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# Investigating the performance of polyester microfibers *in situ* bags using different weft yarn count and density

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**ABSTRACT.** Microfiber fabrics are more efficiency in retaining fine-particles that increase the variation in *in situ* degradability. The aim of this was to examine the performance of *in situ* bags made from different microfiber fabric for meeting the required specification and their ruminal degradability compared with standard Ankom *in situ* bags. Four fabrics were manufactured using polyester microfiber with 1.04 denier, weft yarn counts (150 and 300), weft density (22 and 28 picks / inch), plain 1/1 textile structure. Physical and mechanical properties of manufactured fabrics were measured before and after incubation. Ruminal degradability was measured for three feedstuffs (soybean meal, wheat bran and berseem hay) using three rumen-fistulated rams as a replicates after 24 and 48 hours. Fabric's pore size was significantly decreased as either yarn weft count or density increased. Yarn weft count had a significant effect on all fabric's properties. Air permeability was significantly decreased as fabric's weft yarn count increased. Sample (1) meet the specific requirements for *in situ* bags and showed the nearest degradability values to those observed using Ankom bags for all feedstuffs in most incubation times. Microfiber *in situ* bags could be used in *in situ* ruminal degradation trials to reduce the variation in results due to the present of the fine particles.

**Keywords:** ankom bags; fabric; feedstuffs; incubation; nutrient; pore size.

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## Introduction

*In situ* technique is one of the most important methods used for feed evaluation. It could provide useful information about the rate and extent of nutrient degradation inside the rumen, which enables the formulation of a synchronous least cost rations for better feed utilization (Bogoro, Kalla, & Gaiya, 2006; Khadem, Pahlavan, Afzalzadeh, & Rezaeian, 2007; Aboamer et al., 2015; Aboamer et al., 2017).

Several works evaluated *in situ* bags made from different textile materials (Valente, Detmann, & Sampaio, 2015). In addition, a standard protocol has been introduced by the Nordic feed evaluation system recommended to use polyester bags with 38 µm of pore size (Saatifil PES 38/31, manufactured by Saatitech, Como, Italy). However, the mostly used bags manufactured by ANKOM Technology have 50 ± 10 µm porosity and are available with two sizes (5 cm x 10 cm-R510 and 10cm x 20cm-R1020) for concentrates and roughage, respectively.

Since, *in situ* degradability depends mainly on the efflux of digested feed particles from the pores of the bags, the results were highly affected by bags, pore size, cloth type, weave pattern and bag dimensions (Adesogan, 2005; Valente et al., 2011; Valente et al., 2015). The most effect is the overestimation of feed degradability which was observed due to loss of undigested fine particles from bags pores (Mabjeesh et al., 2000; Wilman & Adesogan, 2000).

Fabrics pores include the spaces (pores) between fibers in the yarns and also the space between two yarns (Babaarslan & Hacıogullari, 2013). Number of parameters affects the pores of the fabrics. Both yarn density and yarn thickness are factors affecting the dimensions of the pores (spaces) between yarns. There is an inversely proportion between the yarn density and dimensions of pores. Increasing yarn density produces a smaller dimension of fabric pores (Babaarslan & Hacıogullari, 2013). All these properties make the filtration efficiency of fabrics made from microfiber higher than traditional fabrics.

Microfiber fabrics are stronger and durable compared with other fabrics of similar weight. In addition, microfibers are non-electrostatic, super-absorbent, absorbing over seven times their weight in water and they dry in one-third of the time of ordinary fibers (Babaarslan, 2013).

There is no previous research studied the performance of *in situ* bags made from microfiber fabrics and their effect on ruminal degradability of feeds. The aim of this work was to: 1) manufacture *in situ* bags using polyester microfibers with two different variables employed, weft yarn count (150 and 300 deniers per filament) and density (22 and 28 picks / inch), 2) investigate fabric ability to meet performance requirements before and after incubation in rumen, and 3) compare the dry matter digestibility values of some dairy feedstuffs using the manufactured bags with Ankorm *in situ* bags (ANKOM SKU: R510, and ANKOM SKU: R1020).

## Material and Methods

### Manufacturing of polyester microfibers bags

An innovative idea was done, and its main purpose was providing a scientific study for the production of these textile bags at the local level. In this study, polyester microfiber with 1.04 denier, warp count (150 denier, weft yarn counts (150 and 300 Deniers), warp density (30 picks / inch), weft density (22 and 28 picks / inch), plain 1/1 textile structure were used to manufacture four samples of fabric. The weft yarn count of samples 1 and 2, and 3 and 4 were 150 and 300 deniers, respectively. While, the weft density of the samples 1 and 3, and 2 and 4 were 22 and 28 (picks/inch), respectively, as shown in Table 1.

**Table 1.** Fabric's constructional parameters.

Sample No.	Warp count (denier)	Weft count (denier)	Weft density (picks / inch)	No. of filaments per yarn	Denier per filament	Fabric cover factor	Fabric weight (g m <sup>-2</sup> )	Fabric Thickness (mm)
1	150	150	22	144	1.04	17.9	97	0.21
2		150	28	144	1.04	19.3	115	0.24
3		300	22	288	1.04	19.9	145	0.27
4		300	28	288	1.04	22	165	0.29

### Laboratory tests

Laboratory tests were done to examine the performance of the manufactured samples for meeting the required specification of *in situ* bags before and after incubation.

Two measurements of mechanical properties were conducted using universal testing machine, tensile strength was applied according to Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method) using ASTM D5035; and tear strength was applied according to Standard Test Method for Tearing Strength of Fabrics by the Tongue (Single Rip) Procedure (Constant-Rate-of-Extension Tensile Testing Machine) using ASTM D2261, while air permeability was performed according to Standard Test Method for Air Permeability of Textile Fabrics using ASTM D737. Three replicates were measured for two laboratory tests: Breaking load and Elongation and Air permeability in both directions warp and weft and the average values were taken, while in tear strength tests three replicates were measured, the five highest peak forces for each replicate were calculated and the average values for the fifteen reading were calculated.

### In vitro trial

The nylon bag technique as described by (Ørskov, Hovell, & Mould, 1980), was applied for degradability coefficients determination to study the performance of manufactured bags in field. *In situ* trials were conducted using three of cannulated rams (50.60 ± 3.05 kg of body weight) at the Marryot Research Station, Desert Research Centre, Ministry of Agriculture, 35 km south of Alexandria, Egypt. Rams were fed at maintenance level 40:60 concentrate to roughage as replicates. The dry matter degradability was determined for three feedstuffs; two sources of concentrates (soybean meal and wheat bran) and one roughage source (berseem hay). Feed samples were grinded to 2 mm before incubation in the rumen for 24 and 48 hrs. Feed samples (1.5 - 2 and 3.5 - 4 g for concentrates and roughages, respectively) were inserted into a previously weighted, clean, dry and numbered bag, then,

incubated in the rumen at 1 hour after the morning feeding. After incubation, the bags with residues were taken out of the rumen, dipped immediately into cold water to stop microbial activity, then washed under running cold water until the water was clear, after which the bags were drained, dried for 72h at 60°C, cooled in a desiccator and weighed. The solubility or washing loss at 0 hour was defined as weight loss after soaking the bags, with the substrate, for 1 hour in water at 38°C then washing and drying in a similar way. The ruminal disappearance rate of tested feed at each individual incubation time was calculated as the difference between the contents in the initial samples and the residues remaining after incubation in the rumen and expressed as a percentage of the content of the initial sample. In order to study the effect of incubation and frequently drying and washing on the physical and mechanical properties of the bags, new bag was used for each feed sample.

### Scanning electron microscope (SEM)

SEM was done for samples using a scanning electron probe micro analyzer (type T-scan–Czech Republic). The sample was cut at size about 1\*1 cm, sample sections were stained with Chrome in an individual instrument. The SEM samples were labeled using indelible marker in order to be identified, and then the specimens were put inside the scanning electron microscope to be measured. The surface morphologies for samples were imaged at different magnifications (2000x, 3000x), using 5kV accelerating voltage.

### Statistical analysis

Results were reported based on the mean values of observation with their standard error of means. ANOVA Two-way Repeated Measurements were used to statistically analyze the differences in fabrics' physical and mechanical properties before and after incubation using SPSS, version 24 (SPSS, 2016). Differences in *in situ* ruminal degradability were statistically analyzed using One-way ANOVA and means compared using Tukey HSD test. The level of significance was at P value=0.05.

## Results

### Physical and mechanical properties of manufactured fabrics

Table 1 represents the constructional parameters of the manufactured samples. Increase yarn weft count produce higher thickness fabrics. Sample 4 had the highest fabric thickness (0.29, mm). The physical and mechanical properties of the manufactured samples before and after incubation in the rumen are presented in table 2. Data show that, manufactured *in situ* bags had a wide range for fabrics pore size (30.0 – 72.7,  $\mu\text{m}$ ). Fabric's pore size was significantly affected by both yarn weft count and density ( $p < 0.001$ ) with no significant interaction ( $p = 0.089$ ). Fabric's pore size was decreased as increasing either weft yarn count or density. Sample 4 had the lowest fabric pore size. In contrast, sample 1 had largest pore size (72.7  $\mu\text{m}$ ) with lowest weft count and density.

In general, the effect of yarn weft count was significant for all fabric's properties. Tensile strength for both weft and warp directions were increased as increasing yarn weft count, while the rate of increase was greater for weft direction. However, their effect on tensile elongation differed. As yarn weft count increased, tensile elongation was increased for the warp direction ( $p < 0.05$ ). However, it decreased at weft direction. Also, tear strength was affected by increasing weft count. It was decreased at the warp direction, while markedly increased at the weft direction ( $p < 0.001$ ). Both air and water permeability were decreased as increasing yarn weft count ( $p < 0.001$ ). However, the rate of decay of air permeability was markedly higher than of water permeability.

On the other hand, both tensile strength and elongation at the weft direction were significantly improved as increasing yarn weft density. However, at the warp direction, the tear strength was decreased. Furthermore, both air and water permeability were remarkably decreased by increasing yarn weft density ( $p < 0.001$ ).

In general, all measured fabric's properties were significantly affected by incubation in the rumen ( $p < 0.02$ ). As shown in Table 2, incubation had a negative effect on the tensile strength of sample 2 for both weft and warp directions, while other samples were not affected.

In addition, tensile elongation for warp direction was increased after rumen incubation for all samples. Also, incubation was significantly affected by fabric's tear strength for weft direction. The weft tear strength was significantly increased for sample 2 while, decreased for sample (4).

The air permeability of sample 2 was dramatically decreased after incubation ( $p < 0.05$ ). However, other samples did not affected.

**Table 2.** Fabric's physical and mechanical properties.

Item	Sample No.	Weft Count (denier)	Weft density (picks / inch)	Incubation		SEM	P value			
				Before	After		W	D	I	I*W*D
Pore size ( $\mu\text{m}$ )	1	150	22	72.7		1.03	<0.001	<0.001		
	2		28	42.1						
	3	300	22	53.5						
	4		28	30.0						
Warp tensile strength (N)	1	150	22	751.8	500.1	9.50	0.001	0.036	<0.001	0.587
	2		28	742.0	585.1					
	3	300	22	810.7	621.1					
	4		28	853.2	694.6					
Warp tensile elongation (%)	1	150	22	25.3	57.0	0.96	0.004	0.061	<0.001	0.470
	2		28	29.7	38.7					
	3	300	22	36.0	55.7					
	4		28	43.0	46.0					
Weft tensile strength (N)	1	150	22	490.3 <sup>a</sup>	477.3 <sup>a</sup>	10.96	<0.001	<0.001	<0.001	0.014
	2		28	686.5 <sup>b</sup>	503.4 <sup>a</sup>					
	3	300	22	925.1 <sup>c</sup>	823.8 <sup>c</sup>					
	4		28	1245.4 <sup>d</sup>	1167.0 <sup>d</sup>					
Weft tensile elongation (%)	1	150	22	27.7	53.3	0.77	<0.001	0.019	0.015	0.163
	2		28	38.0	32.7					
	3	300	22	24.0	33.7					
	4		28	31.3	18.7					
Warp tear strength (N)	1	150	22	42.4	66.5	0.61	0.042	<0.001	<0.001	0.586
	2		28	34.2	64.8					
	3	300	22	40.8	62.5					
	4		28	31.9	62.4					
Weft tear strength (N)	1	150	22	39.4 <sup>b</sup>	42.7 <sup>b</sup>	0.41	<0.001	0.782	<0.001	<0.001
	2		28	32.1 <sup>a</sup>	60.1 <sup>d</sup>					
	3	300	22	61.4 <sup>d</sup>	61.4 <sup>d</sup>					
	4		28	64.9 <sup>d</sup>	48.7 <sup>c</sup>					
Air permeability ( $\text{cm}^3/\text{cm}^2.\text{sec}$ )	1	150	22	26.7 <sup>d</sup>	26.5 <sup>d</sup>	0.08	<0.001	<0.001	<0.001	<0.001
	2		28	17.2 <sup>c</sup>	8.7 <sup>b</sup>					
	3	300	22	8.1 <sup>b</sup>	7.3 <sup>b</sup>					
	4		28	1.9 <sup>a</sup>	1.6 <sup>a</sup>					
Water permeability (L/sec.)	1	150	22	1.5		0.03	<0.001	<0.001		
	2		28	1.2						
	3	300	22	1.4						
	4		28	0.5						

<sup>a-d</sup>Means with different superscripts differ ( $p < 0.05$ ). I= Effect of Incubation. <sup>1</sup>Probability of significant effect due to the weft yarn count (W), density (D), and their interaction ( $I \times W \times D$ ).

### ***In situ* DM degradability coefficients**

Table (3) represents the *in situ* DM degradability coefficients for the some commonly used feedstuffs using both manufactured *in situ* bags and standard Ankom bags. For all feedstuff, no significant difference was observed for either DM washing loss or ruminal degradability after 24 hours between sample 1 and Ankom bags. However, sample 1 had a slightly higher value for *in situ* ruminal degradability after 48 hours compared with Ankom bags.

Sample 4 had the lowest ruminal degradability for all feedstuffs. Samples 2 and 3 had approximately the same values of ruminal DM degradability for all feedstuffs, but they were significantly lower than observed for Ankom bags.

### **Scanning electron microscope (SEM)**

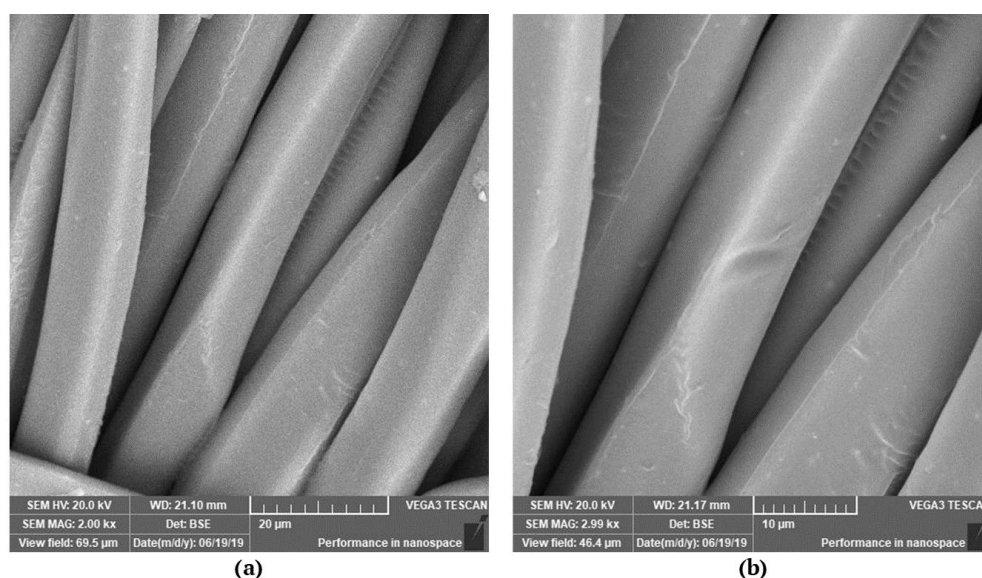
SEM was done for sample 1 before and after incubation, it was magnified in 2000 and 3000 X. Figure 1 show number of fibers with smooth surface before incubation and after washing. Figure 2 show the sample

after incubation and the feedstuff particles on the surface of the fabric due to exposing the sample in the incubation conditions (oven- humidity- temperature-strength).

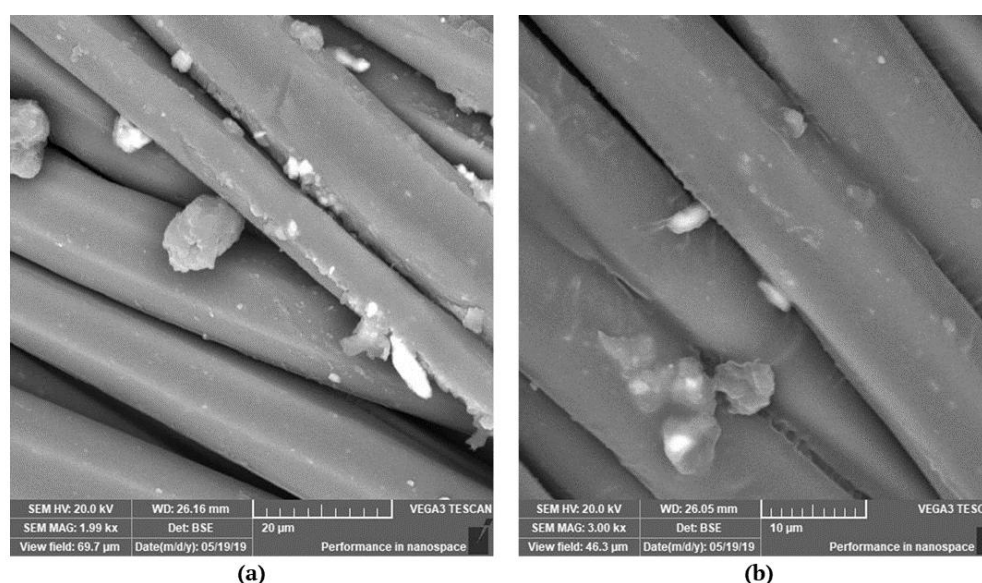
**Table 3.** *In situ* dry matter degradability of selected feedstuffs.

Feedstuff	Incubation time (h)	DM degradability, %				Ankom bags	SEM	Pvalue
		150		300				
		30*22	30*28	30*22	30*28			
		Samples No.						
		1	2	3	4			
Soybean meal	0	20.9 <sup>bc</sup>	18.1 <sup>b</sup>	24.3 <sup>c</sup>	10.8 <sup>a</sup>	19.7 <sup>bc</sup>	1.28	<0.001
	24	70.2 <sup>c</sup>	53.5 <sup>b</sup>	56.0 <sup>b</sup>	44.1 <sup>a</sup>	72.2 <sup>c</sup>	2.88	<0.001
	48	97.4 <sup>d</sup>	66.1 <sup>b</sup>	62.8 <sup>b</sup>	50.2 <sup>a</sup>	82.2 <sup>c</sup>	4.39	<0.001
Wheat bran	0	21.1 <sup>b</sup>	15.6 <sup>a</sup>	12.6 <sup>a</sup>	14.0 <sup>a</sup>	22.7 <sup>b</sup>	1.12	<0.001
	24	69.5 <sup>b</sup>	62.7 <sup>a</sup>	59.7 <sup>a</sup>	61.0 <sup>a</sup>	68.4 <sup>b</sup>	1.13	<0.001
	48	74.8 <sup>c</sup>	71.2 <sup>abc</sup>	72.7 <sup>bc</sup>	65.5 <sup>a</sup>	68.2 <sup>ab</sup>	1.01	0.004
Berseem hay	0	18.3	16.6	17.7	17.1	15.3	0.46	0.290
	24	56.2 <sup>b</sup>	46.4 <sup>a</sup>	45.3 <sup>a</sup>	42.3 <sup>a</sup>	59.7 <sup>b</sup>	1.85	<0.001
	48	61.6 <sup>c</sup>	61.3 <sup>c</sup>	58.8 <sup>bc</sup>	45.3 <sup>a</sup>	56.5 <sup>b</sup>	1.63	<0.001

<sup>a-d</sup>Means with different superscripts differ ( $p < 0.05$ ).



**Figure 1.** SEM for sample (1) before incubation at X2000 (a) and X3000 (b).



**Figure 2.** SEM for sample 1 after incubation at X2000 (a) and X3000 (b).

## Discussion

The obtained results show that, fabric thickness was increased as yarn weft count increased. Sample (1) had the most suitable fabric thickness. The yarn weft count and the weft density for sample (1) were 150 deniers and 22 picks / inch, respectively. Previous work conducted by (Al-ansary, 2012) reported that, microfiber fabrics are more thickness than traditional fabrics due to increase the number of filaments per yarn. The total number of *in situ* bags incubated in the rumen at one time is limited which make it difficult to be removed, so increasing the thickness of *in situ* bags could make the removal of bags from the rumen more difficult and then decreasing the number of bags incubated in rumen at one time could be required.

On the other hand, fabrics' pore size had been decreased as increasing both yarn weft count and density. Manufactured *in situ* bags samples 2 and 3 met the recommended pore size, while sample 2 had lower pore size than recommended. Although, the fabric pore size of sample 1 was higher than samples 2 and 3, it produced the most nearest values of ruminal degradability to that observed using the standard Ankom bags. In addition, samples (2 and 3) had pore size within the recommended range (42.1 and 53.5  $\mu\text{m}$ , respectively), but they underestimate the ruminal degradability. So, it could be suggested that, the recommended range might be slightly increased when microfiber *in situ* bags is used. That may be due special characteristics of the microfiber fabrics as larger surface area, spaces between filaments, and thickness. Also, lower air and water permeability as increase fabric thickness might provide a stable fermentation condition, while reduce the finer particles escaped from *in situ* bags. The washing loss after zero hour of incubation represents the rapidly or instantaneously degraded fraction (Aboamer et al., 2017) that is highly affected with feed particle size and fabric's pores (Ørskov et al., 1980). Adesogan (2005) observed an underestimation of *in situ* degradability due to the fine particles that pass through bags' pores. Kuwahara, Souza, Ferreira, Costa, and Meirelles (2016) reported significant differences in *in situ* DM degradability between samples of alfalfa ground into three different particle size especially at the initial periods of incubation.

In contrast, sample 4 does not meet the required specifications for *in situ* bags. The very small pores and more fabric thickness prevent air and water from passage through fabrics. These factors might prevent the colonization and digestion of feed particles by ruminal microbes (Vanzant, Cochran, & Titgemeyer, 1998).

On the other hand, *in situ* bags should withstand the incubation and laboratory conditions. Obtained results showed adverse effects on samples 2 after incubation. The weft tensile strength was significantly decreased after incubation, giving a greater possibility for losing feed particle due to fabric damage. In addition, the significant increase in the weft tear strength (32.1 vs. 60.1, N) may be due to accumulate of feed particles between the fibers of yarn which lead to a significant decrease in air permeability (17.2 vs. 7.3  $\text{cm}^3\text{cm}^{-2}\cdot\text{sec}$ ).

## Conclusion

Microfiber fabrics had a greater surface area, filtration efficiency and high ability to retain fine feed particles compared to traditional fabrics. Using microfiber *in situ* bags may be useful to reduce the variation in *in situ* results that occur due to the present of the fine particles after the grinding feeds. Manufactured microfiber *in situ* bag (sample 1) had the nearest degradability values to those observed using Ankom bags.

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