Nanofibers in Food Packaging

Dr. Cagri Tekmen / Application Engineering Manager
Elmarco Ltd., 3-4-1 Sekido, Tama, Sekido Bld 4F, Tokyo 206-0011, Japan
E-mail: cagri.tekmen@elmarco.com

1. Global Food Packaging Facts

With the move toward globalization, food packaging requires longer shelf life, along with monitoring food safety and quality based upon international standards. To address these needs, nanotechnology is enabling new food and beverage packaging technologies. Applications in nano-enabled packaging span development of improved tastes, color, flavor, texture and consistency of foodstuffs, increased absorption and bio-availability of nutrients and health supplements, new food packaging materials with improved mechanical, barrier and antimicrobial properties, and nano-sensors for traceability and monitoring the condition of food during transport and storage. According to a latest study from iRAP, Inc., the total nano-enabled food and beverage packaging market (Table 1) in the year 2008 was $4.13 billion, which is expected to grow in 2009 to $4.21 billion and forecasted to grow to $7.30 billion by 2014, at a CAGR of 11.65%. Active technology represents the largest share of the market, and will continue to do so in 2014, with $4.35 billion in sales, and the intelligent segment will grow to $2.47 billion sales [1].

Table 1. Nano-enabled packaging in the food and beverage market segmented by technology ($ Billions)

	2008	2009	2014	CAGR (%) 2009-1014
Active packaging	2.74	2.79	4.35	9.29
Intelligent packaging	1.03	1.05	2.47	18.7
Controlled release packaging	0.36	0.37	0.48	5.23
Total Market	**4.13**	**4.21**	**7.3**	**11.65**

2. Active Packaging

Active packaging is defined as ‘‘packaging in which subsidiary constituents have been deliberately included in or on either the packaging material or the package headspace to enhance the performance of the package system” [2]. Among active technologies, oxygen scavenger, moisture absorbers and barrier packaging represent more than 80% of the current market. Among the regions, Asia/Pacific, in particular Japan, is the market leader in active nano-enabled packaging, with 45% of the current market, valued at $1.86 billion in 2008 and projected to grow to $3.43 billion by 2014, at a CAGR of 12.63% [1].

2.1 Benefits of Electrospun Nanofibers

One form of active packaging involves the incorporation of antimicrobial agents which are allowed to diffuse into the product to inhibit the proliferation of microorganisms during storage. Recent studies show that antimicrobial packaging can be effective in inhibiting microbial growth on food products and has the potential to extend product shelf-life [3-5]. The majority of antimicrobial active packaging studies reported in the literature to date have involved the dispersion of the active agent in carriers with limited surface areas, such as polymer film and sheet. The controlled release of active substances from these structures was mainly based on concentration-dependent passive diffusion. By virtue of their submicron to nano-scale diameter and very large surface area, electrospun fibers may offer a number of additional advantages compared to film and sheet carriers, such as being more responsive to changes in the surrounding atmosphere (e.g., relative humidity and temperature changes). Furthermore, because the electrospinning process takes place at ambient conditions, electrospun fibers are more suitable for encapsulating thermally-labile active agents as compared to the fibers made by conventional melt spinning process. The large surface area advantage of electrospun fibers has been exploited by many researchers to incorporate bioactive substances. For example, poly(lactic acid) (PLA) fibers were employed to carry antibacterial silver nanoparticles [6, 7]; poly(lactide-co-glycolide), PLA and poly(ethylene-o-vinyl acetate) fibers were studied for their use in the incorporation and release of various drugs [8, 9]. The absence of heat in electrospinning is a key advantage over other encapsulation methods, such as spray drying, and is important for preserving the efficacy of the bioactive substances during the fiber forming process.

2.2 Commercializing of Nano-enabled Packaging

Today, the technology to produce nanofiber-based active packaging products is ready for commercial use. Elmarco's unique Nanospider™ technology allows nanofibers to be produced at industrial scale. As seen from the scanning electron microscope (SEM) picture (Figure 1), PLA nanofibers produced by using Elmarco's NS-Industrial Line (Figure 2) exhibits excellent web and fiber uniformity. The NS-Industrial Line is a modular spinning unit configured with four 1.6 meter wide Nanospider™ electrodes. Up to four NS-Line production units can be combined to produce over 40 million square meters of coated material annually in a single production line. The NS-Line is characterized by it is ease of use, flexibility in configuration, and high quality of nanofibers.

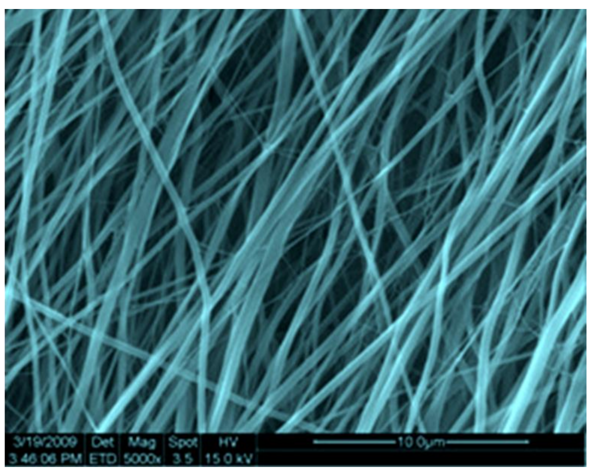

Figure 1. SEM picture of PLA nanofibers produced by NS-Industrial Line

Figure 2. NS-Line (four units) for mass production of nanofibers [10]

References

[1] Nano-enabled packaging for the food and beverage industry – a global technology, industry and market analysis. (2009). Innovative Research and Products (*iRAP*), Inc.

[2] Robertson, G. (2006). Active and intelligent packaging. In G. Robertson (Ed.), Food packaging. Boca Raton: CRC Press

[3] Del Nobile, M. A., Incoronato, A. L., & Panza, O. (2008). Journal of Food Engineering, 89, 57–63.

[4] Rodriguez, a., Nerin, C., & Batlle, R. (2008). Journal of Agricultural and Food Chemistry, 56, 6364–6369.

[5] Fernandez-Saiz, P., Lagaron, J. M., Hernandez-Muñoz, P., & Ocio, M. J. (2008). International Journal of Food Microbiology, 124, 13–20.

[6] Plackett, D., Granbari-Siahkali, A., & Szente, L. (2007). Journal of Applied Polymer Science, 105, 2850–2857.

[7] Xu, X., Yang, Q., Wang, Y., Yun, H., Chen, X., & Jing, X. (2006). European Polymer Journal, 42, 2081–2087.

[8] Katti, D. S., Robinson, K. W., Ko, F. K., & Laurencin, C. T. (2004). Journal of Biomedical Materials Research Part B: Applied Biomaterials, 70, 286–296.

[9] Kenawy, E. R., Bowlin, G. L., Mansfield, K., Layman, J., Simpson, D. G., Sanders, E. H., et al. (2002). Journal of Controlled Release, 81, 57–64.

[10] http://www.elmarco.com/nano/products-services/ns-line