Development of Innovative Packaging Characterized by Active Thermal Insulation Properties

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ABSTRACT

In recent years, one of the most significant innovation in the field of food packaging is represented by active and intelligent packaging. Active and intelligent packaging refers to the packaging able to do something more than only contain and protect the content, such as, extending the shelf life. In this research activity, a new active packaging with thermal insulation properties has been developed and tested. A sampling of innovative packaging has been realized and its functionality has been tested both in laboratory and in real conditions. Results have shown that the innovative packaging is able to control and delay the accidental overheating of fresh food. Results have verified that a better control of the overheating phenomena allows to reduce food waste, reduce the use of refrigerator and increase food quality and safety.

Keywords: packaging, smart materials, composite materials, phase change materials

1 INTRODUCTION

Until a few years ago, the food packaging was limited to protect the product inside, contribute to the conservation, and communicate information. These functions are now taken for granted and packaging must have additional features due to the increasing consumer attention on quality and safety factors. Research in this field is continuously growing and the most significant innovation is represented by active and intelligent packaging. This kind of packaging is projected and realized using innovative materials or techniques able to add new features to the packaging. The main objectives of active and intelligent packaging are extend the shelf life, monitor and communicate the food freshness, improve the conservation quality [1].

Several research activities are presented in literature about active and intelligent packaging. Most of them are related to the study of materials and technologies for controlling the atmosphere inside the packaging. In fact, one of the main external factor effecting the quality of food is the atmosphere composition. Examples are packaging able to absorb oxygen, in order to delay the food oxidation, or packaging able to release anti-bacterial substances.

In addition to the atmosphere composition, the other important external factor effecting the quality of fresh food is the temperature variations [2]. Packaging materials play a significant role in controlling the temperature of the content.

There are many materials and structures that work as good thermal insulation packaging, such as polystyrene foam, but they are not active packaging. In this work, the possibility to develop an active thermal insulation packaging able to be active at a specific temperature has been investigated.

One possible approach to actively control thermal insulation is represented by thermal energy storage approach. Along this direction, large quantity of thermal storage/recovery can be achieved in the form of melting/freezing latent heat by using phase change materials (PCMs).

PCMs are smart materials with a specific phase transition temperature that is selectable in relation with the application in which they are used. The supplied energy during the phase transition is later recovered during the opposite phase transition. Latent heat is the energy which should be absorb or release during the PCMs phase transitions. What makes PCMs interesting for new applications is the possibility to choose the transition temperature and the fact that they can be micro-encapsulated in order to obtain a stable material [3].

PCMs have been studied by several researchers since the eighties. They have been tested in various applications, especially in building industry and in winter clothes. They have demonstrated to have many advantages, but one of their limit is related to the possibility to use PCMs in composite materials.

In this work, an innovative composite material made by cellulose fibers and PCMs, developed in previous research [4], has been tested as active packaging material for fresh food.

2 MATERIALS AND METHODS

2.1 Development of active packaging

The composite material used in this work, already realized in previous research, is made by 50% cellulose fibers and 50% PCMs (w/w) ratios. PCMs used present melting point at 6°C, that means they become active around 6°C [4].

The composite pulp has been worked through consecutive pressing and drying phases in order to obtain a plate slab with the regular thickness of 4 mm. The final panel has been coupled between corrugated cardboard (1 mm thickness) and kraft paper, to obtain a multilayer panel (5 mm thickness). The sandwich panel has been realized in order to confer to the material the suitability for food packaging application. In this case, the suitability is given by the appropriate mechanical properties and the possibility to put the material in contact with food products.

The sandwich panels have been used to realized a sampling of active packaging with the same shape and size as standard packaging in order to compare them in thermal insulation. Standard packaging selected for tests have been the ones used for ready-to-eat lettuce in bags.

As shown in Figure 1, the panels have been processed and cut using the common instrument for the fabrication of this kind of packaging, that is cutting plotter.

Figure 1: Manufacturing of active packaging using common technology for the fabrication of standard packaging.

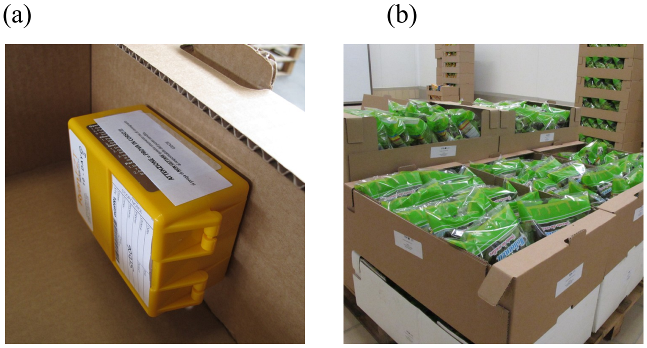
2.2 Tests in real conditions

A sampling of 20 active packaging has been realized in order to test their functionality in real conditions during the distribution of fresh lettuce (ready-to-eat product). They have been compared with 20 standard packaging, commonly used for this application.

One data temperature recorder (RYAN-SENSITECH, mod. EZT) has been placed inside each packaging to monitor the temperature variations during the entire distribution phase. The distribution phase includes different steps. It starts with the packaging phase, when lettuce bags are placed inside each packaging and they are organized on pallets; after that, pallets are transported by refrigerated truck to the food platform; here, packaging are divided for the distribution to the individual supermarkets; finally packaging are sent to the individual shops by the delivery truck. All this itinerary lasts about 24 hours.

Figure 2 shows the beginning of tests during packaging phase, when data temperature recorders and lettuce bags have been put inside the active and standard packaging and all of them are stored on pallets in the cold-store, ready to be delivered. Tests have ended at the supermarkets, when lettuce bags have been pulled out of packaging.

In order to guarantee the freshness of the lettuce, the products should be always stored between 3°C and 8°C.



(a) (b)

Figure 2: (a) Data temperature recorder (RYAN-SENSITECH, mod. EZT) placed inside each packaging; (b) Active and standard packaging monitored in the cold-store.

Temperature variations have been monitored starting from the packaging phase until the products have arrived to the grocery and placed in the refrigerator.

2.3 Laboratory tests

Together with tests in real conditions, laboratory tests have been performed. A sampling of active packaging and standard packaging have been placed inside an industrial refrigerator (Epta) set at 3°C for 24 hours (Figure 3). After that, packaging have been taken out to simulate a break of the cold storage during the distribution phase.

During the whole tests, temperature variations have been recorded using a system of thermocouples (National Instrument system acquisition NI cDAQ 9172) (Figure 3).

Figure 3: Laboratory stage for tests.

3 RESULTS

3.1 Development of active packaging

Figure 4a shows the uniform distribution of PCMs micro-capsules into cellulose matrix to build the composite materials.

Thanks to the multilayer structure realized (Figure 4b), the material presents the required mechanical properties and moreover, the external layers can be place in contact with food products. Using the sandwich panels, a sampling of packaging have been realized using common fabrication techniques (Figure 4c).

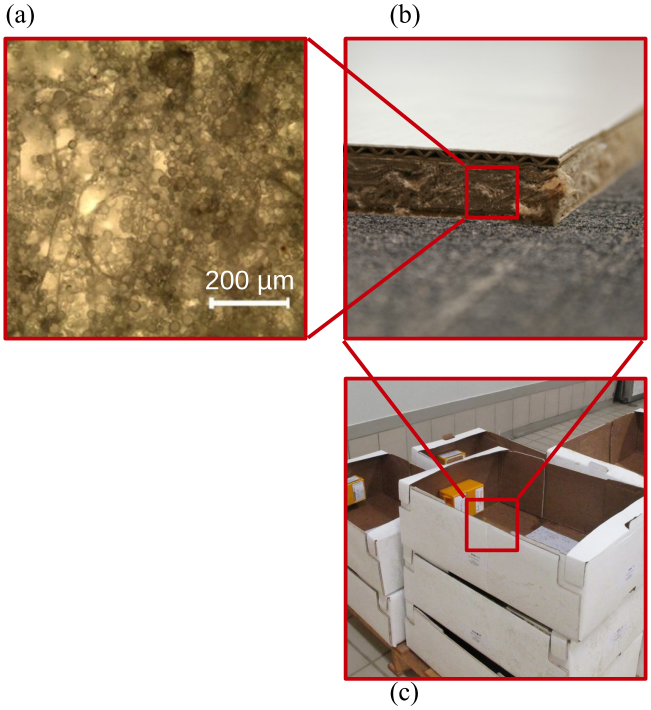


Figure 4: (a) Optical micrographs of PCM particles dispersed into cellulose fibers; (b) Plate slab of composite material coupled between kraft paper and corrugated cardboard; (c) Sandwich panels worked to realize a sampling of packaging.

3.2 Tests in real conditions

Figure 5 reports results obtained during tests in real conditions. The diagram shows the average of the temperature recorded inside active packaging and inside standard packaging, respectively. The time line starts at the packaging phase and ends when products have arrived at the supermarkets.

The diagram shows that during the distribution phase, the temperature is not always kept between 3°C and 8°C, as should be for the optimal conservation of the lettuce. Temperature is subjected to variations and consequently, food suffers undesirable overheating.

The overheating is due to many reasons such as passages in non refrigerated areas, transportation, inadequate attention at the storage temperature, etc.

Results show that the active packaging are able to control the overheating. They have demonstrated to delay the rise of temperature, over 10°C, of 2 hour. At the same time, they keep the temperature always lower compared with standard packaging.

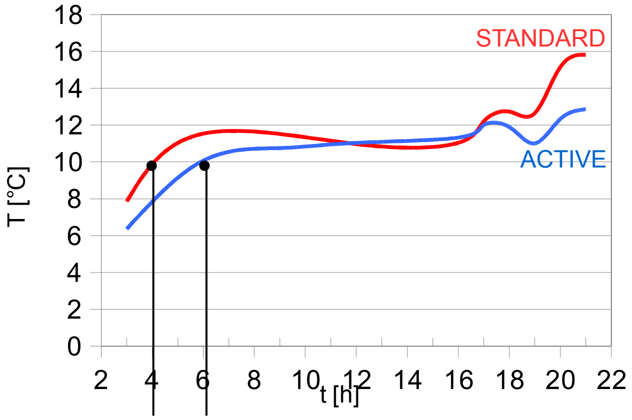


Figure 5: Average of the temperature recorded inside standard packaging and active packaging, respectively.

A specific case has been analyzed. Figure 6 reports the thermic cycle recorded inside one active packaging and one standard packaging. The two packaging arrived at the same grocery.

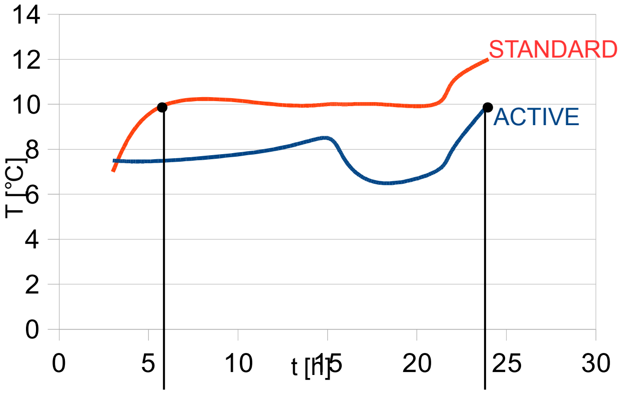


Figure 6: Thermal cycle recorded inside one standard packaging and one active packaging.

The temperature recorded inside active packaging is always lower compare to the temperature inside standard packaging of at least 2 celsius degrees. Moreover active packaging reach the critical temperature of 10°C after more than 15 hours compared to standard packaging.

3.3 Laboratory tests

Tests performed in laboratory confirmed results obtained in real conditions. Active packaging are able to delay the rise of temperature over 10°C of a range of time included between 1 and 5 hours. What is most interesting to be noted from results of laboratory tests is the behavior of active packaging during the storage phase inside the refrigerator. Results are shown in Figure 7: the temperature inside the refrigerator is not constant but it is subjected to the duty cycle of the machine. Temperature was set at 3°C and hot spikes reached up to 8°C. Active packaging have demonstrated to better modulate these hot spikes compare with standard packaging. Hot spikes inside active packaging are always lower of at least 2 celsius degrees compare with standard packaging. That means that using active packaging it would be possible to reduce the energy consumption of refrigerator systems.

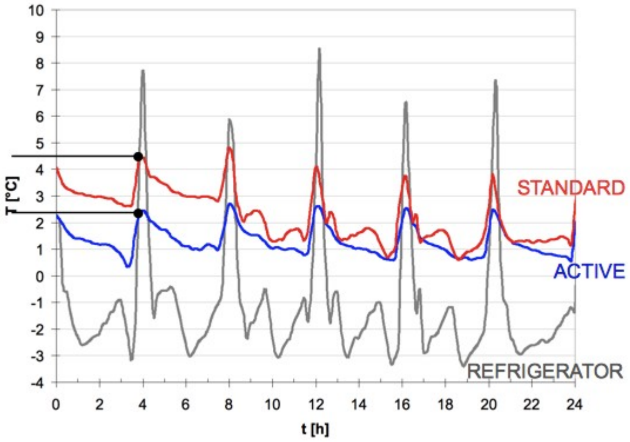


Figure 7: Thermal cycle recorded inside the refrigerator, inside active packaging and inside standard packaging, respectively.

All results obtained have demonstrated that active packaging can play a role in improving the conservation of fresh food. Their active properties are related to the operation of PCMs. Because of their great capacity to absorb and slowly release the latent heat, if PCMs are added into the packaging material, PCMs increase the thermal energy storage capacity of the container [3]. This concept represents an ideal solution for the storage of fresh food which are sensible to the moderate overheating.

4 CONCLUSIONS

An easy technique for PCMs incorporation in cardboard and their possible applications in food packaging materials is reported. A composite material based on PCMs and cellulose fibers has been worked in panels and coupled to obtain a sandwich structure usable for food packaging. The innovative packaging developed is an active packaging with smart thermal insulation properties.

Tests done have demonstrated that active packaging are able to delay the rise of temperature compare with standard packaging and also to control the hot spikes inside the refrigerator systems. These results imply several possible consequences. The use of active packaging can have environmental, economical and social impacts. In particular, it can reduce food waste and can also reduce the use of refrigerator systems. It improves food quality and shelf life; finally, the developed active packaging can significantly contribute to food safety because they play an important role in controlling the spread of epidemics in food, related with the increase of temperature [5].

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