AUTEX 2022 Conference Proceedings 978-83-66741-75-1

DOI: 10.34658/9788366741751.72

MELT SPINNING OF POLYPROPYLENE (PP) MULTIFILAMENTS YARNS: EFFECT OF MYRRH RESIN ON MULTIFILAMENT YARNS PROPERTIES

Evaldas Bolskis[1(*)], Erika Adomavičiūtė[1], Egidijus Griškonis[2]

[1] Faculty of Mechanical Engineering and Design, Kaunas University of Technology, Studentu Str. 56, Kaunas, Lithuania
[2] Faculty of Chemical Technology, Kaunas University of Technology, Radvilenu pl. 19, Kaunas, Lithuania
[(*)] *Email:* evaldas.bolskis@ktu.edu

ABSTRACT

Melt-spinning is the most widely used polymeric multifilament yarn production method. It's easy to scale and it is highly productive. Using this method can be formed multifilament yarns with various functionalities, using additives. The aim of this research is to investigate the formation of melt-spun multifilament polypropylene (PP) yarns modified with 10% ethanolic myrrh resin extract. In this study, multifilament yarns were successfully formed from PP with a myrrh resin by melt-spinning at two different drawing ratios (1.5; 2.5). It was indicated that processing parameters have a significant influence on the multifilament linear density (tex), tenacity (cN/tex) and tensile strain (%). Modification of PP with ethanolic myrrh extract has a significant influence on the mechanical properties of the melt spun multifilament yarns.

KEYWORDS

Polypropylene, melt-spinning, myrrh resin, multifilament yarns.

INTRODUCTION

Fibrous materials have already been successfully used for many years in a variety of applications (medical, electronic, packing, etc.) due to their functional performances, offered by modified engineered fibers and filament yarns [1]. Melt-spinning is one of the most widely used processes compared to wet or dry-spinning to produce polymeric filaments. The melt-spinning process is productive and cost effective yarns formation process [1–5]. There are two main advantages of melt-spinning: 1)solvents do not need to be used in the production of polymer yarns 2), it is possible to use additives and form multicomponent yarns with various functionalities [6,7].

The formation of multifilament yarns with the melt spinning process can use two or more polymers of different chemical composition [7]. The important process variables of melt spinning are extrusion temperature; mass throughput per spinneret hole; cooling conditions; size and shape of the spinneret holes; spin line length and take-up velocity of the filaments, or filament drawing ratio. These process variables influence the structure and properties of melt-spun filaments [8,9].
Many polymers can be used in melt-spinning processes, such as polyesters, polyurethanes, polyolefins, polyamides, and biopolymers [7].

PP is a strong, nonbiodegradable, thermoplastic material. The high thermal stability of PP makes it suitable for medical parts that have to be frequently sterilized, which require relatively high temperature treatments. It is suitable for a good thermostability used for medical applications. PP sutures, hernia meshes have good resistance, stability, and low-tissue reaction [10–12].

Natural compounds from plants demonstrate antibacterial, antifungal, and antioxidant activity.

One of them is myrrh resin, which has long been used as a medicine and wound dressing. It has good antimicrobial effects. Compositionally, myrrh consists of alcohol-soluble resins (25–40%), volatile oils (3–8%) and a water-soluble gum (30–60%) [13–16].

In a previous study[17], was estimated possibility of forming PLA biodegradable multifilament yarns with high concentration pine rosin was estimated. The aim of this research is to investigate the possibilities of forming melt-spun multifilament PP yarns with 10% myrrh resin. To investigate the influence of myrrh extract on the PP melt spinning process, at different drawing ratios were analyzed. In this investigation, the influence of myrrh extracts on the structure and mechanical properties of PP melt-spun yarns were investigated.

MATERIALS AND METHODS

Materials

Polypropylene (PP) granules which grades is H253 FF/3 was purchased from (Sibur International GmbH, Vienna, Austria). This type of PP granules are intended for the production of multifilament yams. Myrrh resin was imported from India (Ekokolekcija, Vilnius, Lithuania).

Methods

Preparation of myrrh ethanolic extract and modification of PP granules are the same conditions and procedure as described in previous work [18]. The modification procedure was repeated four times, while bicomponent PP/Myrrh extract granules of 90/10 wt/wt were formed.

Multifilament yarns of pure PP and PP/Myrrh resin were manufactured by single screw extruder equipment COLLIN® CMF 100 (Dr. Collin Gmbh, Germany) with seven heating zones, where the temperature during the experiments was set to 220 °C. The average extruder speed was set to 29 rpm. Circular spinnerets with 24 holes (diameter 0.45 mm) were used during these experiments. Cooling of the filaments achieved with cross-flow air quenching at a temperature of 14 °C. The temperature of the stretching rolls was as follows: S1 – S4 = 75 °C in all experiments. Multifilament yarns from polymers were formed changing melt-spinning parameters. Which are given in Table 1.

Table 1. Parameters for the spinning step to obtain multifilament yarns.

Code	Samples	Stretching rolls linear speed m/min				Drawing ratio
		S1	S2	S3	S4	
A	PP	100	116	139	150	1.5
B	PP + 10% Myrrh					
A1	PP	100	150	204	251	2.5
B1	PP + 10% Myrrh					

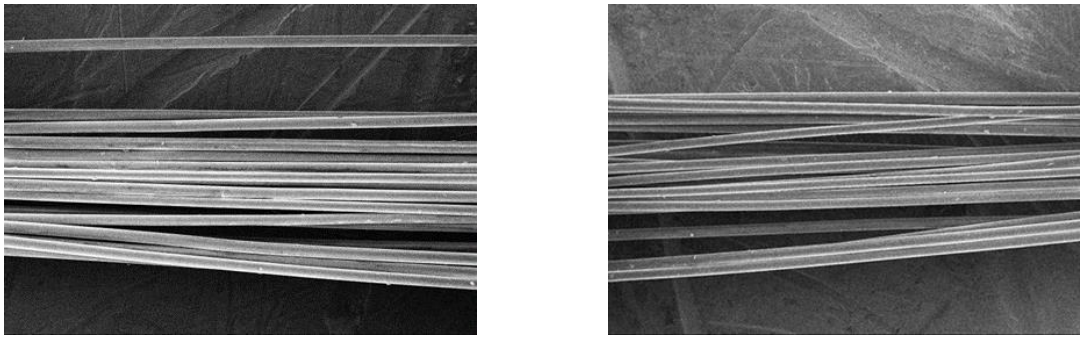
Methods of estimation of linear density and multifilament yarn mechanical properties

The linear density of the yarns was measured based on the previous work method [18]. The structure of PP multifilament yarns was determined using a scanning electron microscope SEM S-3400N (Hitachi, Tokyo, Japan (beam voltage: 3 kV, magnification: 50×, scale bar: 1 mm)). The diameter of the fiber was evaluated using SEM images and the software NIS-Elements D (Nikon Corporation, Tokyo, Japan). Mechanical properties (tenacity (cN/tex) and tensile strain (%)) of PP and PP/Myrrh multifilament yarns were determined according to the EN ISO 2062:2009 standard. Universal testing equipment Zwick/Roell (Zwick GmbH & Co. KG, Germany) with the testXpert® operating program was used. The length between the clamps was 100 mm and the stretching speed was 500 mm/min and a pretension of 0.5 cN/tex. The number of tensile tests for the package was 35.

RESULTS AND DISCUSSION

Were successfully formed PP and PP modified with myrrh extract multifilament yarns by melt-spinning process. From the images presented in Figure 1 it is possible to state that modification of the PP granules with myrrh (Figure 1b) do not have a visual influence on the yarn surface – there are no cracks or myrrh derivatives.

Linear density, tensile tests on the formed polymeric multifilament yarns were analysed in order to determine how the mechanical properties were influenced by the presence of 10% myrrh resin in PP when multifilament yarns were formed at 1.5 and 2.5 drawing ratio (DR). Data of linear density (tex), mechanical properties: tenacity (cN/tex), and tensile strain (%) of pure polymers PP and PP/Myrrh resin multifilament yarns are presented in Table 2 and the typical stress–strain curves are presented in Figure 2.



(a) **(b)**

Figure 1. SEM images of (a) multifilament PP yarns formed at 2.5 draw ratio; (b) PP with 10 % myrrh resin multifilament formed in the 2.5 draw ratio.

Table 2. Mechanical properties of the formed multifilament yarns.

Code of sample	Linear density of multifilament yarns (tex)	Tenacity, (cN/tex)	Tensile strain, (%)
A	96.9 ± 1.6	9.1 ± 0.4	651.1 ± 46.8
B	85.2 ± 2.1	9.5 ± 0.3	562.9 ± 37.5
A1	54.9 ± 1.1	14.1 ± 0.4	413.0 ± 25.0
B1	50.2 ± 1.2	15.9 ± 0.5	277.0 ± 15.6

The linear density (tex) of multifilament yarns PP yarns depends on the technological parameters of melt spinning, the viscosity of melt. The increase of drawing ratio from 1.5 to 2.5 resulted in approximately 40% decrease of melt spun yarns linear density. Modification of PP with 10% ethanolic myrrh extract has an influence on multifilament yarns linear density too. Linear density of PP/Myrrh yarns at DR 1.5 decrease approximately 12%, at DR 2.5 - 9%.

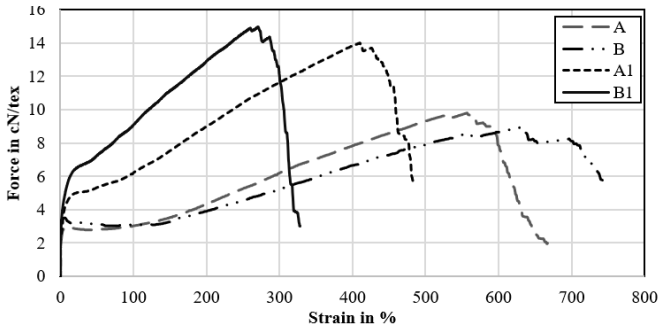


Figure 2. Typical stress–strain curves of the multifilament yarns formed A – pure PP – DR = 1.5; B – PP/Myrrh -DR=1.5; C - pure PP DR=2; D - PP/Myrrh DR=2; E – pure PP DR=2.5; F PP/Myrrh DR=2.5.

Analysing mechanical properties of melt spun yarns were investigated tenacity (cN/tex) and tensile strain (%) of pure PP and PP with myrrh resin extract. When the drawing ratio increased from 1.5 to 2.5, tenacity of multifilament yarns increased approximately 1.7 times. Significant influence of myrrh resin modification on PP was notice analysing tenacity of multifilament yarns at DR 2.5. - tenacity increase approximately 13%. The draw ratio had a significant influence on the properties of the melt-spun yarn due to changes in the microstructure (polymer alignments and crystallinity) and mechanical properties [9]. It can presume, that myrrh resin increase the PP chain's mobility, which improves multifilament yarns drawability. When drawing ratio increase from 1.5 to 2.5, tensile strain pure PP multifilament yarns decrease approximately 37% (A and A1) and 51% (B and B1) modified PP multifilament yarns. Comparing results at the same drawing ratio indicated that multifilament PP with myrrh yarns have an approximately 14% (DR 1.5) and 33% (DR 2.5) lower tensile strain nor pure PP . This can explain slightly increased molecular orientation in PP polymer [19].

CONCLUSION

Multifilament yarns from pure PP and PP with myrrh were successfully melt-spun. It was estimated that the increase of draw ratio from 1.5 to 2.5, had influence on tenacity and tensile strain of yarns. Multifilament yarns at higher drawing rate have 35-40% higher tenacity and 37-50% lower tensile strain. PP multifilament yarns with 10% myrrh extract have slightly higher (about 13%) tenacity and lower (14-33%) tensile strain nor pure PP multifilament yarns. It is possible to state, that myrrh resin increases PP drawability.

ACKNOWLEDGMENT

E.B. would like to thank the Research Council of Lithuania for funding their PhD studies.

REFERENCES

[1] Naeimirad M., *Melt-spun PLA liquid-filled fibers: physical, morphological, and thermal properties*, J. Text. Inst. 2019, vol.110, pp. 89–99, doi:10.1080/00405000.2018.1465336.

[2] Park S.J., *Melt-spun shaped fibers with enhanced surface effects: Fiber fabrication, characterization and application to woven scaffolds*, Acta Biomater. 2013, no 9, pp. 7719–7726, doi:10.1016/j.actbio.2013.05.001.

[3] Pawar S.H., *Applications of transition metal nanoparticles in antimicrobial therapy*, Biomaterials and Tissue Engineering Bulletin 2017, no 3, pp. 28–34.

[4] Reifler F.A., *Polymer optical fibers for textile applications - Bicomponent melt spinning from cyclic olefin polymer and structural characteristics revealed by wide angle X-ray diffraction*, Polymer (Guildf). 2014, vol. 55.

[5] Feng X., *The effects of polymer carrier, hot melt extrusion process and downstream processing parameters on the moisture sorption properties of amorphous solid dispersions*, J. Pharm. Pharmacol. 2016, vol. 68, pp. 692–704, doi:10.1111/jphp.12488.

[6] Miranda C.S., Ribeiro A.R.M., Homem N.C., Felgueiras H.P., *Spun biotextiles in tissue engineering and biomolecules delivery systems*, Antibiotics 2020, no 9, doi:10.3390/antibiotics9040174.

[7] Hufenus R., Yan Y., Dauner M., Kikutani T., *Melt-spun fibers for textile applications*, Materials (Basel). 2020, no 13, pp. 1–32, doi:10.3390/ma13194298.

[8] Krikštanavičienė K., Stanys S., Jonaitienė V., *Dependence of Polypropylene Yarn Mechanical Properties on Manufacturing Parameters*, Mater. Sci. 2014, vol. 20, doi:10.5755/j01.ms.20.3.4138.

[9] Gajjar C.R., Stallrich J.W., Pasquinelli M.A., King M.W., *Process-Property Relationships for Melt-Spun Poly(lactic acid) Yarn*, ACS Omega 2021, no 6, pp. 15920–15928, doi:10.1021/acsomega.1c01557.

[10] Tsioptsias C., *Polypropylene nanocomposite fibers: A review of current trends and new developments*, J. Plast. Film Sheeting 2021, vol. 37, pp. 283–311, doi:10.1177/8756087920972146.

[11] Adomavičiūtė E., *Formation and characterization of melt-spun polypropylene fibers with propolis for medical applications*, J. Text. Inst. 2018, no. 109, pp. 278–284, doi:10.1080/00405000.2017.1341295.
[12] Radheshkumar C., Münstedt H., *Antimicrobial polymers from polypropylene/silver composites-Ag+ release measured by anode stripping voltammetry*, React. Funct. Polym. 2006, vol. 66, pp. 780–788.
[13] Al Alamoudi H.A., Salem A.A., *Application of myrrh extract as an eco-friendly dye and antimicrobial agent on wool and silk fabrics part 1: Dyeing with myrrh extract*, J. Nat. Fibers 2019, no 16, pp. 1006–1014, doi:10.1080/15440478.2018.1447417.
[14] El-S., *Green synthesis of densely dispersed and stable silver nanoparticles using myrrh extract and evaluation of their antibacterial activity*, J. Nanostructure Chem. 2013, no 3, pp. 1–7, doi:10.1186/2193-8865-3-8.
[15] Auda S.H., *Antimicrobial evaluation of novel buccoadhesive films containing Myrrh extract*, Polym. Bull. 2017, vol. 74, pp. 4041–4054, doi:10.1007/s00289-017-1946-x.
[16] Alminderej F.M., *Study of new cellulosic dressing with enhanced antibacterial performance grafted with a biopolymer of chitosan and myrrh polysaccharide extract*, Arab. J. Chem. 2020, no 13, pp. 3672–3681,
[17] Bolskis E., *Formation and Investigation of Mechanical , Thermal, Optical and Wetting Properties of Melt-Spun Multifilament Poly(lactic acid) Yarns with Added Rosins*, Polymers, 2022, doi.org/10.3390/polym14030379
[18] Bolskis E., Adomavičiūtė E., Griškonis E., Norvydas V., *Influence of Myrrh Extracts on the Properties of PLA Films and Melt-Spun Multifilament Yarns*, Materials (Basel). 2020, no 13, doi:10.3390/ma13173824.
[19] Lee S.H., Youn J.R., *Properties of polypropylene/layered-silicate nanocomposites and melt-spun fibers*, J. Appl. Polym. Sci.2008, vol. 109, pp. 1221–1231, doi:https://doi.org/10.1002/app.28222.