

# **Best Material for Commercial packaging of Food products and Incorporating Track and Trace systems**

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## **Abstract**

In food industry, preserving a particular food product is as important as producing it. There are already many materials currently used in preserving food products and some particular materials used in packaging may also affect the total price of the product. In the first part of paper, particularly talk about the materials used in preserving liquid and frozen materials and the negative effects of them like how a particular material initiates the formation of microorganisms. A biodegradable polymer with a coating of nanoparticles is suggested to replace them and an evaluation of experiment is carried out to prove its working efficiency. After suggesting a suitable material, the next step in the sequence is transportation. In the next part of the paper, talk about the problems faced in transportation and how the food products are affected through it. This discusses how using the Track and Transportation methods could overcome these problems and about one of these methods and their working process. In addition, each step of these processes is verified by possible experimental comparison.

## **Keywords**

Preserving, Food Products, Biodegradable Polymer, Coating of Nanoparticles, Track and Transportation.

## **1. Introduction**

Food products are packaged through different kinds of processes with various kinds of materials, depending upon the type of the food product. The main operations involved in any type of food industry is Processing and Packaging. Processing is the crucial part, determining the quality of the food and packaging is the final phase of the food product. These packaging criteria and method depends upon the product of food. For example, Liquid and Solid foods cannot have the same type of packaging or the same kind of packaging material. For review, a table of generally used packing materials for different food products are given below (Table 1):

Table 2. Packing materials for different food products (Shaw, 2015)

<b>Packaging Material</b>	<b>Food products</b>
Aseptic processing	Eggs and dairy products
Trays	Fish and meat
Bags	Chip sand rice
Boxes	Frozen foods. e.g.: pizzas, cereals
Cans	Liquid food, soft drinks
Cartons	Milk and juices

Regardless of the packaging material, a general packaging should have minimum objectives like physical protection, barrier protection, containment protection, quantity control, and security risks.

## **2. Materials**

While selecting a particular material for the packaging systems, the minimum requirements looked for are that the material should be flexible, light weight, no matter what type of food is preserved. There are particular materials selected like glass and metal for high end and sensitive products because of their special properties including corrosion resistant. On the other hand, liquid food and drinks like beverages and frozen foods are packaged by using mostly two materials namely Aluminum and Tin. Though they are regarded as safe materials and could be used in food processing, there are certain effects of them that cause negative effects on both human health and environment. This paper is going to talk about such adverse effects of these metals used in food packaging systems.

### **2.1 Tin metal**

Tin is a naturally occurring metal, which has corrosion resistant properties, and seldom used as a corrosion inhibitor for metals like steel. In Food industry, beverages and food cans are made, using the Tinsplate material, which is a concentration of Tin layer coated on both sides of a carbon steel strip. Food containers coated with inside layer of tin, usually have a thin layer of varnish between the Tin metal and the food, to stop the metal from leaking into our preserved products. The beverages and liquid foods are produced to maintain their characteristics for a long time, but due to unexpected atmospheric changes they may increase in their acidic nature and react with the protective layer causing it to leak and mix up with the contents of the food, which consumed, in worst cases may lead to tumor disease in lungs. Some materials, lose their characteristics way before the predicted expiry date, which initiates the acidic reaction and correspondingly leading to micro organic activity in the can caused along with the metal. Tin allergies can irritate skin and destroys tissues particularly in the eyes and the respiratory system (Dr. Edward Group, 2013).

### **2.2 Aluminum metal**

The mostly used metal along with Tin during packaging of liquid food and beverages is Aluminum. It has more advanced properties than Tin in areas of thermal conductivity, flexibility, recyclability, low density, and excellent barrier functions like keeping out air, light and stopping the formation of microorganisms. Aluminum can be easily cut, rolled into thin foil and join and can still retain much of its strength. For these capabilities, aluminum is also provided as a packaging material for cosmetics and pharmaceutical products, but when used as an inside coating, it may undergo the same mechanism like Tin and may exhibit some severe effects including the disadvantages caused due to Tin (Roney et al., 2011). Though it has not been scientifically proven, there is more evidence linking aluminum and Alzheimer's disease. Studies indicate, when aluminum leaks and enters the human body through the food components, it goes directly to the brain and binds to protein called transferrin. The function of the protein transferrin, is to transport iron around the body, as the concentration of aluminum intake increases, they block the movement of these transferrin receptors making them vulnerable in Alzheimer's disease (Schechter et al., 2010). Aluminum is much more harmful as the consumer gets old, because the toxins become harder to reduce. As a remedy, a layer may be introduced between aluminum and food as done in tin, rather these coatings also have concerns of their own. For example, a polymer coating ensures that acid and salts in beverages never actually come into contact with metal, but as the storing time increases polymer itself becomes edible dissolving into foods, and also initiating leakage of aluminum, causing greater damage to one's health (Alyssa, 2011).

### **2.3 Alternative Materials for Food Packaging Applications**

To overcome these disadvantages of Aluminum and Tin, many bio-polymers have been researched to develop materials suitable for packaging of different types of food products with no effect on health and environmental issues. The main reason for selecting the bio-polymers was due to their edible nature, but many bio-polymers lacked in mechanical strength and barrier properties, and it was founded that these properties could be developed by adding certain reinforcing compounds like Nano-composites (Henriette, 2009). Nano particles have larger surface area than micro-scale particles which helps the filler matrix interactions and the performance of the resulting material. Nanoparticles exhibit other functions like, when added to a particular polymer it exhibits anti-microbial activity, enzyme immobilization, bio-sensing, etc. (Adame and Beall, 2009). From which it can conclude that nanoparticle coated films would stop the formation of microorganisms even if there is a leakage of the material. It is believed that Nano technology has the power to revolutionize the food industry by contributing stronger high efficient barrier packaging materials, more potent anti-microbial agents, and a host of sensors which can detect or trace contaminants, gasses in packaged foods. Here, one such kind of Nano-particle have been studied for using food packaging systems as well as their effects and applications on anti-microbial and sensors are overviewed (Timothy, 2011).

## **2.4 Zinc oxide (ZnO) - Nanoparticles Coated Polyethylene Films for Food Packaging:**

The development of effective biocidal agents as a substitute for food packaging material, has focused on the research of nanostructures of coinage metals like silver, copper, zinc and gold to overcome its defective properties. Silver and gold cannot be used with consideration to industrialization because of their high cost. Therefore, current work focusses on metal oxides like ZnO as a combination for biocidal antibacterial agents. Bio-degradable polymers like starch and cellulose are the best materials considered for the preparation of packaging films as polyethylene based films exhibits excellent mechanical strength and high moisture barrier properties but they only lack in a property of working as an antibacterial agent (Tankhiwale & Bajpai, 2012). The work deals with in-situ preparation of ZnO nanoparticles onto starch coated polythene film and investigate anti-microbial action of film.

## **3. Experiment**

### **3.1 Preparation of polyethylene film**

After obtaining Starch and polyethylene films from laboratories, the coating of starch onto polyethylene films was carried out at room temperature. The concentration of starch was dissolved in water of about 3%. After the coating, the film was placed in a starch solution for a period of 2 hours. Then the film was taken out and dried at 30 degrees in dust free chamber. As a result of this process, starch forms as a thin layer at the water/polythene interface. This whole process is termed as prewetting.

### **3.2 Preparation of ZnO Nanoparticle Loaded Film**

The ZnO particles are prepared by in-situ method onto starch coated polyethylene film (SCP). The SCP film was placed in an aqueous solution with 2% of zinc sulphate, for 12 hours at 30°C. The loaded film was then shifted into a concentration of 0.02M aqueous solution of sodium hydroxide. After 4 hours, the film is kept in an oven, at 70°C for complete conversion of  $\text{Zn}(\text{OH})_2$  into ZnO. Finally, the film is washed and stored for further use.

### **3.3 Packaging and Antibacterial Activity**

This ZnO loaded polyethylene film is applied to a metal in a closed atmosphere and an artificial bacteria named E. coli is introduced into the atmosphere, and was monitored by zone inhibition method. In this particular process a certain length pieces were cut from the test films and were placed on artificial bacteria. The plates were incubated for 48hrs at 37°C in an incubation chamber (closed atmosphere), and then they were tested visually for zones of inhibition around the film. The geometric size of the zone formed was measured at two cross sectional points and the average value was considered as the diameter of the zone. Now, the pieces were cut into unit cm squares and then immersed into 20 ml nutrient. The artificial bacteria were again introduced and the solution was transferred to an orbital shaker and rotated at 200 rpm at 37°C. The system was sampled at constant intervals during incubation to obtain microbial growth and leaking activity. The procedure was repeated for control polythene film and the final optical density was measured indicated at 600nm.

## **4. Results and Discussion**

Starch coated film (SCB) could be used as an antibacterial film, when loaded with ZnO nanoparticles. The working procedure could be said as, when SCB film is placed in Zn solution, ions enter into starch network and are bound to electro negative atoms present in cellulosic rings. The experiment found that, about 30% of the coated starch film is lost when placed in contact with water vapors under relative humidity of 100%. The results show that there is a suppressed growth rate in the solution containing Zinc oxide loaded film and on the other hand, there is an appreciable growth of bacteria in the absence of these films. Formation of inhibition zone around the nanoparticle film indicates that nanoparticles have diffused away from the film causing bacterial film death and forming clear zone of inhibition around the film, which means if food stuff is wrapped by the film then ZnO particles diffuse into the food stuff and attack the bacteria and as zinc is also used as a nutrient, so if consumed it shall not produce any harmful effect on the health of the user. Use of ZnO particles will make this film nonhazardous to health, environment friendly and economically cheaper compared to other metals.

### **4.1 Incorporating Track and Trace systems for food manufacturing systems**

In an industry, where food is involved there are minimal risks that are undeniable in manufacturing process, and if not managed well, it can have a devastating effect on the health of consumer.

Globalization has opened up many new opportunities and international markets. However, with those opportunities, demand and supply chains stretch across long distances and national borders makes them more vulnerable to disruption. If transportation system is not clearly monitored and managed, then their disruptions can cause significant losses to a business damaging the reputation and manufacturing contracts of a particular company. According to statistics in 2014, there were 76 food recalls which were coordinated by food standards of Australia and New Zealand (FSANZ), among which 35% of the food recalled was due to microbial contamination caused by disruptions in transportation procedures (FSANZ, 2015).

Contamination of food is not the only problems faced by the manufacturer during the transportation, but also includes difficulties like over-coming counterfeiting and fake goods that have a significant effect on health and economy. In their website havoscopes, estimated that there is counterfeiting of products worth 653.77 billion USD. It also estimated that 26 different products are counterfeited in 88 different countries. According to its survey, drugs and food are the primary counterfeited products in the black market worth of 250 billion USD. United States of America is the victim of counterfeited loss estimated loss worth 225 billion USD. More than 25,000 tons of food was seized in 47 countries in an international ride filed under counterfeiting of food. Along with foods, drugs are also under high effect of counterfeiting. In an article by Spink & Moyer (2011), they defined food fraud as, a collective term used to encompass the deliberate and intentional substitution, edition, tampering, or misrepresentation of food, food ingredients, or food packaging and misleading statements, made about a product for personal economic gain.

These disastrous effects can be avoided by efficient enabling of Track and Trace technology (T&T). The perspective of T&T changed the entire supply management as well. Usually, the process of the material of products is, that they are produced at manufacturer, then it is moved in a sequential order to wholesaler, retailer and then to the consumer. Sometimes from wholesalers to consumers directly. In-depth, integration of T&T makes all three persons (wholesaler, retailer, and consumer) can see the product's stage from the manufacturer's server. The packaging will also play an important role in T&T (Thomas, 2016). At primary level the labels are printed and stored in the servers or database at manufacturer's end, which are scanned after the packing of each unit. Then multi units are packed together and stored in another package, this is called secondary packaging. Secondary packages are moved to pallets that are usually tertiary packaging. Integrating high-performance logistics enables the date to store at servers and retrieve back the information, whenever it is needed. Many improvements are made in T&T sector to eliminate the risk of counterfeiting in recent times. The law enforcement acting in a strict and more efficient manner mitigated the risk of international food and material production and provided an efficient scope to track and trace the product. This also enabled the manufacturer to keep up the brand value and profitable return on investments (Mahalik and Nambiar, 2010). T&T has many different types of technology, such as RFID (Radio frequency identification cards), NFC tags (Nearby field communication tags), QR codes, Unique Identification (UID) and other linear barcodes for tracking of the products. This paper discussed about one such T&T technology, RFID (Radio Frequency Identification Cards) which has most advantages than the other listed techniques (Calle, 2014).

## **4.2 Radio Frequency Identification Cards**

In RFID based track and trace anti-counterfeiting, each product is attached with an RFID tag to which a unique product identifier commonly called as PID, is programmed during manufacturing, the RFID tag becomes the physical part of the product item moving through the supply chain from its origin to final consumer's end. The product items are tracked and authenticated, at any transportation change if required from the manufacturer's end to distributor, retailer, and till it reached to consumer's hand, ensuring the accuracy of the product authentication and in preventing any possible means of counterfeiting. This approach is considered beneficial and economically viable for the owners of high brand names to implement and operate, and to prevent counterfeiting. For the application of an RFID enable track entry system, there are three main issues to consider 1) Data formatting, 2) Processing, 3) Transmission mechanism (Choi et al., 2016). The working structure of an RFID tag is discussed below as follows:

- I. It consists of two layers namely front and back end layers. The front end deals with tag programming and data acquisition, whereas the back end deals with product authentication and processing. The back end consists of 4 servers, which handles different works and are named as (Chaudhry and Zimmerman, 2013)
  - (a) Information server (IS),
  - (b) Authentication server (AS),
  - (c) Records server (RS), and
  - (d) Pedigree server (PS).

The working mechanism starts as IS collects the official information of the company, this helps in making a geographical picture of the product transportation route (Obama, 2011). Legitimate suppliers and retailers are first registered in the IS and while transportation, each item is tagged with an RFID sticker and programmed with an RFID. The PID along with the information forms of the product is then synchronized into back end AS, and sent to RS for storage. This whole process can be termed as Tag data processing and synchronization. Through this process, the items moved through the supply chain nodes can be identified using RFID equipment at each stage of the transportation for authentication. The supply chain partners should reject any product with suspicious activities is shown in the accompanying Figure 1.

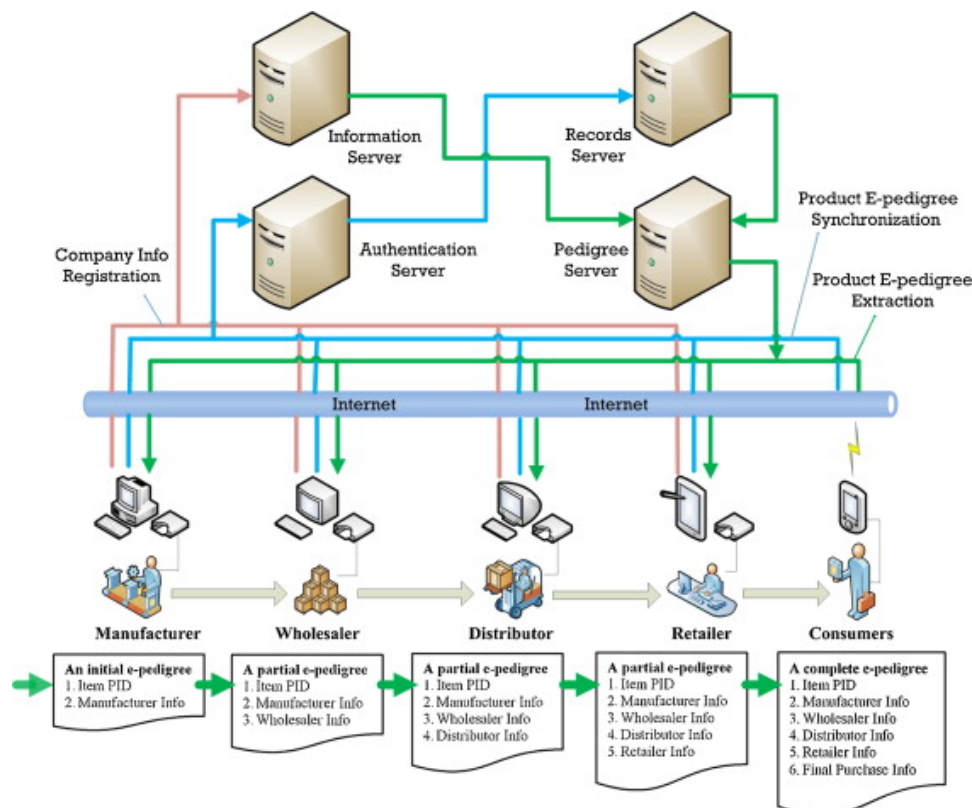


Figure 1: The flow chat of RFID Track and Trace systems. (Taken from Calle L. de C., 2014)

- II. This authentication and total control over product is achieved through the RFID tag, which consists of an algorithm called as TDPS (Tag Data Processing and synchronization Algorithm). This algorithm can consider as the heart of whole track and trace system. This algorithm aims at solving critical issues of product synchronization in apparel packaging lines. TDPS consists of five main steps named as i) Tag EPC writing, ii) EPC verification and TID reading, iii) Tag locking, iv) Locking verification, and v) E-pedigree creation and synchronization.
- III. In the first step, the reader starts to write a unique PID to the moving tag in the interrogation zone. In the step two, EPC verification and TID reading sequentially conduct the tagged item moving in the packaging line. Then in the sequential steps three and four, tag locking and verification is done, if the product is failed in these steps the process restarts and if it is passed through this, the item is processed to the final step where an initial e-pedigree is generated (Bansal et al., 2013).
- IV. The above steps are implemented to verify the TDPS algorithm. Especially a production line, which uses RFID system, is set to surpass apparel product packaging. The first four steps concentrate on the relationship between tag moving speed and accuracy at each step. And in the last step, the performing efficiency of e-pedigree encryption is evaluated as shown in the accompanying Figure 2 (Li, 2013).

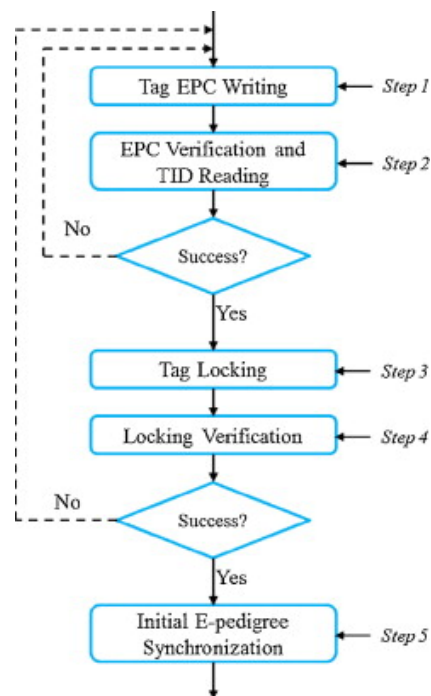


Figure 2: TDPS Flow chart. (Taken from Choi et al., 2015)

## 5. Experimental validation of TDPS

To prove that this efficient working system of RFID is based on this algorithm, an experimental process is evaluated for each step, which proves their working efficiency as discussed below:

### 5.1 Critical tag moving speed:

When the tag enters the interrogation zone, a reader repeatedly executes to write 96 bits of data to it. Around 7000 times, the tag EPC writing were conducted to study how the tag moving speed effects the EPC writing performance. It was observed that the tag EPC writing rate could hardly achieve cent percentage. From the graph, it can be seen that the success rate of the tag remains virtually constant at 92% up to a critical tag moving speed of 0.2m/sec beyond which the success rate drops sharply as shown in the accompanying Figure 3.

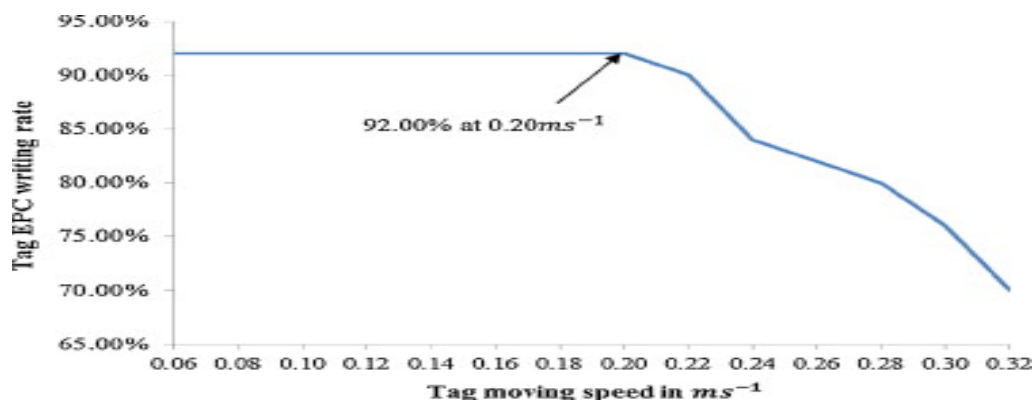


Figure 3: Relationship between tag moving rate and EPC writing rate. (Taken from Choi et al., 2015)

### **5.2 Verification of tag EPC writing**

The second step in this process is to verify that, the product tag in the first step is well written or not. A reader is set up to read-back the complete data and if the read back is correct, then the reader moves to the next item and if any error occurs the reader repeats his read back process until it is corrected or removed from the line. Evaluated results shows that TDPS sorts out all tags with incomplete EPC, even if the tag verification rate is high.

### **5.3 Tag locking verification**

This experimental verification can be done by using another reader to continuously conduct the virtual function of the moving tag. The tag-locking rate is at different moving speeds and the tag moving speed does not affect the locking performance.

### **5.4 Verification of tag locking**

This category consists of two sub steps. The first one is called EPC locking verification and the second one is called access password locking verification. Two separate experiments are conducted for these two different categories which showed that their rates are cent percent success, even the tag moving speed reaches maximum.

These experimental results of the TDPS steps indicate that the tag EPC writing is affected only by tag moving speed and is identified as the bottleneck of production initial e-pedigree generation. It concludes that the critical speed and the corresponding tag EPC writing rate will severely limit the packaging line output.

## **6. Conclusion**

Currently used food packaging materials may not seem dangerous but will definitely affect human health in long run and it is better to find a possible substitute for it. The nano-materials coated polymers are suggested due to its high working efficiency, low cost and edible nature, which if consumed does not have an adverse effect on human health. No matter what kind of precautions take, if it fails in transporting the authentic product to the consumer then all the hardships undergone to produce a quality product is wasted. This is prevented by incorporating track and trace system. Though only one type of T&T system is discussed here, there are other many technologies that even with low efficiency works adequately with particular products. All manufacturers regardless of their products must adopt this technology for an efficient way of handling and supply the products into markets. Track and Trace integration are the best technique that can eliminate counterfeited products in the global market. It not only keeps people away from spurious, hazardous products but also maintain a healthy relationship with consumer and manufacturer without compromising on the quality and quantity of the product. Following few regulations and terms of law enforcement, manufacturers can maintain their trust and loyalty, where they can proudly exhibit their product in the market.

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## **Biography**

**Sarder Sadique**, Assistant Professor in mechanical Engineering, Weisberg Division of Engineering, Marshall University. He has a Bachelor degree in Materials Engineering from the Bangladesh University of Engineering and Technology, and a Masters leading to Ph.D. in Mechanical Engineering from the National University of Singapore (NUS 2015 ranking: 12<sup>th</sup> in the world). He has been a faculty member and Department Head at the Curtin University of Technology, Malaysia; faculty member and researcher at Centennial College, Toronto, Ontario, Canada; member at Sheridan College, Toronto, Ontario, Canada faculty member at University of Texas at El Paso and University of Southern Mississippi; and most recently a faculty member at Central Michigan University. He has published journal and conference papers. Dr. Sadique has a broad-based research interests such as Advanced Manufacturing Processes, Hybrid Renewable Energy (solar and wind), Biosensors and Biorobotics, Nanobioengineering, Nanobiomechanics, Elastohydrodynamic Lubrication, Nano-tribology and Fuel Cells. He is affiliated with ASME, IEOM, PEO, OSPE, STLE, EA, IEB etc.