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ORIGINAL RESEARCH ARTICLE

INVESTIGATION OF MECHANICAL PROPERTIES OF POLYPROPYLENE FILM AS VACUUM PACKAGING MATERIAL FOR DRIED FISH

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ABSTRACT

This study investigated the mechanical properties of three sets of polypropylene packaging films and existing dried fish packaging films and the quality of dried fish packaging in Nigeria... The polypropylene packaging films were produced in three batches A, B and C with thicknesses of 130µm, 150µm and 180µm respectively. The results showed that samples A, B and C had tensile strengths of 48N/mm^2, 51.8N/mm^2 and 61N/mm^2 with Elongation at Break of 690.2%, 729.8% and 760% respectively. Also, the Dart Impact Strength of the samples were observed to be 191g/130µm, 208g/150µm and 231g/180µm respectively. Additionally, samples N and K (existing fish packaging films) had tensile strengths of 34.6N/mm^2 and 31.2N/mm^2 and Elongation at Break of 279.2% and 267.2% respectively. Furthermore, it was revealed that sample N exhibited better mechanical properties than sample K, while the produced polypropylene packaging films had the best mechanical properties among the samples tested. Using modern systems such as vacuum packaging and modified atmosphere packaging (MAP) techniques, fish packaging and storage was improved. This research is important in light of the significant increase in aquaculture activities in Nigeria due to increased fish production and government intervention in developing the sector, since it offers good moisture barrier properties, transparency and sealability with good cost efficiency and recyclability.It helps to preserve and protect the product's quality, flavor and shelf life while providing a visually appealing package for consumers.

1.0 Introduction

The process of designing, manufacturing, and evaluating products and packages is known as packaging technology. This harmonized system of organizing goods for logistics, transportation, sales, and consumption as reported by Olayemi, (2012) is particularly important to the dried fish business in Nigeria, where inadequate packaging materials have been identified as a major problem (Folorunsho *et al.,* 2015). Research has shown that the films used for packaging dried fish in Nigeria are not strong enough to protect it against microbial infection, insect attack, and nutrient loss (Folorunsho *et al.,* 2015). Lack of quality dried fish production and poor marketing have been exacerbated by this trend. Therefore, it is essential to investigate the appropriate dried fish packaging films with improved mechanical properties (Izzhati *et al.,* 2018). Mechanical strength is one of the main factors considered when selecting fish packaging films (Adejumo, 2013) due to the shape and spines of dried fish (Ainara *et al.,* 2019). Commonly used packaging films include polypropylene, polyamide (nylon), low-density polyethylene (LDPE), high-density polyethylene (HDPE), polyester, polyethylene terephthalate (PET), polyvinyl, and cellulose (Agnieszka, 2018). However, the films currently used in Nigeria do not demonstrate sufficient strength and properties to protect dried fish from mechanical and environmental damage (Fakunle *et al.,* 2018). To guarantee quality and safety for dried fish consumers, it is necessary to prioritize the production of effective packaging films. Beniamino *et al.* (2020) noted that a good packaging film can also be regarded as a silent seller of its product.

Polypropylene is better than other packaging films because of its low density, light weight, and cost-effectiveness, thus making it a suitable option for drying fish. However, the selection of the right packaging films for dried fish should not be based solely on availability and cost, but also on other important factors such as mechanical abrasion and puncture resistance (Vilasia and Gabriel 2019). The use of improper packaging materials may lead to nutritional loss, endangerment of consumers and insect infestation (Zuzana, 2017). The mechanical properties of packaging films can be altered by taking into consideration the nature of the product it would be enclosing and adjusting the processing parameters accordingly (Suryakanta, 2015). Interestingly, the increasing global population and inadequate food resources, coupled with protein deficiency, necessitate the use of methods to extend the shelf life of dried fish (Nuray, 2017). For example, Vacuum packaging is used to protect the dried fish from the effects of environmental factors and microorganisms, as well as maintain its original colour, taste and flavour (Nicolas and Claire, 2019). Vacuum packaging works on the principle that microorganisms such as mould and yeast require oxygen for survival, thus when the oxygen concentration in the packaging is less than 1%, microorganism growth and reproduction rate will drop significantly (Nuray, 2017). The use of polypropylene film as a packaging material offers several advantages including its barrier property against moisture, transparency and recyclability but also come with some environmental considerations. Its suitability depends on the specific products and packaging requirements. This study, therefore, seeks to investigate the mechanical properties of polypropylene films for packaging of dried fish, by testing and comparing them with existing packaging films.

2.0 Materials and Methods

The polypropylene packaging film was produced by Green Gold Technology Nigeria limited, Niger state based on the supplied specifications for this research purpose. Using the Cast film extrusion method, melted resin was extruded horizontally through a flat-shaped die forming a thin film held to some extremely refined chilled rollers via air curtains. Extra chill rollers were employed to rapidly cool the film before trimming to size and rolling the produced films.

2.1 Mechanical Tests Method for Polypropylene Film

The following mechanical tests were carried out on the film samples;

2.1.1 Tensile Strength and Percentage Elongation at Break Test

The experiment to determine the tensile strength and percentage elongation at break of three batches of produced polypropylene packaging films and existing dried fish packaging films was conducted at Green Gold Technology Nigeria Limited, Minna, Niger State. ASTM D 2990 and

NIS 835:2017 standards were adopted for the packaging films (ASTM, 2018). The thickness of all samples was measured using micrometre screw gauge, and the length and width were measured using a metre rule. To conduct the test, the samples were cut into dumb bell shapes of 85 mm length and 25 mm width, and loaded into the tensile grips (Figures 1 and 2). The grips were moved at a constant speed while the machine recorded the varying distance between them and the force applied. Once the specimen failed, the tensile strength and percentage elongation at break were noted from the indicator. This process was repeated for all three sets of samples and existing dried fish packaging films, and conducted in five replicates. Figure 3 shows dumb bell shaped specimens from a set of samples of the produced polypropylene packaging film.

Figure 1: Tensile Strength Machine with Load indicator attached

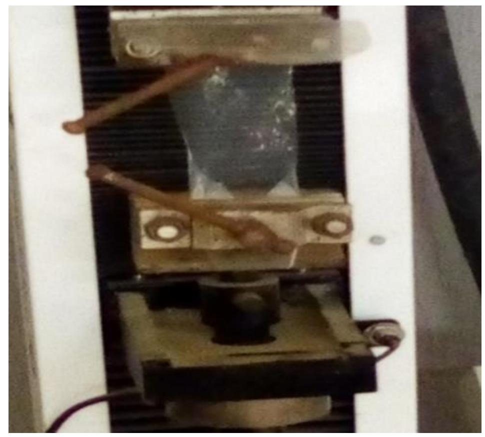

Figure 2: A Specimen held by the upper and lower grips of tensile strength machine during testing

Figure 3: Dumb bell-shaped specimen from a set of samples of Produced polypropylene film ready for testing

2.1.2 Dart Impact Strength Tester

The dart impact strength test for the three batches of polypropylene packaging films, as well as existing dried fish packaging films, was conducted according to the NIS 835:2017 standard for standard packaging films. The polypropylene packaging film sample was firmly attached to the disc with screws, and the dart weight was dropped onto it. This was repeated nine more times, each with a new sample. The mass of the dart weight at 50% failure of the sample was recorded and expressed as the mass at which the sample failed per the thickness of the sample (g/μm). The same tests were conducted in five replicates on ten samples from each set of polypropylene packaging films and existing fish packaging films.

2.1.3 Drop Impact Resistance Test

The drop impact resistance test was conducted on both the produced polypropylene packaging films and existing dried fish packaging films using the standard procedure in accordance with the method adopted from NIS 835:2017 for standard packaging films. The test load (Ballast) was placed in the polypropylene packaging film (sample) according to the dimensions of the film, and it was gently deflated before closing its mouth with an appropriate closing system (sealing) at about 100mm from the mouth. The filled polypropylene packaging film was then placed on the trap of the testing machine so that its bottom was 1.20m ± 0.01m above the smooth test surface. The film was dropped once and inspected for tears or rupture before the test loads were removed. Pass or fail results were recorded for each sample. This process was repeated for 30 produced polypropylene packaging films and the existing dried fish packaging films, and the test was conducted in five replicates.

2.1.4 Coefficient of Friction Test

The Coefficient of Friction test was conducted in accordance with ASTM D 1894, adopted from NIS 835:2017, to evaluate the performance of three batches of produced polypropylene packaging films and existing dried fish packaging films. The samples were taped to the plate and sled and attached to a load cell on the testing machine actuator via a rope that ran through a pulley. The rope was then pulled at a constant rate and the load at which the sample started to move was recorded graphically. The testing stopped once the designated sliding distance had been achieved and the static and kinetic Coefficient of Friction values were then calculated.

2.2 Vacuum Packaging of Dried Fish Using Produced Polypropylene Films

The Product Development and Engineering Department of the National Institute for Freshwater Fisheries Research (NIFFR) in Kainji, Niger State, carried out vacuum packaging of dried fish using the produced polypropylene films. Three sets of samples were used to package the dried fish, with six packages in each set.

3.0 Results and Discussion

3.1 Mean Values of Mechanical Properties of Produced Polypropylene and Existing Packaging Films

The mechanical properties of polypropylene packaging films and existing fish packaging films were investigated and the mean values for each sample were determined. Five replicates of each sample were conducted, and the results are presented in Table 1.

Table 1: Mean Values of Tested Parameter of Mechanical Properties of Produced Polypropylene and Existing Dried Fish Packaging Films

S/ N	Tested Parameter	Produced Polypropylene Packaging Film			Existing Dried Fish Packaging Film	
		Sample A	Sample B	Sample C	Sample N	Sample K
1	Thickness (µm)	130	150	180	140	130
2	Length (mm)	340	340	340	320	300
3	Width (mm)	300	300	300	285	260
4	Tensile Strength (N/mm^2)	48	51.8	61	34.6	31.2
5	Elongation at Break (%)	690.2	729.8	760	279.2	267.2
6	Drop Impact Resistance	Pass	Pass	Pass	Pass	Fail
7	Dart Impact Strength (g/µm)	191/130	208/150	231/180	143./140	133/130
8	Coefficient of Friction	MD^a=0.15 TD^b=0.15	MD^a=0.15 TD^b=0.15	MD^a=0.15 TD^b=0.15	MD^a=0.15 TD^b=0.15	MD^a=0.10 TD^b=0.19

Where,

MD= Machine direction; TD = Transverse direction; a=longitudinal: direction parallel to extrusion direction; b=transverse: direction perpendicular to extrusion direction

Table 1 depict that the produced polypropylene packaging films have higher tensile strength and elongation at break compared to the existing dried fish packaging films which agrees with the findings of Saber and Mohamed (2019). Sample C has the highest tensile strength of 61 N/mm^2 and elongation at break of 760%, while Sample K has the lowest tensile strength of 37.2 N/mm^2 and elongation at break of 511%. The comparison of these mechanical properties show that the produced polypropylene packaging films are more robust and reliable due to their high tensile strength and elongation as against the existing dried fish packaging films.

The mechanical properties of the produced polypropylene packaging films and existing dried fish packaging films were tested. The results showed that the produced polypropylene packaging films demonstrated higher tensile strength and elongation at break. Sample K of the existing dried fish packaging films showed the lowest dart impact strength, burst during the drop impact resistance test and had different coefficient of friction values for machine direction (MD) and transverse direction (TD). Abdurrahman *et al. (*2015) strongly emphasized that packaging film should be selected based on their mechanical performance. The investigated mechanical properties of produced polypropylene packaging films and the existing dried fish packaging films proved that the produced samples had better mechanical strength as demonstrated during the various tests conducted. The produced polypropylene packaging films samples demonstrated different tensile strength and elongation at break. The difference in this mechanical strength is due to the difference in thickness of the packaging films and will address the findings of Agomuo *et al.* (2017). This study also provides solutions to some of the challenges stated by Folorunsho *et al.* (2015) and one of the recommendations made by Abolagba and Akise (2011), which suggested that other fish packaging materials be developed while existing ones improved to avoid fish spoilage and reduce cost.

The dart impact strength of the produced polypropylene packaging films confirm the suitability of the films for dried fish packaging most especially its high resistance to puncture. Such packaging films can withstand the spines of dried fish, mechanical damage and environmental factors as established by Omnexus (2020). The existing dried fish packaging film (sample K) has lower dart impact strength compared to the produced film which is in line with report by Ales *et al.* (2017). None of the produced polypropylene packaging films samples ruptured during the drop impact resistance test which suggests that the package can survive drops or any accidental falls during handling and transportation. Unlike the existing dried fish films, sample KCoefficient of friction (COF) for all samples were similar except, for sample K. Although, various packaging operations requires different COF hence the outcome of the study agrees with Ljevak *et al. (*2018).

3.2 Packaging of Dried Fish Using Single Chamber Vacuum Packaging Machine

The three set samples of the produced polypropylene packaging films were used to package dried fish using single chamber vacuum packaging machine. Six packages from each set of samples were selected. Figure 4 shows packaged dried cat fish and cod fish (stock fish) in produced polypropylene packaging films.

Figure 4: Vacuum Packaged Cat Fish and Cod Fish (Stock Fish) in Produced Polypropylene Packaging Films

4.0 Conclusions

This study examined the mechanical properties of newly-produced polypropylene packaging films for vacuum packaging of dried fish using three sets of samples. Similarly, the mechanical properties of the produced polypropylene packaging films were compared to those of existing dried fish packaging films. The following conclusions were drawn:

i. Suitable standardized polypropylene packaging films with superior mechanical properties for dried fish packaging were produced.
ii. The produced polypropylene films also exhibited similar Coefficient of Friction for the three sets of samples, with MDa =0.15 and TDb =0.15.
iii. The produced polypropylene packaging films exhibited sufficient mechanical strength in comparison to the existing dried fish packaging films.
iv. Based on the results of the study, the produced polypropylene packaging films demonstrated better mechanical properties than the existing dried fish packaging films.

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