investigated.

Table 1 shows the morphological and structural-mechanical characteristics of wet CaPGPs. Wet, spherical, composite gel particles (2% AP+3% HS) have a diameter of 2.62±0.12 mm, which is less than the diameter of wet gel particles from 3% HS (2.81±0.10 mm), but larger than the diameter of wet gel particles from 2% AP (2.50±0.17 mm). The density of wet composite gel particles (0.92±0.13 mg/mm^3) and gel particles from 3% HS (0.93±0.13 mg/mm^3) is practically the same, and higher than the density of wet gel particles from 2% AP (0.76±0.16 mg/mm^3).

Table 1.

Morphological and structural-mechanical characteristics of wet CaPGPs

Gel particles	Diameter, mm	Density, mg/mm^3
2% AP	2.50±0.17	0.76±0.16
3% HS	2.81±0.10	0.93±0.10
2% AP+3% HS	2.62±0.12	0.92±0.13

Table 2 shows the morphological and structural-mechanical characteristics of dry CaPGPs. Dry gel particles from 2% AP were larger (1.18±0.19 mm) than dry gel particles from 3% HS (1.04±0.07 mm) and dry composite gel particles (1.01±0.06 mm). However, dry composite gel particles and dry gel particles from HP were approximately 3 times denser than dry gel particles from AP.

The swelling of the obtained gel particles in an SGF was studied (Fig. 1).

Table 2.

Morphological and structural-mechanical characteristics of dry CaPGPs

Gel particles	Diameter, mm	Density, mg/mm^3
2% AP	1.18±0.19	0.21±0.11
3% HS	1.04±0.07	0.64±0.14
2% AP+3% HS	1.01±0.06	0.62±0.12

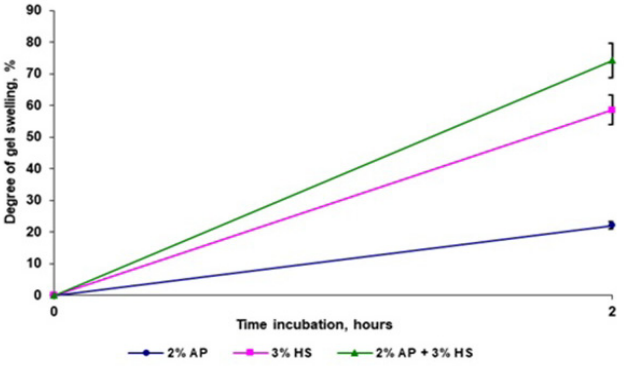

Fig.1. *Swelling of composite CaPGPs formed from AP (2%) and HS (3%) in an SGF.*

Composite CaPGPs swelled by 74.2% in SGF. Gel particles from HS swelled less strongly (by 58.6%), and the degree of swelling of gel particles from AP (by 22.0%) was more than 3 times lower.

Figure 2 shows the density of gel particles swollen in the gastric fluid, compared to the original density of dry gel particles.

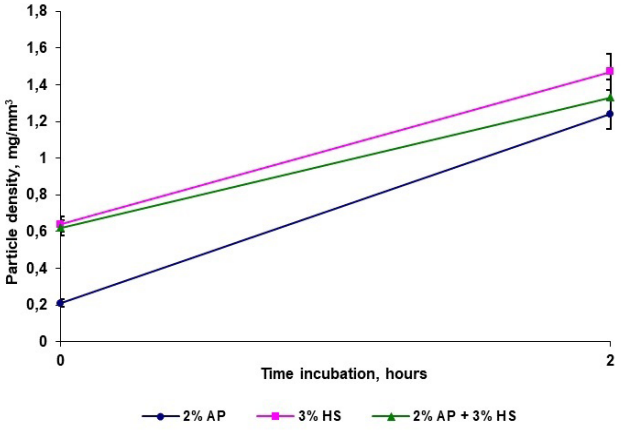

Fig. 2. *Density of composite CaPGPs formed from AP (2%) and HS (3%) in an SGF.*

The density of gel particles from 2% AP after 2h of incubation in SGF increased most strongly, by 1.03 mg/mm^3, in comparison with the density of the original dry particles of AP. To a lesser extent, in an acidic gastric fluid, the density of gel particles from HS and composite gel particles increased by 0.83 mg/mm^3 and 0.71 mg/mm^3, respectively.

Thus, dry composite CaPGPs formed from 2% AP and 3% HS and CaPGPs formed from 3% HS had a comparable diameter and density. The diameter of dry CaPGPs formed from 2% AP was 1.1-1.2 times larger, but their density was 3 times lower than the density of particles in the 2 above-mentioned variants of CaPGPs. Composite CaPGPs swelled by 74.2% in SGF. The degree of swelling in an acidic gastric fluid of CaPGPs formed from HS was 15.6% lower, and CaPGPs formed from AP –52.2%.

Thus, composite CaPGPs swelled in an SGF to a greater extent than CaPGPs formed from AP or CaPGPs formed from HS.

Competing interests

The authors declare that they have no competing interests.

Sources of Funding

The work was performed on the theme of research work (State registration number AAAA-A17-117012310147-8).

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