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Review
Pregledni rad

TECHNOLOGY OF FOOD PACKAGING
TEHNOLOŠKO-TEHNIČKI SISTEMI PAKOVANJA PREHRAMBENIH PROIZVODA

Milan ĐEVIĆ, Aleksandra DIMITRIJEVIĆ
Faculty of Agriculture, 11080 Belgrade, Nemanjina 6, Serbia
e-mail: saskad@agrif.bg.ac.rs

ABSTRACT

Food packaging science is a discipline which applies the principles from four major areas of science (material science, food science, information science and socioeconomics) in order to understand the properties of packaging materials, the packaging requirements of food, the packaging systems etc. In the food packaging industry market response is an initiating force for the food packaging technology development.

In this paper an overview of food packaging technology is given as well as most important packaging functions and environments. The typical food packaging development process which may serve as a guide for designing food packaging systems is also presented. The paper gives the examples of analyzing food packaging systems and food packaging levels that can be optimized to provide the most efficient solution.

***Key words**: food, packing, technology, development.*

REZIME

Proces pakovanja hrane ima podjednaku važnost kao i sam proces proizvodnje hrane. Kao finalni postupak u veoma kompleksnom procesu proizvodnje hrane u sistemu «od njive do trpeze» tehnološko-tehnički sistem pakovanja mora da zadovolji višestruke kriterijume koji su, često, i u suprotnosti.

Poznavanje ambalaže i procesa pakovanja poljoprivrednih i prehrambenih proizvoda može znatno olakšati postupke projektovanja i optimizacije transporta i skladištenja na imanjima i, samim tim, dovede do određenih ušteda kako u energetskom tako i u ekonomskom pogledu. Sam krajnji cilj ambalaže i pakovanja poljoprivrednih i prehrambenih proizvoda je svakako dvojak i to, najpre, održavanje kvaliteta upakovanog proizvoda ali i komercijalni u smislu što boljeg reklamiranja upakovane robe.

Tehnološko-tehnički sistemi pakovanja hrane se mogu posmatrati sa više aspekata i to sa aspekta nauke o materijalima za pakovanje, zatim sa aspekta nauke o hrani i o samom procesu njene proizvodnje, kroz informacione tehnologije i sa socio-ekonomskog aspekta.

Cilj rada je da prikaže osnove tehnologije pakovanja kao i najznačajnije funkcije pakovanja i ambalažiranja poljoprivrednih i prehrambenih proizvoda. U radu su dati i primeri mogućih analiza tehnološko-tehničkih sistema pakovanja čija primena za ishod ima optimalno tehnološko-tehničko rešenje sistema pakovanja prehrambenih proizvoda. Dati primeri se mogu posmatrati kao praktični saveti koji kombinuju elemente funkcije ambalaže i socio-ekonomske parametre kao i elemente funkcije ambalaže i ekologije. U daljem toku rada prikazani su osnovni elementi i uticajni faktori razvoja tehnološko-tehničkog sistema pakovanja prehrambenih proizvoda. Ovde se najpre misli na određivanje samih potreba proizvoda koji se pakuje, zatim na analizu materijala od koga je izrađena ambalaža i na tehničke sisteme pakovanja kao i na evaluaciju izrađenog prototipa i njegovo konačno pojavljivanje na tržištu.

***Ključne reči**: prehrambeni proizvodi, pakovanje, tehnologija, tehnološki razvoj.*

INTRODUCTION

Food packaging science is a discipline which applies the principles from four major areas of science (materials science, food science, information science, and socioeconomics) to understand the properties of packaging materials, the packaging requirements of foods, the packaging system, etc. Food packaging technology is a set of practical solutions for delivering high quality and safe food products to the consumer in an efficient manner. Examples of food packaging technology are modified atmosphere packaging, microwavable packaging, and aseptic packaging.

Quality of different food products depend, mostly, on packaging materials but, also, on requirements and procedures of modern packing (*Gvozdenović and Lazić, 2008*). The improvement of packaging process means modernification of equipment as well as improving the qualitative properties of applied packaging materials. The role of contemporary food packaging is not only a protection and selling but also prolongation of shelf life with maintenance of quality (*Lazić et al, 2008*). Some of the authors refer to packaging technology and science as partly art and partly science but agree that both are important for the development of effective and efficient food packages and packaging systems (*Sun Lee et al, 2008*).

MATERIAL

This paper can be looked at as a introduction material for food packaging technology. It comprises several contemporary literature sources as well as some practical examples for food packaging analysis.

DISCUSSION

Food Packaging Technology

Food packaging technology is a set of science-based solutions to address specific food packaging needs. Examples are tamper evident packaging, modified atmosphere packaging, aseptic packaging, and microwavable packaging which are aimed at enhancing safety, quality, and convenience for the consumer. Packaging technologies are also important for improving the efficiency of package manufacture, distribution, retail display, and waste disposal for the industry.

Innovative technologies such as antimicrobial packaging, controlled release packaging, nanotechnology, biosensors, and radio frequency identification (RFID) have attracted much interest from the packaging community in recent years (*Brody et al, 2001, Vermeiren et al, 1999, Appendini and Hotchkiss, 2002*). Since the development of a new technology is typically costly, it should be justified carefully based on its ability of this technology to enhance certain packaging functions to meet certain socioeconomic needs (*Yam et al, 2005, Anonymus, 2000*).

Packaging Functions

A food package must serve one or more functions to justify its existence. Traditionally, food packaging has four basic functions: protection, convenience, communication, and containment. A package design may be evaluated based on how well the package performs the required functions in a cost effective manner:

- *Protection* - Protecting the food from physical damage, physiochemical deterioration, microbial spoilage, and product tampering is probably the most important function of packaging. Without proper protection, the food may become unappetizing, less nutritious, and unsafe to consume. The required packaging protection depends on the stability and fragility of the food, the desired shelf life of the food package, and the distribution environment. Good package integrity is also required to protect against loss of hermetic condition and microbial penetration. Generally, the protection function of packaging is limited to foods whose shelf lives are controlled by environmental factors relating to physical damages, humidity, oxygen, light, and to some extent, temperature. Packaging is usually not effective for protecting foods whose shelf lives are controlled by internal factors.

- *Convenience* - This is an important function to satisfy the busy consumer lifestyle. Examples of convenient food packages are ready-to-eat meals, heat-and-eat meals, and self-heating packages. Examples of convenient features are easy opening, resealability, and microwavability.

- *Communication* - The function of communicating is important to create brand identity and influence consumer buying decisions. The package communicates with the consumer through written texts, brand logo, and graphics. In many countries, nutritional facts such as calories, fat, cholesterol, and carbohydrate are required on all food packages. The communication function is also important for facilitating distribution and retail checkouts. The barcode has virtually become an integral part of every commercial food package.

- *Containment* - Containing the food product is the most basic function of packaging. The requirement for containment depends on the size, weight, form, and shape of the enclosed food; for example, a solid food has different requirements from a liquid food. The containment function is also closely related to the rigidity of the package.

Food Packaging Systems

Food packaging is a system that involves certain physical components and operations. The major physical components are the food, the package, and the environment; the major operations are the manufacture, the distribution, and the disposal of the food package. In designing a food packaging system, these physical components and operations must be integrated efficiently to prevent overpackaging or underpackaging.

Levels of Packaging

A food packaging system may involve up to four levels of packaging:

- The primary package is usually a single unit purchased by the consumer at the retail store. Examples are a bottle of milk, a box of chocolates, a bag of potato chips, a can of ham, etc. Since the primary package is in direct contact with the food, it is in the best position to protect and promote the food product.

- The secondary package is usually a corrugated fiberboard box that contains a number of primary packages. The simplest type of secondary package is probably a plastic ring that holds several cans or bottles. The major role of the secondary package is to facilitate handling of multiple primary packages in the retail store.

- The tertiary package is one that holds a number of secondary packages. An example is a stretched-wrapped pallet of corrugated fiberboard boxes. Its major role is to facilitate handling in the warehouse and retail store.

- The quaternary package is one that holds a number of tertiary packages. An example is a large metal container holding several pallets to be placed inside a truck, train, or ship. Its major role is to facilitate long distance distribution.

These different levels should be optimized to provide the most efficient packaging solution. For example, the protection of a food product may be allocated to the primary packaging and the secondary packaging in a judicious manner so that the protection requirement is met while the cost is minimized.

Package Forms

Packaging may be classified into three forms: flexible packaging, semirigid packaging, and rigid packaging. These forms of packaging provide a wide selection of choices for various foods. A flexible package, such as a pouch or a bag, is one whose shape or contour is significantly affected when filled and sealed with the enclosed product. Due to the pliancy of the package wall, the internal pressure of a flexible package is approximately the same as the external pressure, and the package may be inflated or deflated according to the external conditions. A semirigid package, such as a plastic tray or container, is one whose shape or contour is not significantly affected when filled and sealed with the enclosed product, but it can be deformed with finger pressure (about 60 kPa). A rigid package, such as a metal can or a glass jar, is one that does not change shape or break unless excessive external force is applied.

All three forms of packaging have both advantages and disadvantages. For instance, a flexible pouch can easily accommodate foods of irregular shapes, but its closure integrity may not be as good as that of a rigid container.

Tables for Analyzing Food Packaging Systems

Based on the above discussions, the following tables may be constructed to provide an overview of the relationships between packaging functions and socioeconomic needs, technology, and packaging environments. These tables are particularly useful during the early stage of the package development process for facilitating brainstorming and identifying key areas for further consideration.

Functions / Socioeconomics Table

In this table, packaging functions and socioeconomic needs are arranged in columns and rows. For a particular situation, the socioeconomic needs are identified and prioritized, not necessary the same as shown in Table 1. Each cell in the table is then considered to determine its relevance and importance. Using this table, a product development team may conclude that, for example, food safety and saving rime are most important to the consumer and to the success of a new product. The team will then focus on enhancing the protection and convenience functions of the package to satisfy these needs.

Table 1. Functions/socioeconomics table

		PACKAGING FUNCTIONS			
		Containment	Protection	Convenience	Communication
SOCIOECONOMICS	Consumer life-style				
	Values				
	Profits				
	Safety / biosecurity				
	Regulations				
	Environment				

Functions / Technologies Table

In this table, packaging functions and technologies are arranged in columns and rows. This table is useful for evaluating the strengths and weaknesses of new technologies, based on their impact on the packaging functions. New technologies may also be introduced to improve operational efficiency or to reduce cost, preferably without compromising the existing packaging functions.

Table 2. Functions/technologies table

		PACKAGING FUNCTIONS			
		Containment	Protection	Convenience	Communication
TECHNOLOGIES	Active packaging				
	Bio-based materials				
	Barrier materials				
	Intelligent packaging				
	Advanced machinery				

Table 2 lists some technologies that have received much attention in recent years For example, active packaging (such as oxygen scavenger and antimicrobial film) is for enhancing the protection function, and intelligent packaging (such as time-temperature indicator and RFID tags) is for enhancing the communication function of the package.

While new technologies are aimed at achieving certain benefits, they sometimes also create unintended problems. For example, replacing glass with plastics may provide the benefits of versatility and cost effectiveness, but it also creates concerns of undesired compounds from the plastics migrating to the food. Replacing synthetic plastics with biobased materials can help minimize packaging waste to the environment, but most biobased materials have relatively poor mechanical properties.

Functions / Environments Table

In this table, packaging functions and environments are arranged in columns and rows. This table is useful for identifying certain packaging features, operations, devices, or considerations that are important for the package to function under certain environments.

For many food packaging systems, it is possible to associate items to most of the cells in Table 3. Although the selection and interpretation of the cell items involve somewhat subjective choices, the functions/environments table helps the product development team to consider all aspects of the food packaging system in a systematic manner. Shown below are examples of items that may be associated with the cells. With some imagination, other helpful items may also be associated.

Table 3. Functions/environments table

		PACKAGING FUNCTIONS			
		Containment	Protection	Convenience	Communication
ENVIRONMENTS	Physical				
	Ambient				
	Human				

- *Containment / physical.* The size and type of package determine how much and what kind of food can be contained and how much physical abuses the package can withstand.
- *Containment / ambient.* The size and type of package determine how much and what kind of food can be contained and the ability of the package to protect against oxygen, moisture, or light from the ambient environment.
- *Containment / human.* The size and type of package determine how much and what kind of food can be contained and ease of use of the package to humans (*Mead et al 1999*).
- *Protection / physical.* Mechanical strength and seal strength are important for protecting the product from physical abuses.
- *Protection / ambient.* Barrier properties and seal integrity are important for protecting the food product from the adverse effects of oxygen, moisture, microbes, and light in the ambient environment.
- *Protection / human.* Tamper evident packaging is useful to protect the consumer from product tampering. Regulations are necessary to protect from unsafe packages harmful to the consumer.
- *Convenience / physical.* Efficiently bundled packages offer convenience to the manufacturer during storage and distribution.
- *Convenience / ambient.* Aseptic packages offer the convenience of storing food products at ambient environment instead of refrigerated conditions.
- *Convenience / human.* Microwavable packages and easy-to-open packages offer convenience to the consumer.
- *Communication / physical.* Barcodes can facilitate communication of information through the physical distribution of the product in the supply chain.
- *Communication / ambient.* Time-temperature indicators and biosensors may be attached to the package to communicate the conditions of the ambient environment.
- *Communication / human.* Nutrition labels, instructions, and graphics on the package can provide useful information to the consumer.

To take a step further, relative values (from 0 to 100) may be assigned to the cells in Figure 3 (*Lochart, 1997*). A 3-dimensional chart may then be generated using the functions, environments, and relative values as x, y, and z coordinates.

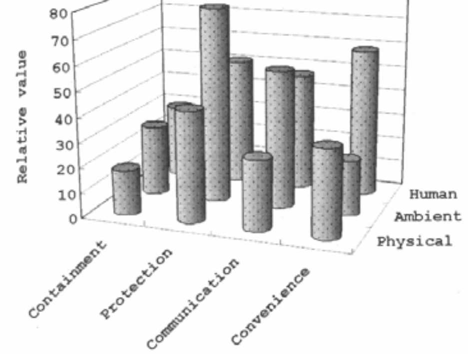

Fig. 1. Three-dimensional plot of functions/environments

The determination of these relative values is a process that frequently requires subjective judgment. A hypothetical example of this chart is shown in Figure 1. The chart provides a bird's eye view of the functions/environments relationships and is useful for prioritizing the cells and identifying areas of strength and weakness of the food packaging system.

Food Package Development

The food packaging development process involves many considerations and activities The socioeconomic pulling forces, different levels of packaging different forms of packaging, and functions/environments matrix are all important considerations. Typical activities involved in food package development are shown in Table 4.

While designing a food packaging system is a complicated process using the concepts and tables presented in this chapter will provide a good start for this process. In later chapters, more detailed information about the science and technology of food packaging will be presented.

Table 4. A typical food packaging development process

Step 1 Determine product/package requirements	Step 2 Select package materials and equipment	Step 3 Evaluate prototype packages	Step 4 Test packaging system in market
Food product - Formulation - Processing - Stability to light. O_2 and H_2O Marketing - Desired shelf life - Distributor chain - Cost constrains - Launch timing - Product positioning - Package size Production - Existing equipment - Plain capability - Cost per unit calculations	Work with suppliers of packaging materials and machines to identify options. Determine cost and availability. Compare stock versus custom package. Work closely with product development to better understand ingredients and possible issues relating to packaging. Regulation compliance.	Conduct shelf life testing to determine quality retention at ambient and elevated temperatures. Conduct distribution testing to determine robustness and integrity of package. Conduct product/package interaction testing. Evaluate feasibility of scale-up at final production facility.	Produce final food packages. Confirm all major requirements are met. Retrieve packages from market for evaluation and confirmation. Monitor consumer feedback during test market or national rollout. Refine package/process design if necessary
Marketing group typically leads discussions based upon consumer data, while technical group provides input on feasibility.	Timing is critical to package design. Identify potential issues that may delay timeline.	Scale-up package at production facility is important prior to initial run to identify potential process issues.	Final package is tested as part of a concept fulfillment test to confirm consumer acceptance of product and package.

CONCLUSION

Food packaging science is a discipline which applies the principles from four major areas of science (materials science, food science, information science, and socioeconomics) to understand the properties of packaging materials, the packaging requirements of foods, the packaging system, etc. A food package must serve one or more functions to justify its existence. The practice of packaging art alone, with little consideration of the relevant science, frequently leads to ineffective designs and poor products, especially when dealing with complex food packaging systems. Innovative technologies such as antimicrobial packaging, controlled release packaging, nanotechnology, biosensors, and radio frequency identification (RFID) have attracted much interest from the packaging community in recent years. Further development of food packaging systems is based on further development of bio-polymers which is very important regarding ecology demands.

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