The Scientific Bulletin of VALAHIA University
MATERIALS and MECHANICS –Vol. 20 , No. 22

DOI 10.2478/bsmm-2024-0003

STUDIES ON THE PHYSICAL STRUCTURAL PROPERTIES OF PACKAGING USED IN THE FOOD INDUSTRY

Elena Valentina STOIAN[1], Maria Cristiana ENESCU[1], Sofia SLĂMNOIU TEODORESCU [1], Ion Valentin GURGU [2], Cristina Alexandra MINCĂ[3]

[1] Valahia University of Târgoviste, Faculty of Materials Engineering and Mechanics,13 Sinaia Alley, 130004, Tirgoviște, România, [2] Valahia University of Târgoviste, Institute of Multidisciplinary Research for Science and Technology 130004 Tirgoviște, România, [3] Valahia University of Târgoviste, Faculty of Materials Engineering and Mechanics,13 Sinaia Alley, 130004, Tirgoviște, România, master`s student

E-mail: cristiana_enescu@yahoo.com

Abstract: *Packaging is the basic necessity of every product. Without packaging the product cannot be stored or moved from one location to another. The packaging gives the product an identity. Therefore, the packaging constitutes a protective covering of the product in such a way as to protect the product during handling, storage and movement. The purpose of this work was to study and analyze the evolution of packaging in the food industry, because the quality of products that are stored in casseroles must to remain the same and not be influenced by the quality of the packaging. Samples were taken by hand, by cutting, from white and black polypropylene pots, as well as wood fiber pots. They were correctly labeled, and later they were analyzed in the laboratories of ICSTM Valahia, performing FTIR, Raman spectroscopy and optical microscopy analyses.*

Keywords: *casseroles, polypropylene, wood fiber, FTIR, Raman, optical microscopy*

1. INTRODUCTION

Since prehistoric times, we have always had a need to store or transport food, although there is no recorded evidence of this, it is believed that the first "packaging". We ever used was made from leaves, from nuts or gourds,from animal skins.[1-5]

Figure 1. The evolution of packaging in the food industry

Chronologically, the evolution of food packaging began in 1879 with the appearance of cardboard and in 1817 of folding cardboard. In 1908, cellophane was invented by Jacques E. Brandenberger who thought of a transparent, protective packaging in 1900. [4-10]
In 1954, polypropylene was born. This material is the main path to sustainability because it degrades faster than any other plastic material.

Later, in 1957, aluminum was introduced for the first time in the production of packaging for cans. The year 2000 is the year of the appearance of ecological, sustainable composite materials (which use wood fibers, sugar cane fibers, cotton fibers, etc.) as reinforcing agents.

Packaging is the process of providing a protective and informative covering of the product. The packaging is a way as to protect the product during handling, storage and movement of this [7-12].

The food industry provide most of the food consumed by the world's population.
In the last decades, packaging has diversified a lot. The development of materials from the functional point of view led to the emergence of different types of packaging.

According to the material used to make the packaging, we can find packaging made of paper and cardboard, glass, metal, plastic, wood, wood substitutes and braids, textiles, complex materials.
According to the manufacturing system, fixed, dismountable, foldable packaging can be distinguished.

According to the specifics of the packaged product, there are packaging for food products, for non-food products, for dangerous products, individual, collective [10-18].

2. EXPERIMENTAL PART

Samples were collected manually by cutting, from the white and black polypropylene pots, as well as from the wood fiber pots. They have been designed so as to be as easy as possible to use in the characterization devices.

The correct sampling was carried out as cleanly as possible, with the help of gloves, because the sampling rocess has a major importance on the assessment of the quality of the materials, in order to obtain quality results.

After the samples were cut, they were correctly labeled, according to figures 2, 3 and 4, and later they were analyzed in the ICSTM Valahia laboratories. FTIR and RAMAN spectroscopy analyzes were carried out, as well as optical microscopy analyses.

Figure 2. White polypropylene samples (PP – w)

Figure 3. Black polypropylene samples (PP – b)

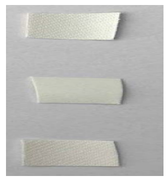

Figure 4. Wood fiber samples (wf)

Polypropylene (PP) is a colorless and odorless substance, with a density of 900 kg\m^3 lower than that of PE. It has a better resistance to heat, the PP packaging can be sterilized at 115-120^0 C. The permeability to water vapor is low, and the permeability to gases is average.

Wood fibers are cellulose elements. Those are extracted from trees and used to obtain paper. It can be extracted as a primary product or collected during sawmilling. Abbreviations such as PP for polypropylene casings and WF for wood fiber casings have been used.

2.1 FTIR spectroscopy analysis

Analysis is Fourier Transform Infrared Spectroscopy. This method is an analytical technique used to identify organic, polymeric materials.

The FTIR analysis method uses infrared light to scan test samples . This method is used also to determine the chemical properties of materials.During the utilisation the FTIR device emits radiation, and the absorbed radiation is converted into vibrational energy.

Figure 5. IR spectrometer with fourier transform (FTIR) coupled with a high resolution IR microscope

Table 1. Assignment of vibration bands for black PP

Wavenumber (cm^{-1})	Intensity	Assignment of vibration bands
FTIR		
2949	ms	C-H$_3$ asymmetric vibration /C-H$_3$ aromatic vibration
2917	m	C-H$_2$ symmetrical vibration
2866	m	CH$_3$ stretching band
2838	mw	C-H întindere
1730	vs	C-C ring vibration/C=O vibration
1452	vs	CH$_3$ symmetrical bending
1375	s	CH$_3$ symmetrical bending
1167	s	C-H motion lane
1102	s	CH$_2$ twist vibration
1044	s	CH$_2$ twist vibration
997	s	CH$_3$- movement vibration
972	vs	C-C stretching band
841	m	C-H motion lane

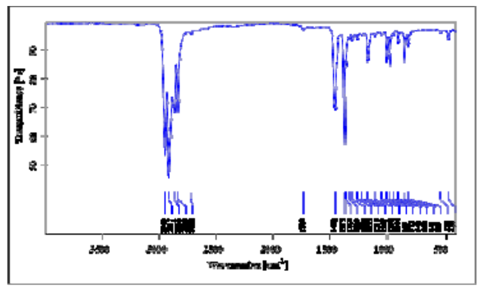

Figure 6. FTIR polypropylene (PP – white)

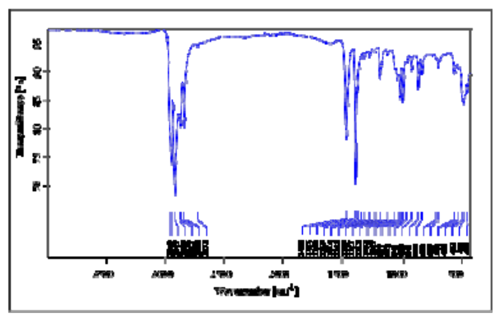

Figure 7. FTIR polypropylene (PP – black)

Table 2. Assignment of vibration bands for white PP

Wavenumber (cm^{-1})	Intensity	Assignment of vibration bands
FTIR		
2949	ms	C-H$_3$ asymmetric stretching vibration
2917	m	C-H$_2$ symmetrical vibration
2867	m	CH$_3$ stretching band
2838	mw	stretching C-H
1730	vs	C-C ring vibration/ C=O vibration
1453	vs	CH$_3$ symmetrical bending
1375	s	CH$_3$ symmetrical bending
1167	s	C-H movement band
1102	s	CH$_2$ twist vibration
1044	s	CH$_2$ twist vibration
997	s	CH3- stretching vibration
972	vs	C-C movement band
941	m	CH$_2$ symmetrical bending
899	m	CH$_2$ symmetrical bending
841	m	CH$_2$ symmetrical bending

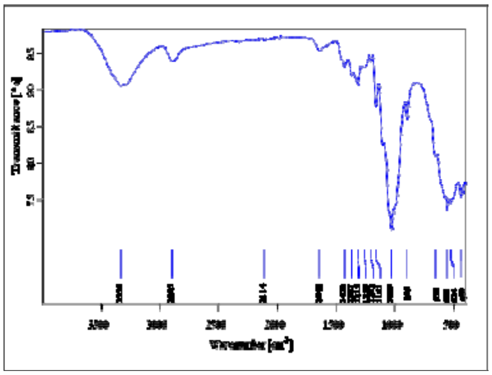

Figure 8. FTIR wood fiber (WF)

Table 3. Assignment of vibration bands for wood fiber (WF)

Wavenumber (cm^{-1})	Intensity	Assignment of vibration bands
FTIR		
3391	ms	hydroxyl group stretching
3330	ms	O-H stretching
3300	ms	O-H vibration
3276	ms	O-H absorption peak
3400	ms	O-H stretching vibration
2906	m	C-H stretching vibration
2896	m	C-H vibration
2890	m	CH_2 stretching vibration
1736	m	C=O stretching vibration
1642	m	C=O vibration
1640	m	C-O link strip
1604	m	C=C aromatic vibration
1516	m	C-H deformation
1419	m	CH2
1373	m	C-H deformation vibration
1372	m	C- H asymmetric
1312	m	OH bent
1258	m	C=C vibration
1238	m	C=O stretching vibration
1200	m	C-O stretching vibration
1157	m	C- O antisymmetric
1061	mw	C-O vibration
1029	mw	C-O stretching vibration
1026	mw	C- O- C skeletal pyranose ring
901	mw	C- H sucessive link
898	vs	β-glycosidic bond

2.2 Raman Spectroscopy

It is a spectroscopic technique used to observe the motion in a system like vibrational, rotational, and other low-frequency modes.
The spectroscopy is usefull to identify the molecules and to study the chemical bonds.

Experimentally, the Raman spectrum is obtained following well-established steps. At first the laser wavelength λ_0 is selected so that there is no fluorescence. The wavelengths of the scattered Raman radiation are measured and subsequently the intensity of the scattered radiation is graphically represented as a function of the Raman displacement, expressed in cm^{-1}.
Each maximum is attributed to an interatomic oscillation mode of chemical bonds and the Raman spectrum is unique for a given chemical structure, the technique being a non-destructive one.

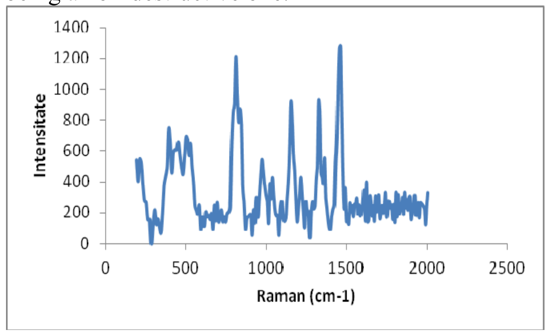

Fig.9 The Raman spectrum of white PP

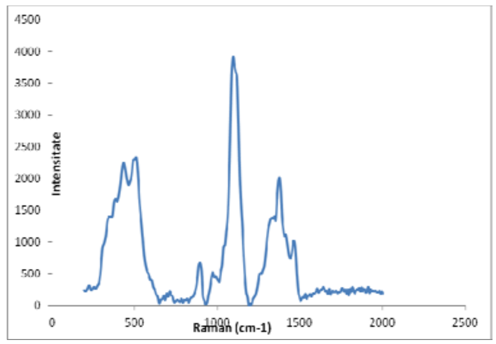

Figure 10. The Raman spectrum of wood fiber WF

2.3 Optical microscopy

The microscopies shown in figures 11-22, taken at different magnifications, were performed on both types of black and white polypropylene, representative being the microscopies in section.

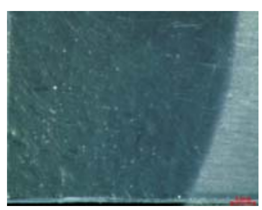

Figure 11. Microscopy front PP white 2x

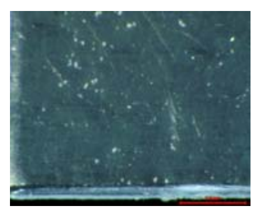

Figure 12. Microscopy front PP white 6x

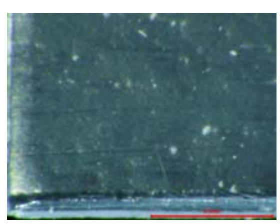

Figure 13. Microscopy front PP white 10x

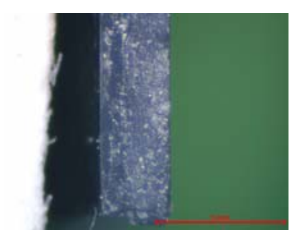

Figure 14. Microscopy in section PP white 10 x

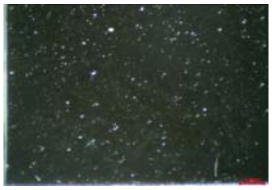

Figure 15. Microscopy PP black face 2x

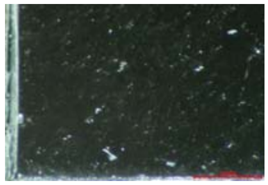

Figure 16. Microscopy PP black face 6x

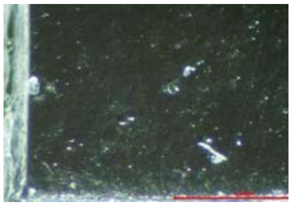

Figure 17. Microscopy PP black face 10x

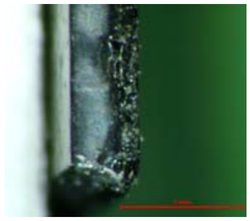

Figure 18. Microscopy in section PP black 10 x

Figure 19. Microscopy WF face 2x

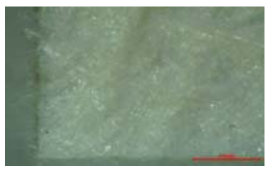

Figure 20. Microscopy WF face 6x

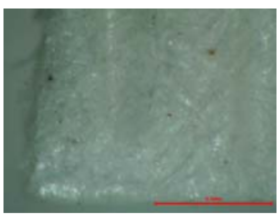

Figure 21. Microscopy WF face 10x

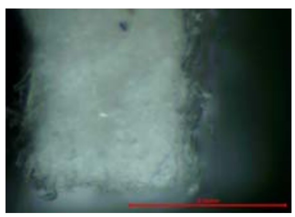

Figure 22. Microscopy in section WF 10 x

The four microscopes (figures 19-22) made on the wooden fiber casseroles, show the relatively homogeneous dispersion of the wood microfibers in the additive used to obtain the casseroles, as well as the random orientation of the fibers.

3. RESULTS AND DISCUTIONS

The study of the chemical composition and FTIR spectra was carried out on one sample of each material (polypropylene and wood fiber). Wood fiber casserole shows differences in the content of organic components such as cellulose, hemicelluloses and lignin.

More detailed characterizations of the polypropylene and wood fiber samples were carried out using Raman spectra and electron microscopy.

Both techniques (Raman spectroscopy and FTIR) are widely used methods for probing the molecular structure of the sample as a function of the interaction of photons with atomic bonds.
Black polypropylene is more effective than white polypropylene because it does not allow UV rays to penetrate and alter the quality of food. the obtained experimental results show that the samples analyzed do not contain in their composition toxic compounds harmful to health, they are resistant to food acids and alcohols, they are resistant from -10^0 C to +120 ^{0}C.
Black polypropylene can be used in the microwave oven, because no toxic compounds are released at food heating temperatures.

White polypropylene is translucent, environmentally friendly and non-toxic. The melting point is at 160^0 C, it has chemical resistance to corrosion, medium impact resistance and low resistance under the action of UV rays.

4. CONCLUSIONS

This paper presents the results of the comparative FTIR spectroscopic study of two types of materials, namely white and black polypropylene and cellulose wood fibers.

Plastic materials are used very frequently today, but they have a long period of over 500 years of resistance in the environment without decomposing. That is why the recycling and recovery of these materials at the end of the products' life has become an essential factor required by the EU.

Plastic packaging, and especially casseroles, are a threat to the environment, that is why new solutions are being sought to replace them, by creating new ecological, sustainable and environmentally friendly materials, composite materials with wood fibers, sugar cane, cotton fibers, etc.

Therefore, wood fiber is ecological, non-polluting, favorable and friendly to the environment and is an optimal option for avoiding the use of plastic materials.

REFERENCES

[1] M. Besson, P. Gallezot, and C. Pinel, “Conversion of biomass into chemicals over metal catalysts,” Chemical Reviews, vol. 114, no. 3, pp. 1827–1870, 2014.

[2] N. N. di Nasso, N. Roncucci, F. Triana, C. Tozzini, and E. Bonari, “Productivity of giant reed (Arundo donax L.) and miscanthus (Miscanthus × giganteus greef et deuter) as energy crops: growth analysis,” Italian Journal of Agronomy, vol. 6, no. 3, pp. 141–147, 2011.

[3] N. N. O. di Nasso, N. Roncucci, F. Triana, C. Tozzini, and E. Bonari, “Seasonal nutrient dynamics and biomass quality of giant reed (Arundo donax L.) and miscanthus (Miscanthus x giganteus Greef et Deuter) as energy crops,” Italian Journal of Agronomy, vol. 6, no. 3, pp. 152–158, 2011.

[4] Poletto, M., Ornaghi, H.L. and Zattera A.J. (2014) Native Cellulose: Structure, Characterization and Thermal Properties. Materials, 7, 6105-6119. https://doi.org/10.3390/ma7096105.

[5] Danial, W.H., Majid, Z.A., Muhid, M.N.M., Triwahyono, S., Bakar, M.B. and Ramli, Z. (2015) The Reuse of

Wastepaper for the Extraction of Cellulose Nanocrystals. Carbohydrate Polymers , 118, 165-169. https://doi.org/10.1016/j.carbpol.2014.10.072

[6] Popescu, M.C., Popescu, C.M., Lisa, G. and Sakata, Z. (2011) Evaluation of Morphological and Chemical Aspects of Different Wood Species by Spectroscopy and Thermal Methods. Journal of Molecular Structure , 988, 65-72. https://doi.org/10.1016/j.molstruc.2010.12.004.

[7] C.Pinzaru, S., Müller, Cs., Brezestean, I., Barchewitz, D., Glamuzina, B. Cyanobacteria detection and Raman spectroscopy characterization with a highly sensitive, high resolution fiber optic portable Raman system. Studia UBB Physica 2016b, 61: 99-108.

[8] Rusu M., Rusu D. L., Tehnologii de prelucrare a polimerilor, vol. I, Editura Dosoftei, Iași, 1995.

[9] Stănescu Paul O., Teodorescu D., Hubca Gh., Ambalaje polimerice pentru produse alimentare, Editura MATRIX ROM, București, 2010 .

[10] Tudose Z. R., Ibănescu I., Vasiliu M., Stancu A., Cristian Gh., Procese, operații și utilaje în industria chimică, Editura Didactica și Pedagogică, București, 1977;

[11] Sathishkumar TP, Navaneethakrishnan P, Shankar S, et al. Characterization of natural fiber and composites – a review. J Reinf Plast Comp 2013; 32: 1446–1465.

[12] Sathishkumar TP, Navaneethakrishnan P, Shankar S, et al. Characterization of new cellulose sansevieria ehrenbergii fibers for polymer composites. Compos Interfaces 2013; 20(8): 575–593.

[13] Mishra S, Mohanty AK and Drzal LT. Studies on mechanical performance of biofiber/glass reinforced polyester hybrid composites. Compos Sci Techno 2003; 63: 1377–1387.

[14] Salleh Z, Taib YM, Koay Mei Hyie, et al. Fracture Toughness Investigation on Long Kenaf/Woven Glass Hybrid Composite Due To Water Absorption Effect. Procedia Eng 2012; 41: 1667–1673.

[15] Rigoberto Burguen, Mario J, Quagliata, Amar K and Mohanty. Hybrid biofiber-based composites for structural cellular plates. Compos Part A 2005; 36: 581–593.

[16] Kushwaha PK and Rakesh Kumar. The studies on performance of epoxy and polyester-based composites reinforced with bamboo and glass fibers. J Reinf Plast Comp 2010; 29: 1952–1962.

[17] Marouf, A. & Momen, R.F. (2004). An evaluation of the permeability to phosphine through different polymers used for the bag storage of grain. Int. Conf. Controlled Atmosphere and Fumigation in Stored Prod. Gold-Coast Australia, FTIC Ltd. Publishing, Israel, ISSN 1021-9730.

[18] Lamberti, M. & Escher, F. (2007). Aluminium foil as a food packaging material in comparison with other materials. Food Rev. Intern. 23 (4): 407-433, ISSN 8755-9129.