

Comparison of Release Characteristics of Polyethylene Monofilament LN and Polypropylene Multifilament LN

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Abstract: Objective of the study is to compare the retention/release of active ingredient by polyethylene monofilament LN and polypropylene multifilament LN. Alpha-cypermethrin (5.0 g/kg ± 25%) incorporated polyethylene and polypropylene LNs were manufactured using 120 denier high-density polyethylene monofilament yarns and polypropylene multifilament yarns 120 denier (24 filaments each 5 denier), respectively. PE and PP LNs manufactured were sampled according to WHO protocol to determine alpha-cypermethrin contents and within net distributions. The nets were washed with 2 g/L of *Savon de Marseille*. Both PE and PP nets have retention index > 95% on application of free migration stage behaviour model. After 25 washes, the PE net retained 88% alpha-cypermethrin while the PP net retained only 33% with respect to initial concentration. That is, depletion of alpha-cypermethrin with respect to the initial concentration (wash-0) is higher in the case of PP net than the PE net. As active ingredient and additives remain the same in both the nets higher depletion of active ingredient from PP nets should be due to smaller radius of individual filaments in the PP multifilament yarns. Moreover, the higher void volume in polypropylene comparing to polyethylene might be an additional factor enhancing the depletion of the active ingredient from the PP LN.

1. BACKGROUND: It is important to understand the retention/release of the active ingredient from the polymer matrix to decide loading (concentration) of active ingredient and other additives so that the LN fulfills WHOPES criteria with respect to washing and has sustained bio-efficacy after washings. Polyethylene monofilament LN and polypropylene multifilament LN are compared for the release/retention of alpha-cypermethrin. The two LNs differed only their polymer matrix whereas all the other constituents remained identical.

2. MATERIALS AND METHODS:

- ❖ **Alpha-cypermethrin master batch** containing 15% active ingredient was used.
- ❖ **Polyethylene (PE) monofilament yarn (120 denier)** was extruded after mixing HDPE granules with the master batch to attain the target concentration of 5 g/kg.
- ❖ **Polypropylene (PP) multifilament yarn (120 denier, 24 yarns each 5 denier)** was extruded after mixing polypropylene granules with the master batch to obtain the target concentration 5 g/kg.
- ❖ **PE and PP LLINs** were made by warp knitting the yarns.
- ❖ **LLINs were sampled** according to WHO protocol for determination of active ingredient concentration.
- ❖ **Nets samples were washed** with 2 g/L of *Savon de Marseille* and three samples of size 25 cm x 25 cm were used for each wash stage.
- ❖ **Alpha-cypermethrin concentration (AS content)** was determined in gas chromatography (GC) using diethyl phthalate as internal standard after extraction from the nets in refluxing xylene (CIPAC method 454/LN/ M2.1 & 3.2 (GC-FID)). Average of duplicate injections was taken to determine AS content of each sample.
- ❖ Agilent GC System 7890A with Auto Sampler 7693 was used.

3. RESULTS:

Table 1. ACM Content

No.	ACM Content (g/kg)	
	PE	PP
1	5.63	4.71
2	5.61	4.59
3	5.57	4.56
Mean	5.60	4.62

Table 2. ACM within net distribution

No.	ACM Content (g/kg)	
	PE	PP
1	5.68	4.32
2	5.61	4.57
3	5.48	4.67
4	5.52	4.78
5	5.64	4.71
Mean	5.59	4.61
Std. Dev	0.075	0.160
RSD(%)	1.338	3.473

All total alpha-cypermethrin content determinations are mean of dual chromatographic injections.

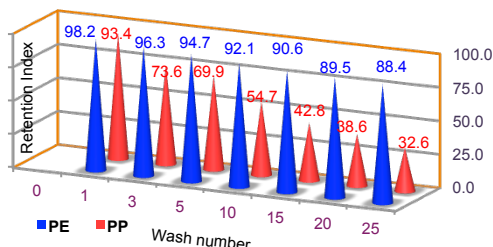


Fig 1. Retention of ACM with respect to initial concentration

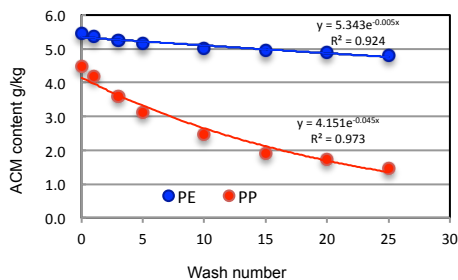


Fig 2. Wash Curve

Table 3. Wash resistance - Free Migration Stage ($\sqrt[n]{t_n / t_0}$)

Wash	1	3	5	10	15	20	25
PE	98.2	98.8	98.9	99.2	99.3	99.4	99.5
PP	93.0	93.0	93.1	94.1	94.5	95.3	95.6

1. Retention index of alpha-cypermethrin at each wash stage on applying free migration stage behaviour is >95% for PE and ≥ 93% for PP nets.
2. However, depletion of active ingredient with respect to wash-zero (initial concentration) is higher in PP nets.
3. The results are comparable to the results of Small Scale Collaborative Trial (CIPAC 4828/R) on four different LNs.
4. In the report CIPAC 4828/R: After five washes active ingredient content of the PP net reduced to 64.7% (varied from 50.3 to 86.8 among the five laboratory results).
5. Phase-2 trial of Lifenet® also indicates depletion of higher amount of active ingredient after 20 washes. It varied from 62% to 76% and the average is 67% (Report of the Fourteenth WHOPES Working Group Meeting).

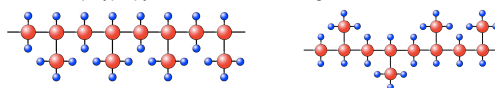
4. DISCUSSION

- ✓ Applying Fick's Laws of diffusion, the rate of diffusion J,

$$J = \frac{\text{Diffusivity} \times \text{Concentration gradient}}{\text{Thickness of filament}}$$

As diffusion is inversely proportional to thickness more active ingredient molecules migrate to the surface of a multifilament yarn than to that of a monofilament yarn.

- ✓ Diffusion of vapours in a polymer depends on the polymer structure, plasticisers and other adjuvants.
- ✓ Polypropylene is more amorphous than high density polyethylene (HDPE) and PP has more void space for vapours to diffuse.
- ✓ Polypropylene has isotactic and atactic structures and amorphous nature of polypropylene is due to atactic regions.



Isotactic

Atactic

- ✓ Density of PP is ≈ 0.9 g/cm³; Density of HDPE is >0.94 g/cm³



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