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THERMAL AND STRUCTURAL ANALYSIS OF BIO-DEGRADABLE PLA-BASED NANO ALUMINUM FOILS FOR HEAT DEPOSITION

[1]R.Narmada,[2]K.Mounika
[12]Associate Professor
Department Of Mechanical Engineering
Sree Chaitanya College of Engineering, Karimnagar

Abstract:

The development of natural and biodegradable materials based on biodegradable food packaging materials is one of the largest global environmental issues of our time. But the waste problem may be at least somewhat resolved by employing bio-based packaging materials, such as food-grade or biodegradable films created from recycled materials. With the correct product selection and packaging method, goods may remain consistent and fresh for as long as they are promoted and used. Nevertheless, due to its subpar mechanical and gas barrier properties, the market's access to bio-based food packaging is limited. They use Ansys 2020 R1 in their investigation to look at thermal and structural research. The aluminium PLA aerofoils 3N, 6N, and 9N were examined, along with the 120C, 360C, 400C, and 500C applied temperatures. Finally, a comparison of the confirmed results.

Keywords: PLA, aluminium, biodegradable, ANSYS

I. INTRODUCTION

Food packaging should be able to assure the quality and safety of foods throughout the distribution chain. The main function of packaging applied to food is to preserve it from pathogenic microorganisms or chemical contamination, as well as from unfavorable environmental conditions (e.g., inadequate oxygen, carbon dioxide or moisture contents or presence of light) during storage and distribution [1]. Additional functions are also associated, such as energy and material costs, recyclability, sustainability, and disposability. In daily life, use of plastic materials in packaging has gone up extensively over the past three decades as most consumer and trade goods are encompassed with a packaging. It has also led to deposition of a colossal volume of plastic wastes in water bodies and also in landfills or municipal waste recovery sites, where their sorting and recovery are devouring both energy and money [2] [3]. It has further started to imperil living creatures. Detrimental effects of fossil fuel-based packaging wastes have increased the death toll of sea animals and birds Plastics can be recycled in lieu of being buried, but there are limitations with different types of plastic products [4].

Aluminum foil can even help create a home version of a low country boil or clambake. While it's downright indispensable in the kitchen, aluminum foil has plenty of uses in other parts of the house, too [5]. Here are some clever ways to use aluminum foil outside the kitchen that you may not have thought about before. Although aluminum foil is very thin, it has strong barrier properties, which can completely block light, gas and other substances, improve freshness and protect moisture, and prevent the leakage or mixing of flavors, which can effectively maintain the original flavor and characteristics of the product [7]. Foods and pre-packaged foods packaged in aluminum foil lunch boxes and containers can realize cold and hot chain distribution, which is convenient for production and sales, and is also convenient for catering companies, restaurants, supermarkets and families to store, avoid product deterioration, extend shelf life, and reduce food waste [6].

1.1 Aluminum foil

Aluminum foil is a thin type of metal that is typically coated in aluminum. Aluminum foil is useful because it's durable, light, strong, versatile, and can be easily recycled. It is used for cooking or heating up food but also as a lining for pans when they are washed. You can line the bottom of your pan with a sheet of aluminum foil to prevent spills or grease splatters when you pour your wet ingredients in [8]. It's often used to wrap leftovers or to make individual packets of convenience foods (like pot stickers

More than 90% of all food products now a days made packaged to maintain the temperature after cooking. The packaging not only protects the food from spoilage and contamination, but also often is chosen in order to improve the looks so that more people of the respective target group are drawn to the product. Aluminum has extremely high recyclability, and recycled aluminum can be used to produce many products. The energy required for the regeneration process of aluminum foil is only less than 5% of the energy required for the production of primary aluminum, and the greenhouse gas emissions are 95% less than that of primary aluminum [9]. The aluminum foil lunch box can be easily compressed after use, easy to sort, thereby reducing the amount of garbage. Even if the aluminum foil is buried, it will not pollute the soil and water. Compared with other resources, aluminum has abundant resource reserves, and the amount of recycled aluminum is continuously increasing, and the resource bottleneck is small. Aluminum foil is very thin and light. The thickness is usually 0.009-0.03mm, and the weight is only a few grams to 10 grams. It uses very few materials. It is the packaging material with the highest product-to-packaging ratio [10]. If aluminum foil lunch boxes and containers can be widely used and promoted, they can replace plastic and paper products, save a lot of resource consumption such as oil resources and wood, improve resource efficiency and improve environmental quality.

1.2 Significance of work and scope:

The technical parameters have to observe for more clarification on usage of NANO materials in films. In the future, the use of green composites to improve the dispersion and interfacial adhesion of PLA and carbon Nano materials would further enhance their performance. The development of an advanced single suitable and effective method to incorporate CNMs into PLA without losing the CNMs dispersed state (as in solution casting) is essential. By taking the advantage of PLA mixed with Nano's a biodegradable food-based packaging foils should develop with high strength is one of the enhanced research areas can be focused. In any case, there has been consistently expanding exertion in the advancement of various types of packing materials so as to upgrade their adequacy in keeping the nourishment quality with improved properties can be prepared.

1.3 Objective of the work

As a part of research biodegradable short fibers should be processed for packaging applications, even though fibers can be used for packaging applications a limited amount of PLA and Nano aluminum with base aluminum possess strength to the packaging foils. Food applications needed more tests for packing foils investigations need to improve in all types of properties such as mechanical, thermal and chemical. To check the mechanical and thermal enhancement in NANO addition in packaging films.

2.0 Literature Review

The food market demands new technologies, which are essential to keep market leadership in the food processing industry to produce fresh, authentic, convenient, and flavorful food products, prolonging the product's shelf life and freshness with improved quality food. Echegoyen Y, Nerin C [11] As a results, scientists and industry stakeholders have already identified potential uses of nanotechnology in virtually every segment of the food industry, from agriculture (e.g., pesticide, fertilizer or vaccine delivery; animal and plant pathogen detection; and targeted genetic engineering). According to Ali, S., W., Rajendran. [12] nanotechnologies are set to impact on the food industry at all stages of production from primary production at farming level, due to advances in pesticide efficacy and delivery (novel formulations and better crop adherence), to processing where emulsion creation and encapsulation have progressed to the nanoscale Borchert, n., b., kerry j [13] The most active area of food nanoscience research and development is packaging: the global nano-enabled food and beverage packaging market was 4,13 billion US dollars in 2008 and has been projected to grow to 7,3 billion by 2014, representing an annual growth rate of 11,65% Long, M., Wang, J., Zhuang, H., J. [14] Currently, food packaging represents the largest area of use of nanotechnology in food industry. Also, the area of food packaging has seen much innovation in barrier improvement with the use of various nanoscale fillers and this has also resulted in reduced effects of targeted accelerating factors of spoilage and contamination Patino, J., H., Luis [15] In their study, application of nanotechnology in food packaging was discussed. Moreover, nano packaging, nano composites, and nano sensors in intelligent packaging were presented. In this review, highlighted the promising approach to nano silver in packaging food Paula, E., L., Mano, V., [16] Moreover, zinc oxide, titanium dioxide, magnesium oxide nanoparticles were described. described an op to chemical CO2 sensor which uses a phosphorescent reporter dye phosphorescent Pt-porphyrin Pt TFPP and a colorimetric pH indicator -naphthol phthalein incorporated in plastic matrix together with a phase transfer agent tetraethyl- or cetyltrimethylammonium hydroxide. Pavelková, A. [17] presented chitosan-based carbon dioxide (CO2) indicator to monitor freshness or quality of packaged foods during their storage. For the enhancement of signal strength of indicator, 2-amino-2- methyl-1-propanol (AMP) was used as an additive to the chitosan solution. R. J. B., Marques [18] This new optoelectronic nose composed of seven sensing materials prepared by the incorporation of pH indicators and chromogenic reagents selective to metabolites into inorganic materials Rao, J., Mcclements, D.J. [19] the nose has been applied to monitor fresh pork sausage ageing. The results strongly suggest the potential feasibility of the use of colorimetric arrays as systems for easy, rapid and effective meat freshness assessment able to inform retailers and consumers about the safety state of the fresh pork sausages.

3.0 Research methodology

In food packaging, monolayer films cannot satisfy the entire requirement because different food commodities require different barrier and mechanical properties. Polymer nanocomposites are the latest materials aimed at solving this problem.

Materials used for Nano biodegradable foils

- Short fiber (coir natural fiber extractable glucose extraction)
- Alumina
- PLA 411
- Al2O3 Nano

3.1 Process of sample preparation

The PLA with inclusion of Starch mixture was pre-heated using a heating plate up to 50 degree Centigrade. The alumina Nano particles and chopped glass/carbon fibers of length 1-7 mm (termed as short fibers) with the variation of 1, 2, 3, 4, and 5 wt. % was considered for the open casting process. The respective particles and fibers were added separately into the resin in a 100 ml beaker with the aid of a mechanical stirrer running at 100 rpm for 4 h. To reduce the particle agglomeration by shear mixing process, the mixture was further homogenized at a relatively high stirring speed of 500 rpm for 30 min. For the hybrid composites; a constant amount of 2 wt. % alumina particles were added to the PLA-matrix mixture. After being sealed in a glass beaker, it was transferred to bath ultra-sonication (22 kHz in frequency, 55 % power intensity with a sweep mode) followed by probe ultra-sonication for 30 min to achieve the fine particle or fiber dispersion and degassed for 4 h at 75degree Centigrade.

Figure 3.4: Sample preparation process after mould pouring to compression rolling to get different thickness.

3.2 Material properties of foil with 60µm

S.no	Property	Value
1	Tensile -UTS (MPa)	30.61
2	Burst strength	Medium
3	Micro hardness (HV)	10.15

3.3 Simulation study- ANSYS 2022 R 1

Present work simulated for finite element thermal and structural analysis with temperatures 120C, 360C, 400C, 500C with structural load of 100, 200,300 gms. A uniform load distributed on 300x 300mm foil with the addition of thermal loads.

4.5 Static structural analysis Aluminum aero foils with different load conditions Minimum values

parameters	3N	6N	9N
Total Deformation	1.53	4.429	2.226
Equivalent Elastic Strain	3.8531	4.9781	0.
Shear Stress	0.226	0.208	0.

Table: Static structural analysis Aluminum aero foils Maximum and minimum Strain values

Force	Equivalent Elastic Strain (mm/mm) Maximum	Equivalent Elastic Strain (mm/mm) Minimum
3N	5.5611	3.8531e-004

6N	1.1757	4.9781e-004
9N	0.	0.

Table: Static structural analysis Aluminum aero foils Maximum and minimum Shear Stress values

Force	Shear Stress (hbar)Maximum	Shear Stress (hbar) Minimum
3N	0.29156	0.226
6N	0.62481	0.208
9N	0.	0.

4.6 Transient thermal Analysis:

Transient thermal analysis is the evaluation of how a system responds to fixed and varying boundary conditions over time. For fixed boundary conditions, the time to reach a steady state temperature can be evaluated, as well as how long operating conditions can be sustained before reaching a threshold temperature. For time-varying boundary conditions, transient analysis can show you the resulting thermal response of the system.

Figure: Applied Temperature 120C

Figure: Temperature 120C & Total heat flux

Figure: Thermal Error

4.8 Transient thermal Analysis Applied Temperature at 360C

Figure: Temperature 360C & Total heat flux

Figure: Thermal Error

4.9 Transient thermal Analysis Applied Temperature at 400C

Figure: Thermal Temperature 400C & Figure: Total heat flux

Figure: Thermal Error

4.10 Transient thermal Analysis Applied Temperature at 500C

Figure: Temperature at 500C & Total heat flux

Figure: Thermal Error

Table: Aluminum Aero foil different temperature variation

Applied Temperatures Aluminum aero foils	Temperature (^{0}C) Minimum	Temperature(^{0}C) Maximum
12^{0}C	12.	13.88
36^{0}C	33.383	36.
40^{0}C	36.639	40.
50^{0}C	44.785	50.

Table: Aluminum Aero foil different Total Heat Flux variation

Applied Temperatures Aluminum aero foils	Total Heat Flux (w/mm^2) Minimum	Total Heat Flux (w/mm^2) Maximum
12^{0}C	6.5377	7.5337
36^{0}C	9.1634	10.56
40^{0}C	11.784	13.58
50^{0}C	1.34	21.135

Table: Aluminum Aero foil different Thermal Error variation

Applied Temperatures Aluminum aero files	Thermal Error Minimum	Thermal Error Maximum
12^{0}C	4.1395e-022	9.3365
36^{0}C	3.8748e-021	18.369
40^{0}C	4.9137e-021	30.389
50^{0}C	7.7862e-021	73.655

5.0 CONCLUSION

Nanotechnology has opened up a world of possibilities for creative food packaging solutions that benefit businesses and consumers alike during the last ten years. Even at this early level of packaging material quality improvement, nanotechnology will provide significant advantages that will need continuous investment in nanotechnological applications in packaging materials. Nanotechnology may provide many advantages in terms of enhanced functional attributes that would make food packaging Food packaging must protect the food from physical damage as well as impurities like dirt and insects. Food packs must also have a variety of other attributes pertaining to the material's physical qualities, be easy to handle, and be able to discharge food. Furthermore, this study offered novel and efficient nanotechnology-based polymer materials for food packaging. Actually, polymer nanotechnology may be used to further develop and accomplish all of the primary goals of the package, including communication, marketing, preservation and protection, and confinement. In order to create new food packaging materials with improved mechanical, barrier, and antimicrobial qualities as well as the capacity to track and monitor the condition of food during storage and transportation, many of the largest food packaging companies in the world are actively looking into the possibilities of polymer nanotechnology.

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