Chapter 19
Control of Perishable Goods in Cold Logistic Chains by Bionanosensors

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ABSTRACT

Nanotechnology can contribute to food security in supply chains of agri production-consumption systems. The unique properties of nanoparticles have stimulated the increasing interest in their application as biosensing. Biosensing devices are designed for the biological recognition of events and signal transduction. Many types of nanoparticles can be used as biosensors, but gold nanoparticles have sparked most interest. In the work presented here, we will address the problem of fruit and vegetable decay and rotting during transportation and storage, which could be easily generalized also onto post-harvest loss prevention in general. During the process of rotting, different compounds, including different gasses, are released into the environment. The application of sensitive bionanosensors in the storage/transport containers can detect any changes due to fruit and vegetable decay and transduce the signal. The goal of this is to reduce the logistics cost for this items. Therefore, our approach requires a multidisciplinary and an interdisciplinary approach in science and technology. The cold supply chain is namely a science, a technology and a process which combines applied bio-nanotechnology, innovations in the industrial engineering of cooling processes including sensors for temperature and humidity measurements, transportation, and applied mathematics. It is a science, since it requires the understanding of chemical and biological processes linked to perishability and the systems theory which enables the developing of a theoretical framework for the control of systems with perturbed time-lags. Secondly, it is a technology developed in engineering which relies on the physical means to assure appropriate temperature conditions along the CSC and, thirdly, it is also a process, since a series of tasks must be performed to prepare, store, and transport the cargo as well as monitor the temperature and humidity of sensitive cargo and give proper feedback control, as it will be outlined in this chapter. Therefore, we shall discuss how

DOI: 10.4018/978-1-5225-1798-6.ch019

to break the silos of separated knowledge to build an interdisciplinary and multidisciplinary science of post-harvest loss prevention. Considering the sensors as floating activity cells, modelled as floating nodes, in a graph of such a system, an extended Material Requirement Planning (MRP) theory will be described which will make it possible to determine the optimal feedback control in post-harvest loss prevention, based on bionanosensors. Therefore, we present also a model how to use nanotechnology from the packaging facility to the final retail. Any changes in time, distance, humidity or temperature in the chain could cause the Net Present Value (NPV) of the activities and their added value in the supply chain to be perturbed, as presented in the subchapter. In this chapter we give the answers to the questions, how to measure the effects of some perturbations in a supply chain on the stability of perishable agricultural goods in such systems and how nanotechnology can contribute with the appropriate packaging and control which preserves the required level of quality and quantity of the product at the final delivery. The presented model will not include multicriteria optimization but will stay at the NPV approach. But the annuity stream achieved by improved sensing and feedback control could be easily combined with environmental and medical/health criteria. An interdisciplinary perspective of industrial engineering and management demonstrates how the development of creative ideas born in separate research fields can be liaised into an innovative design of smart control devices and their installation in trucks and warehouses. These innovative technologies could contribute to an increase in the NPV of activities in the supply chains of perishable goods in general.

INTRODUCTION

Nanotechnology and Nanomaterials in Agri-Food Sector

Nanotechnology is the creation and use of materials or devices at 1 to 100 nanometer (nm) https://ec.europa.eu/jrc/en/research-topic/nanotechnology). At these dimensions, materials exhibit different physical properties and behaviors not observed at the microscopic level. The new properties of materials at the nanoscale could develop and transform different technologies and create an added value.[1] The properties of materials can be different from that at larger scale. For example, materials at the nanoscale are more reactive because they have a relatively larger surface area when compared to the same mass of material produced in a larger form. In addition, at nanoscale the quantum effects can begin to dominate the behavior of matter affecting the optical, electrical and magnetic behavior of materials

The nanotechnologies have been in the phase of global growth for two decades as investigated by the bibliometric analysis, the topic analysis, the citation network analysis, and by different methods and authors (Islam & Miyazaki, 2010; Chen et al., 2013; Cozzens, Cortes, Soumonni, & Woodson, 2013).

In 2011 the European Commission (EC) developed a Recommendation (2011/696/EU) on the definition of nanomaterials. Following this document, a nanomaterial is defined as a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where 50% or more of the particles in the number size distribution and one or more external dimensions are in the size range of 1 nm-100 nm.

According to EC (2013) and European Food Safety Authority (EFSA, 2014), *agriculture* is the backbone of most developing countries, with more than 60% of the population relying on it for their livelihood (EC, 2013; European Food Society Association, 2014). The World Bank's (2013) projection is that the *agribusiness* will represent a $ 2.9 trillion industry in global investment by 2030 (World

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