ICAM2009
11th International Conference
on Advanced Materials
Rio de Janeiro Brazil
September 20 - 25

Improved barrier, mechanical and thermal properties of hydrophilic edible films by incorporation of nanoparticles and nanofibers

T.H. McHugh(1), L. H. C. Mattoso(2), M. R. de Moura(3), H.M.C.de Azeredo(4), N. Dogan5, R.J. Avena-Bustillos(1,6)*

(1) Agricultural Research Service, Western Regional Research Center, 800 Buchanan St. Albany CA, 94710. Tara.McHugh@ars.usda.gov
(2) National Nanotechnology Laboratory for Agriculture, EMBRAPA-CNPDIA, Rua 15 de novembro, 1452, São Carlos, 13560-970, SP, Brazil. mattoso@cnpdia.embrapa.br
(3) Chemistry Department – UFSCar, São Carlos/SP, Brazil. mregina@cnpdia.embrapa.br
(4). EMBRAPA Tropical Agroindustry, R. Dra. Sara Mesquita, 2270, CEP 60511-110, Fortaleza/CE, Brazil. ette@cnpat.embrapa.br
(5) Nestle Research Center. Lausanne, Switzerland. Nihan.Dogan@rdls.nestle.com
(6) Dept. of Biological and Agricultural Engineering, University of California, Davis, One Shields Ave., Davis, CA 95616. Roberto.Avena@ars.usda.gov. * Corresponding author

Abstract – Edible films and coatings are used to increase shelf-life and quality of food products by reducing water vapor and oxygen permeability while improving mechanical handling and appearance. Physical properties of hydrophilic biopolymers used in edible films and coatings formulations can be improved by addition of nanoparticles and nanofibers.

Microcrystalline cellulose (MCC) microparticles (1), chitosan (CS) nanoparticles (2) were prepared and incorporated in hydroxypropyl methylcellulose (HPMC) films under different conditions. Mechanical properties, water vapor and oxygen permeability, water solubility and scanning and transmission electron microscopy (SEM and TEM) results were analyzed. Incorporation of chitosan nanoparticles in HPMC films improved their mechanical properties significantly (Fig. 1), while also improving film barrier properties significantly (2, 3). Nanoparticles (Fig. 2) tend to occupy the empty spaces in the pores of the HPMC matrix, increasing the collapse of the pores and thereby improving film tensile and barrier properties. Cellulose nanofiber (CNF) also improved mechanical and barrier properties of mango puree edible films (4) as indicated in Table 1. Collaborative research work between USDA/ARS/WRRC and EMBRAPA on development and evaluation of novel edible films formulated with food grade nanoparticles and nanofibers indicated that their incorporation in hydrophilic films can improve mechanical and barrier properties of edible films and coatings.

Table 1 -- Physical properties of mango puree edible films with different concentrations of CNF nanoreinforcements.

CNF (g/100g)^A	TS (MPa)	EB (%)	YM (MPa)	WVP (g.mm/kPa.h.m^2)	T_g (°C)
0	$(4.09 \pm 0.12)^e$	$(44.07 \pm 0.98)^a$	$(19.85 \pm 0.51)^e$	$(2.66 \pm 0.06)^a$	$(-10.63 \pm 0.47)^e$
1	$(4.24 \pm 0.25)^{de}$	$(42.42 \pm 1.90)^{ab}$	$(21.55 \pm 0.98)^e$	$(2.40 \pm 0.19)^{ab}$	$(-8.51 \pm 0.46)^d$
2	$(4.42 \pm 0.14)^{de}$	$(43.30 \pm 1.46)^{ab}$	$(22.56 \pm 0.88)^e$	$(2.17 \pm 0.08)^{bc}$	$(-8.57 \pm 0.33)^d$
5	$(4.58 \pm 0.21)^{cd}$	$(41.79 \pm 0.44)^b$	$(30.93 \pm 1.27)^d$	$(2.16 \pm 0.05)^{bc}$	$(-7.72 \pm 0.26)^c$
10	$(4.91 \pm 0.13)^c$	$(43.19 \pm 1.73)^{ab}$	$(40.88 \pm 1.41)^c$	$(2.03 \pm 0.11)^c$	$(-6.81 \pm 0.36)^b$
18	$(5.54 \pm 0.07)^b$	$(39.8 \pm 0.53)^b$	$(78.82 \pm 5.00)^b$	$(1.90 \pm 0.06)^{cd}$	$(-5.88 \pm 0.25)^a$
36	$(8.76 \pm 0.11)^a$	$(31.54 \pm 2.29)^c$	$(322.05 \pm 19.43)^a$	$(1.67 \pm 0.11)^d$	$(-6.04 \pm 0.17)^a$

^{A}Mass of CNF added to 100 g of mango puree, on a dry basis. TS = tensile strength (MPa); EB = elongation at break (%); YM = Young's modulus (MPa); WVP = water vapor permeability (g.mm/kPa.h.m^2); T_g = glass transition temperature (°C). Means in same column with different letters are significantly different at $P < 0.05$.

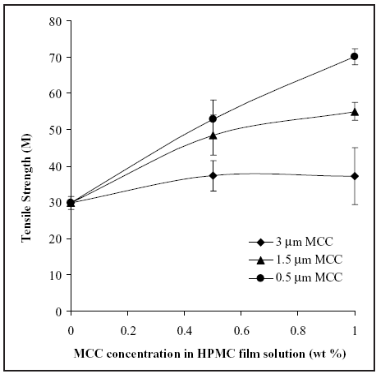

Figure 1: Tensile strength of HPMC films with different concentration and size of MCC

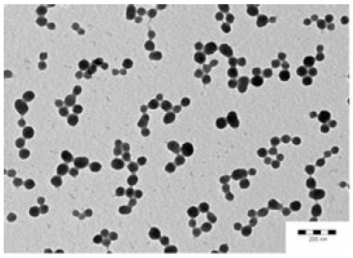

Figure 2: Chitosan nanoparticles visualized by TEM. Scale bar = 200 nm.

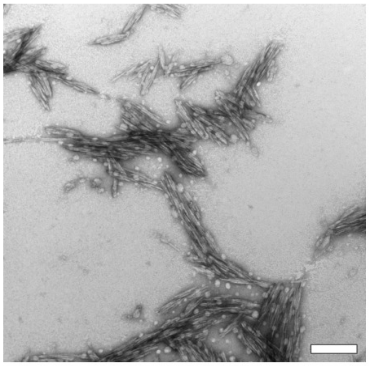

Figure 3: Cellulose nanofibers visualized by TEM. Scale bar = 200 nm.

References

[1] Dogan, N., McHugh, T.H. 2007. J. Food Sci. 72(1):E16-E22.
[2] De Moura, M.R., Avena-Bustillos, R. J. McHugh T.H., Krochta, J.M., Mattoso, L.H.C. 2008. J. Food Sci. 73(7):N31-N37.
[3] De Moura, M.R., Aouada, F.A., Avena-Bustillos, R. J., McHugh T.H., Krochta, J.M., Mattoso, L.H.C. 2009. J. Food Eng., 92:448–453.
[4] Azeredo HMC, Mattoso LHC, Wood D, Williams TG, Avena-Bustillos RJ, McHugh TH. 2009. J. Food Sci. 74(5):N31-N35.