Fragrance Durability Depending on Compression of Knitted Fabric Bandage Coated by Microcapsule Contained Cinnamon Essential Oil

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Abstract. Functional fabric was one of textile targets. Microencapsulation was the good method to develop the different functional textile product including the aroma therapy textile using the natural essential oil. However, the odor is a psychophysical phenomenon so the evaluation of fragrance durability of fabric treated by natural essential oil was always the subject of many researches. In this paper the fragrance durability of the interlock fabric treated by the microcapsules contained the cinnamon oil was investigated. The research had carried out on three kinds of interlock fabric with the different loop lengths. The fabrics were prepared by chief value cotton (CVC) yarn (60% cotton and 40% polyester). The influence of the compression of the knitted fabric bandages on their fragrance intensity had been investigated. The results showed that fabric fragrance intensity was decreased slower when using the microcapsules contained cinnamon oil as the fragrance agent compared to the direct use of cinnamon oil. Moreover, the fragrance intensity of knitted fabric bandage was kept more important under smaller compression exerted by the fabric bandage extension.

Keywords: Fragrance durability · Microcapsules · Knitted fabric · Essential oil · Compression garment

1 Introduction

Functional garment are the textile products with high-added value textile structures and products. Knitted fabric has great advantages in functional textile especially in the medical field because of their loose structure, high flexibility and porosity [1]. Moreover, the different structures of knitted fabric can be varied to meet different requirements in the medical field. So knitted fabrics were considered very suitable for medical textiles, especially high-tech medical textiles. This opens new field of combination of knitting technology and healthcare medical science. Weft-knitted fabric were found divers application in medical sector includes medical dressings, bandages, padding of medical mattress, clothes for surgery and some high-tech products. According to their application, medical textiles are divided into non-implantable, implantable, extra-corporeal textiles

I. A. Parinov et al. (Eds.): *Physics and Mechanics of New Materials and Their Applications*, SPM 20, pp. 34–45, 2023. https://doi.org/10.1007/978-3-031-21572-8_4

and healthcare and hygiene products. Healthcare textile products were used commonly in using the knitted fabrics.

Knitted interlock fabric has high elasticity modulus and stable structure when stretching along the transverse direction. The interlock fabric was considered to generate edge-roll. Weft interlock stitch medical dressings may be used as bioactive dressings for the application of biological materials when they contain bioactive substances as microcapsule with the core of oil essential, that obtains the great attention specially. In the medical textile field, the compression garments were first used in sportwear to improve blood flow, reduced muscle oscillation and reduced muscle injury. Then the compression garments were applied in different biomedical textile targets such as operational reasons, like in the case of tight-fitting garments or girdles, medical reasons, like medical stockings or bandages in the treatment of venous ulceration, deep vein thrombosis or burns. Depending on the kind of therapy, the range of pressure values is determined from the medical aspect. The most important factor for the compression garment was determined pressure to the body, that in many cases, involved to the developing measurement utilized the Laplace law [3–5]. The research had designed the compression sleeves [3]. The results showed that garment pressures of the compression sleeves designed based on the Maklewska Laplace law within the scope of the required pressure value and the deformation could be used for designing the compression sleeves accurately. On the other hand, the formula of Leung Laplace law was not suitable for designing the compression sleeves because the sizes of the compression sleeves which were calculated based on this formular were too small to put on. The calculation of the bandage pressure in venous leg ulcers was investigated by Jan Schuren and Kay Mohr [4]. The research was carried out with the data from three studies including 744 compression bandages applied to artificial legs. The measurements were taken and were compared to the pressure transducers of theoretical compression forces calculated by a modified Laplace's law equation which predicts graduated compression ranging from 27 to 72 mmHg at the ankle, tapering to 18–8 mmHg below the knee. The studies showed that calculations using this equation do not reliably predict actual measured sub-bandage pressures. Macintyre had designed the pressure garments capable of exerting specific pressures on limbs [5]. Author found that the kind of the fabric and the circumference would influence on the pressures calculated by Laplace equations as these formular would need to be established for each fabric separately. Moreover, the results showed that the human limbs with mean circumferences less than 25 cm was small and the pressure exerted cannot be predicted using the Laplace Law. However, with the cylinder models of circumference greater than 30 cm, the Laplace Law could accurately predict the pressures exerted by pressure garment.

Microencapsulation was the modern technique that found largely in the biomedical textile application [6–12]. Microcapsules were small particles that contain an active agent in a polymer material surrounded. The active substance inside the microcapsule is called a core material whereas the material surrounded is called a shell or membrane. Usually, microcapsule size may be between a few micrometres and a few millimetres. The active agent inside the microcapsule could be delivered through their membrane. The liberation is influenced by the different factors such as pore membrane dimension, the temperature, pH and the external force such as compression. Many applications of microcapsule were found in textile field such as Aroma/Fragrant Textiles, antimicrobial

Textiles, insect/Mosquito Repellent Textiles, medical Textiles, Cosmetic Textiles. The antibacterial and wound healing textile band using the St. John's Wort oil and flax seed oil capsulated with Arabic gum was reported [7]. The microcapsule contained the parfum active substances were developed [8, 9]. The modelling drug delivery mechanisms for microencapsulated substances applied on textile was reported [10]. Moreover, the essential oil, used as aroma therapy, was the subject of many researches in the encapsulation for textile used [12–15]. The microcapsules were prepared by complex coacervation technique using the natural gum as wall material [13]. Basil oil, lemongrass oil, orange oil and tea tree oil were used as the active substance in the microcapsule core. Cotton fabric was padded by microcapsule gel and the curing optimisation condition was at a temperature of 80 °C and a time of 60 s [13]. Then the fragrance intensity of the cotton fabric sample padded by the microcapsule contained the essential oil during the washing cycles were investigated. The results showed the fabric samples retained aroma until 30 wash cycles and as the number of wash cycles increased the intensity of aroma decreased. Stan et al. had examined the deposition by padding of microcapsules contained the rose and sage essential oil on woven textile structures, with different fiber compositions (100% cotton and 50% cotton/50% polyester) [15]. In order to improve the durability of microcapsule fixation onto the fabric against external factors, a commercially acrylate-based binder was used. The SEM image showed the presentation of the microcapsule in the fabric surface and the quantity of the microcapsules was lower after five washing cycles in comparison to these ones before washing that led to conclusion as the woven fabric treatments with microcapsules contained rose and sage oil withstood five washing cycles so the washing durability considered acceptable. The authors also reported that air permeability and water vapor permeability of the investigated fabric samples met the minimum requirements for skin contact clothing articles and home clothing (min 30 L/m^2/s for permeability to air and min 25% for water vapor permeability).

Microencapsulation so was found as a good technique for package of essential oils for aroma therapy textiles. However, the influence of the fabric characteristic on the maintained of fabric fragrance was not reported and the liberation of the active substance depending on the fabric compression mechanism was seldom studied, that were the scoop of this research.

2 Experimental Part

2.1 Materials

Interlock fabrics: there were three kinds of interlock knitted fabrics, which were prepared with the different loop lengths (Table 1).

Fragrant argents: The pure cinnamon essential oil from Vietessianc (Vietnam) and the microcapsules contained pure cinnamon essential oil provided by 05/2012/HĐ-NĐT project (Vietnam) were used as fragrant agents in the research. The microcapsules were prepared by solvent evaporation method. The RSPO Eudragit was the microcapsule membrane. Their average size was about 40 μm (Fig. 1).

Preparation of the fragrant fabric samples: Every kind of investigated interlock fabric was cut by 6 samples with dimension 5 × 5 cm^2 to have 18 small samples for 3 kinds fabric. 1 mL of pure cinnamon essential oil was applied to the surface of every of

Table 1 Technical parameters of the investigated interlock fabrics

Fabric code	Material	Yarn count	Horizontal density (stitches/100 mm)	Vertical density (stitches/100 mm)	Loop length 100 stitches (mm)
IT1	60% Cotton 40% PE	Ne 40/1	150	180	235
IT2			150	160	252
IT3			150	140	275

the nine fabric samples and 1 mL of solution of microcapsules contained the cinnamon essential oil was coated evenly to the surface of the nine prepared fabric samples. Here the calculation showed that the quantity of cinnamon oil presented in 1 mL microcapsule was 0.004 mL. Then all 18 fabric samples had put into the refrigerator at temperature of 2 °C and at 20% of relative humidity for 24 h, that process aimed to harden the microcapsules.

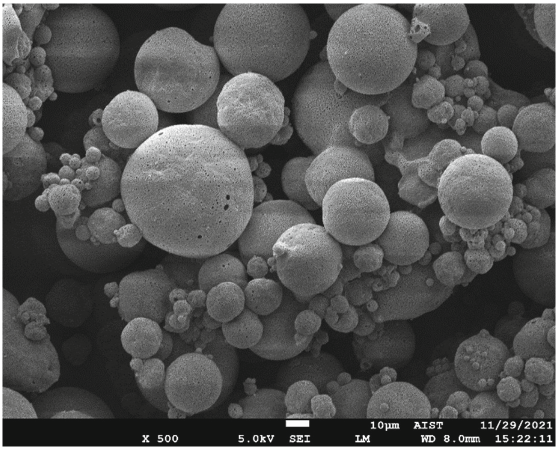

Fig. 1 Microcapsules contained cinnamon essential oil

2.2 Methods

2.2.1 Fragrance Evaluation

The fragrant intensity of the interlock knitted fabric was evaluated by expert method combined the grade dilutation method based on the comparison of diluted sample method using the standard ASTM D 1292-10. The aqueous solution of microcapsule had gradually diluted by distilled water and has been contained in a small bottle of 10 mL. Eleven bottles had been prepared with different ratio of microcapsule volume solution and the bottles had then well tight closed during the experiment. The bottle of total distil water is “no odor” and was considered as “blank”.

Their fragrance grade Fg was calculated (see formula (1)) in dependence on the ratio of microcapsule volume solution V_{ms} (mL) to the total volume solution of microcapsule volume and distilled water volume ($V_{ms} + V_w$) in the bottle. Eleven bottles had been prepared with different ratio of microcapsule volume solution, which was 0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100% (v/v), corresponding to the fragrance points of 0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100.

$$\text{Fg} = V_{ms}/(V_{ms} + V_w) \times 10 \text{ (II.1)} \tag{1}$$

Six perfumers have been trained to participate in the evaluation of the fragrance. They were teachers and students of Hanoi University of Science and Technology, age of 20–37 years old. The perfumers were compliant to the odor panel rules as a part of the assessor's agreement to participate in odor testing. Every perfumer has smelled the fabric sample and compared to the sample bottles with its fragrance grade then has given out a point in a hundred grades. Before changing to evaluate another fabric sample the perfumer have been demanded to smell the bottle of zero fragrance grade. In order to guaranty the objectiveness of evaluation, the perfumer obeyed strictly the above protocol and did not have any discussion during the experiment. Moreover, they must be free of colds or physical conditions that may affect the sense of smell; must not chew gum or eat at least 30 min before participating to the odor panel; must not wear perfume, cologne, or after shave the day of the odor testing, must have their clothes odor free, have their hands clean and no odor of the odor panel [16]. The result of fragrance intensity for every fabric sample was the mean value given by all six perfumers for this fabric sample.

2.2.2 Calculation of the Fabric Band Compression

Laplace law [3–5] was used to calculate the compression exerted by the interlock knitted fabric bandage as

$$\text{Pressure (mmHg)} = \frac{\text{Tension (KgF)} \times \text{Number of layers} \times 4620}{\text{Circumference (cm)} \times \text{Bandage width (cm)}} \tag{2}$$

2.2.3 Preparation of the Compression of the Knitted Fabric Bandage

Four levels of elongation knitted fabric bandage had been prepared by cutting four IT3 knitted fabric samples of equal size (8×3 cm^2). Then the microcapsules contained the cinnamon essential oil had coated on the fabric surface and the fabric samples stored in the refrigerator with the temperature of 2 °C and the relative humidity of 20% for 24 h to solidify the microcapsule on the fabric.

Fabric samples, coated by Eudragit RSPO microcapsules, contained the cinnamon oil essential after being stored in the refrigerator environment were sewn to form a cylinder band. These bandage then was looped into four glass jars. Here four glass jars with different circumferences as 9.7, 12.6, 13.5, 14.7 cm were used to make the knitted fabric elongation of 21.25, 57.5, 68.75, 83.75%, respectively. The fabric surface coated with microcapsules was faced on the wall of the glass jar.

Tensile test: The interlock fabric tensile was measured by TENSILON Instrument (Japan). The test parameters were: tension was 0.1 N, tensile rate was 100 mm/min and gauge length was 100 mm. Specimen size (widthways direction) was 200 × 50 mm^2. Each interlock fabric was tested at a continuous elongation to 200%, and their tensile forces at every elongation was recorded. The test was taken 5 samples for every kind of investigated interlock fabric and the mean value was calculated.

3 Results and Discussion

3.1 Influence of Fabric Characteristic on Fragrance Durability of Interlock Knitted Fabric

Three samples for every kind of interlock knitted fabric were evaluated on fragrance by six perfumers. Thought the odor assessment was quite different between the performers because of their odor threshold, their results (see Table 2) showed the tendency of the fragrance change set during the cycle evaluation. At the beginning the fragrance intensity was recorded maximum value (from 16 points to 22.2 points) for all of fabric kinds. The interlock fabric IT1 with the highest density (lowest loop length) had the highest fragrance intensity of 22.2 points, 19.5 points and 27 points for their three-sample fabric in comparison with the IT2 (16 points, 13.5 points and 17.3 points) and IT3 with 18.2 points, 16.7 points and 18.2 points). The average of fragrance intensity (Fig. 2) helps to observe the tendency and the rate of the liberation of cinnamon essential oil from the fabric.

Table 2 Fragrance intensity of interlock fabrics treated by cinnamon essential oil with 60 min of evaluation interval

Time (min)	Fabric sample								
	Interlock 1			Interlock 2			Interlock 3		
	1	2	3	1	2	3	1	2	3
0	22.2	19.5	27	16	13.5	17.3	18.2	16.7	18.2
60	13.5	15	21	13.7	10.7	12.3	11.5	10	11.5
120	14.7	12.3	10.8	11.7	10.8	10.3	12	9.8	11.3
180	13.3	9.2	7	7.5	7.8	7.3	6.7	8.7	8.8

The liberation rate of the cinnamon oil was highest in first 60 min for all three kinds of fabric. In this period, the fragrance intensity was decreased 27.9, 21.7 and 37.8% for the interlock fabric IT1, IT2, IT3, respectively. During the period 60–120 min the liberation rate was observed slower with the decrease of fragrance intensity for interlock fabric IT1, IT2, IT3; it was respectively 17, 8 and 0%. After 180 min the drop of the fabric fragrance intensity was recorded as 57.2, 51.9 and 54.2% for the fabric IT1, IT2 and IT3, respectively (see Table 3). So, there were not clear difference between three kinds of investigated interlock fabric. The difference in their parameters such as loop length, density may not enough to provide the clear tendency in change of fabric fragrance intensity during the research.

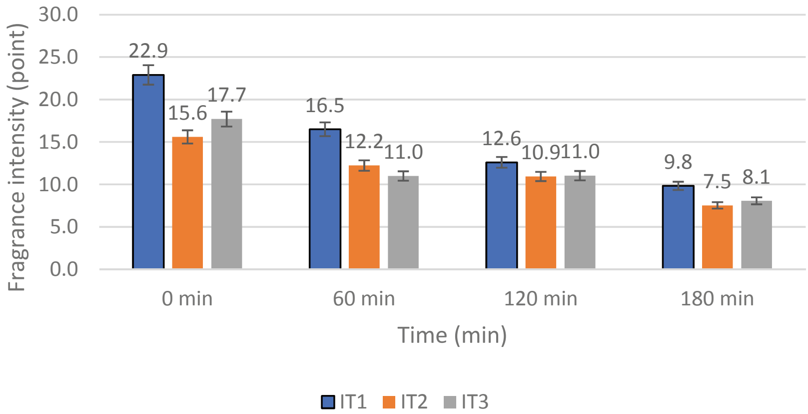

Fig. 2 Average of fragrance intensity of interlock fabrics treated by cinnamon essential oil with 60 min of evaluation interval

For the second test of the fabric fragrance durability, as the agent fragrance was the microcapsule contained the cinnamon oil in their core. The fragrance intensity in the beginning was 12.3 points, 10.8 points and 8.3 points, about only half and much lower than these ones treated directly by cinnamon oil. The reason was the quantity of cinnamon oil present in fabric sample coated by microcapsule was 250 times lower than that one with cinnamon oil. Here one more time, the interlock IT1 with the lowest loop length had the highest fragrance intensity in the beginning of 10.5 points, follow by the IT2 with 9.9 points and the last was IT3 with 8.3 points (Fig. 3). The tendency was the same as the fabric treated by the cinnamon oil. So, the structure of the IT1 fabric may help to keep more the fragrant agent in their structure: the lowest loop length and the highest density of the IT1 fabric led it to have highest fiber hold volume with the more presentation of polyester fiber in their structure. In the consequence the lipophilic cinnamon oil and the microcapsules with the cinnamon oil may be more attracted and kept in the surface of the fabric.

Table 3 Fragrance intensity of interlock fabrics treated by microcapsule coated by cinnamon oil essential with 60 min of evaluation interval

Time (min)	Fabric sample								
	Interlock 1			Interlock 2			Interlock 3		
0	12.3	10.8	8.3	11.3	9.3	9	8.5	8.1	8.2
60	8.6	7.8	6.5	7.5	7.5	6.8	7.8	6.5	6.2
120	6.6	5.8	5.6	7.5	6.8	6	6.5	5.3	6.8
180	5.2	6	5.3	5.5	6	5.8	5.2	5	5.2

For first 60 min, the most important drop of fragrance intensity was observed with 27.6, 26.26 and 18.07% for IT1, IT2, IT3, respectively. So, the rate liberation of the

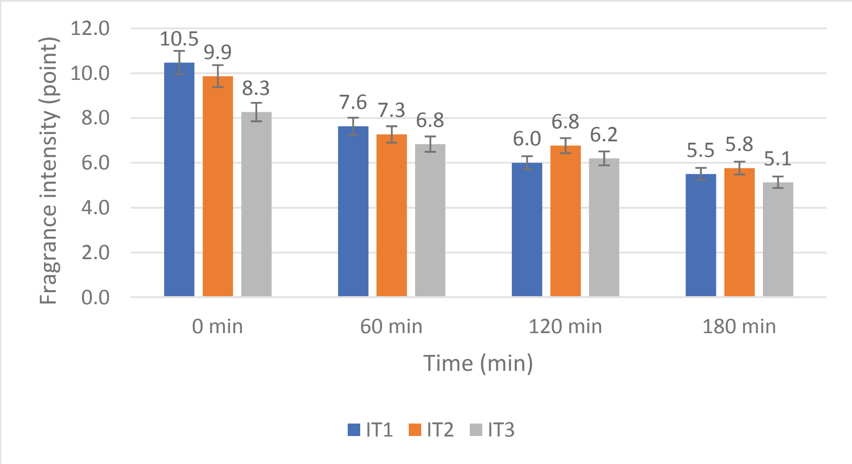

Fig. 3 Average of fragrance intensity of interlock fabrics treated by microcapsule coated by cinnamon essential oil with 60 min of evaluation interval

cinnamon oil was highest with IT1, follow by IT2 and IT3. In the period from 60 to 120 min, the fragrance intensity decrease was 15.23, 5.05 and 7.22% for IT1, IT2, IT3, respectively; it showed the rate diffusion of cinnamon oil was slower than in the first period. For the last interval from 120 to 180 min the fragrance intensity drop was calculated as 4.76, 10.10 and 13.25% for IT1, IT2, IT3, respectively. In total, after 180 min the decrease of the fabric fragrance intensity was recorded as 47.6, 41.1 and 38.6% for the fabric IT1, IT2 and IT3, respectively. The diffusion rate of cinnamon oil of the fabric coated by microcapsules was slower than these ones treated directly by the cinnamon oil in every fabric kind and for all the period of examination. The results suggested that the microcapsule plays role in control of the cinnamon oil diffusion.

3.2 Application of the Laplace Law to Calculate Fabric Compression

The tensile force of the interlock fabric at the four-elongation investigated and the compression exerted which calculated by Laplace law were presented in Table 4.

Table 4 Calculated compression of interlock knitted band at different elongation

Elongation (%)	21.25	57.5	68.75	83.75
Tensile (N)	4.2	10.9	18.0	34.0
Compression (mmHg)	67	133	205	356

3.3 Influence of Compression on the Fragrance Durability of Knitted Bandage Coated by Microcapsules Contained Cinnamon Oil

Four compression levels were investigated in this study to find the relationship between the pressure and the liberation of cinnamon oil from the microcapsule (Fig. 4). The compression exerted by the extension of the knitted bandage and was calculated by Laplace' formula (2). Although the compression calculated was reported in dependence on the sample dimension [2, 3] the research results showed a tendency of the liberation of cinnamon oil from the knitted fabric bandage coated by microcapsules. After 60 min in exertion by the compression of 67, 133, 205 and 356 mmHg, the knitted fabric fragrance intensity measured was 43.1 points, 30 points, 23.1 points and 17.5 points, respectively. The relation between knitted fabric compression and their fragrance intensity was not linear. The diminutions of the fragrance intensity were more important in the range from 67 to 205 mmHg with the 20 points in difference. In the compression range from 205 to 350 mmHg, the drop of the fragrance intensity was only 5.8 points thought the pressure was much more important. Investigation of the microcapsules structure led to the explications of these results. The SEM image of the microcapsule's membrane structure shows many pores in the membrane of the microcapsules (see Fig. 5).

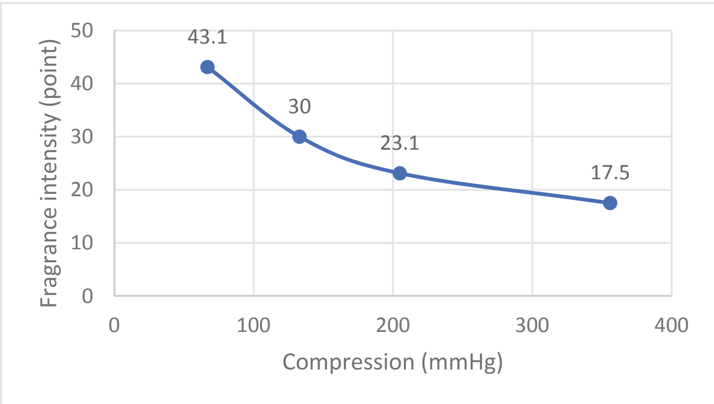

Fig. 4 Fragrance intensity of interlock fabrics exerted by different compression after 60 min

Their dimension was from some tens of nanometers to some hundreds of nanometers. Natural essential oils have known as very volatile substances. So, the evaporation was carried out by the diffusion through the microcapsule pores, plus, compression exerted by the extension of the knitted fabric bandage, plus the pressure posed in the microcapsule and plus the cinnamon essential oil could be diffused. In the consequence, the fragrance intensity of the fabric bandage was decreased.

Observation of the distribution of the microcapsules on the fabric structure may explain in more detail the diffusive process of the cinnamon essential oil. The knitted fabric structure was soft and bulk because of the low yarn twist. The microcapsule dimension was observed as small as the fiber dimension, which was about 20–40 μm (Fig. 6). So almost all microcapsules were found distributed in the fabric surface. These

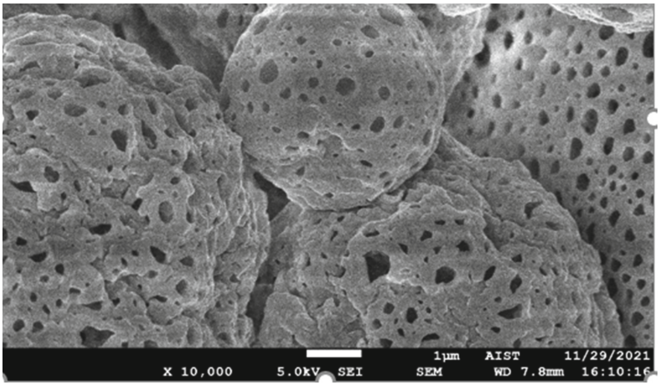

Fig. 5 SEM image of the microcapsule's membrane structure

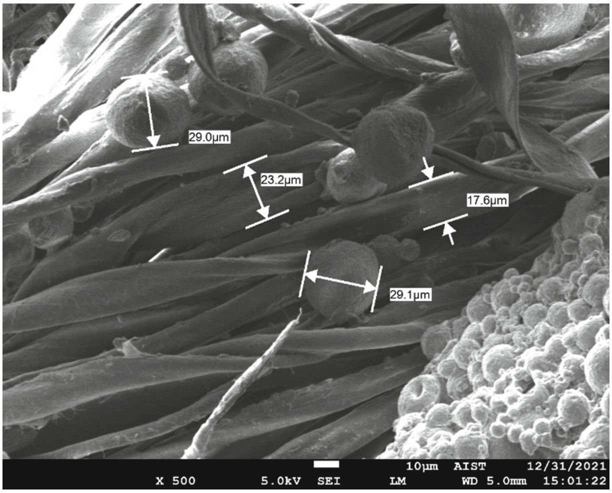

Fig. 6 SEM image of the interlock knitted fabric surface treated by microcapsules contained cinnamon essential oil

microcapsules were face on to the hard glass jar and would stand the first pressure exerted by the knitted fabric bandage to liberate the cinnamon essential oil. Amount of cinnamon essential oil was liberated from these microcapsules.

Some quantities of microcapsules were found in the gap between the yarns and the knit loops (Fig. 7). They were surrounded by the soft fibers and much more difficult to reach by the pressure, generated by the compression of the knitted fabric bandage.

This distribution of the microcapsules, explained as the compression, was more important (from 205 to 350 mmHg), the drop of the fragrance intensity was not correlative. These microcapsules may keep the cinnamon oil in their core and the essential oil liberation was carried out progressively through the membrane pores.

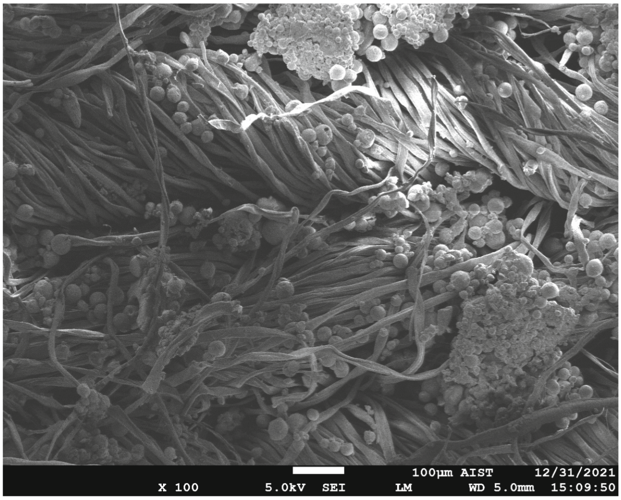

Fig. 7 SEM image of the interlock knitted fabric treated by microcapsules contained cinnamon essential oil

4 Conclusions

The research showed that the fragrance intensity of the interlock fabric coated by the microcapsules contained cinnamon oil was more important than these ones treated directly by the cinnamon oil. The microcapsules with the membrane pores from tens nanometers to hundreds of nanometers help to control the diffusion of the cinnamon oil so the diffusion could be control to obtain the required rate of diffusion of cinnamon oil during use.

The compression exerted by the extension of the knitted fabric bandage could be calculated by the Laplace's law, though the results, could be verified by the experimental measurement, demonstrate the accuracy and the appropriation of the used formula. However, the results showed that the fragrance intensity of the knitted fabric bandage decreased while the compression increased. The membrane pore and the distribution of the microcapsules on the knitted fabric structure was the reason of this tendency.

Acknowledgement. This research is funded by Hanoi University of Science and Technology (HUST) under project number T2021-PC-044. The authors are thankful to Principal of the University, Direction of the School of Textile Garment and Fashion Design, Department of Textile Technology, for providing necessary facilities to carry out this work.

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