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REGULAR ARTICLE

Comparisons of Moisturizing Function Between Rayon Fabric with Collagen Peptides from Fish Scales and Regular Rayon Fabric Under Various Relative Humidity

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Abstract

The study was inspired by the specialized facial masks made of rayon non-woven fabrics which contained collagen peptides for improving moisturizing function. This study explored the moisturizing function of a rayon fabric containing collagen peptides extracted from tilapia fish scales under various conditions of relative humidity. This research had implications for the development of clothing that can prevent dry skin. A two-stage nested design experiment was adopted. The first-stage factor such as the fabric has two levels and the second-stage factor such as the relative humidity with three levels nested under each level of the first-stage factor. Preliminary results indicated that introducing a new variable (i.e., fabric moisturizing value, which combines the moisture regains of adsorption and desorption) would be useful. The moisturizing value of the novel rayon fabric and regular rayon fabric increased with the increase in relative humidity, and moisturizing effect of the novel rayon fabric with collagen peptides was better than that of the regular rayon fabric. Therefore, the novel rayon fabric may be suitable for preventing dry skin in winter.

Keywords Functional fabric · Fiber · Moisturizing value · Nested design experiment · Moisture regains of adsorption and desorption

1 Introduction

The skin, the largest organ of the human body, is often exposed to environment. The outermost layer of the epidermis is the stratum corneum. The skin provides several protective functions [1–4]. The skin regulates body temperature, forms a protective barrier against various stimuli, and prevents the loss of water from the body [2–4].

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However, the skin's protective function is mainly affected by genetic properties, age, lifestyle, and environmental stress such as temperature, humidity, seasonal variation, and radiation exposure [5]. Environmental humidity, especially low environmental humidity, has a strong influence on the skin condition. Low environmental humidity, which often occurs in winter, can degrade the protective function of the skin and increase trans-epidermal water loss. Dry skin is a condition in which the water content in the stratum corneum is less than 10% [6–9].

Individuals with dry skin are more susceptible to skin disease, which can cause physiological discomfort and negative effect quality of life [7, 10, 11]. Understanding how to maintain the moisturizing function of the stratum corneum to prevent dry skin in winter is important.

Methods for preventing dry skin in winter include the application of moisturizers, the use of fine spray mists, minimizing the use of soap, and wearing clothing made from natural fibers [12]. Among these, the application of moisturizers is the most popular. Moisturizers are generally classified into two groups according to the site of application:

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face as well as body, hand, and feet. Within each category, specialized products have been developed for specific areas, such as the lips, under the eyes, and the feet [7, 13]. Moisturizers contain a complex mixture of cosmetic ingredients and aim to keep the skin hydrated [12].

Collagen is a major ingredient in many cosmetic formulations, such as facial masks (especially those designed for facial skin), owing to its good moisturizing function [14, 15]. Collagen, which is a fibrous protein and insoluble in water or oil, has a molecular weight of approximately 300 KDa, and is 1.5 nm in diameter and approximately 280 nm in length. Collagen consists of three polypeptide chains tightly wound together in a triple-helical conformation [16].

The main sources of collagen were from the skin and tendon tissue of porcine, bovine or ovine [17]. In recent decades, the interest in marine collagen from fish skin, bone and scales as a safer of collagen has greatly increased owing to the outbreak of foot and mouth disease, bovine spongiform encephalopathy and avian influenza [18–22], and the porcine collagen was unacceptable for some specific religions such as Judaism and Islam [22].

To overcome its insolubility, collagen is hydrolyzed into peptides through chemical, enzymatic and microbial procedures [23, 24]. Peptides can be dissolved in water because of their small molecular weight, and they can be added easily into several cosmetic formulations [25]. In addition to their use in cosmetic application, collagen peptides were also widely used in food, biomedical and pharmaceutical industries [25, 26].

The use of collagen peptides in the textile industry has so far been limited to facial masks [15, 27, 28], and hence, the study was inspired by the specialized facial masks made of rayon non-woven fabrics which contained collagen peptides for improving moisturizing function.

Clothing, often regarded as a second skin, plays an important role in temperature regulation [29]. Many functional textiles or smart textiles have been developed, such as quick-dry fabrics [30–32], hygroscopic exothermic fibers [33–35], antibacterial and deodorizing fabrics with organic or inorganic materials [36–38], flame retardant fabrics with tannin or polyelectrolyte [39–41], far-infrared fabrics, fiber or films with graphene, germanium or ceramic [42–44] as well as antiultraviolet fabrics and fiber [45–47].

Few studies have investigated the development of textiles or clothing that has moisturizing function, especially those incorporating collagen. The moisturizing effect of textiles can be determined by the measurement of the microclimate between textiles and simulated human using guarded hotplate termed ISO 21232–2018. This document specifies a test method which simulates the microclimate for determining the moisturizing effect of textile materials by measuring water–vapor resistance including air layer and relative humidity using a sweating guarded hotplate. This test method can be applied to fabrics, films, coatings and leather including multilayer assemblies, for use in clothing system [48].

The textile fibers are classified into two categories: natural fibers and man-made fibers [49]. Natural fibers, which exist as such in nature [50], are divided into three main classes according to the sources, i.e., vegetable fibers, animal fibers and mineral fibers. Vegetable fibers include cotton, hemp, flax, jute, and various fibers produced by plants. Animal fibers include wool, camel, silk and various hair-like fibers [50, 51]. Mineral fibers are derived from natural mineral sources such as asbestos [51].

Fibers manufactured artificially through chemicals are called man-made fibers [49], which are classified into synthetic and regenerated fibers [51]. Synthetic fibers are not originated in natural sources, and are made of polymers which are almost always from by-products of petroleum [51]. These polymers include nylon, polyethylene terephthalate, polypropylene, acrylic, and so on [49–51]. Regenerated fibers, derived from cellulose which is obtained from wood pulp or cotton linter, are made by dissolving the cellulose in chemicals or solvent, and processing it into fiber again, such as rayon and lyocell [50, 52].

The hygroscopicity of a textile fiber affects wearer comfort [53]. Among natural fibers, wool, which is an animal fiber, is the most hygroscopic. Among vegetable fibers, jute is the most hygroscopic. The hygroscopicity of rayon is slightly lower than that of jute [49]. Almost all facial masks are made from rayon fibers.

Rayon is the first manufactured fiber and made from wood pulp, and its properties are more similar to natural cellulosic fibers such as cotton or linen than those of petroleum-based synthetic fibers such as nylon or polyester [54]. Rayon, which has a smooth and lustrous appearance like silk is more hygroscopic than that of cotton [49]. Furthermore, rayon fabric is soft to skin, drapes well, is antistatic and breathable [49, 54], easily absorbs perspirations and facilitates effective evaporation of perspirations [55].

Specialized facial masks made of rayon non-woven fabrics that contained collagen peptides have been demonstrated to exhibit moisturizing function. In a study, a novel fabric made of modified polyester yarn containing collagen was found to have better hygroscopicity than that of a fabric made of regular polyester yarn [56], demonstrating the moisturizing function of collagen. The moisturizing effect may be more obvious in rayon than in polyester. Therefore, this study explored the moisturizing function of a rayon fabric containing collagen peptides under various relative humidity conditions. This research had implications for the development of clothing that can prevent dry skin.

2 Experimental

2.1 Materials

Two fabrics were used in this study. First, the regular rayon fiber was produced by the reconversion of the soluble compound to cellulose according to the industrial practice [52], and obtained from Formosa Chemical & Fiber Co, LTD in Taiwan (FCFC). Second, the novel rayon fiber was produced by two steps, i.e., extracting collagen peptides from tilapia fish scales, and then blending the collagen peptides into the regular rayon fiber.

An enzymatic method was applied to extract the collagen peptides from fish scales [57]. Briefly, the fish scales were washed with distilled water thrice to get rid of impurities and then heated for 15 min at 120 ℃ to soften the fish scales. The heated fish scales were smashed into small pieces by disperser. Then, subjected to hydrolysis under 1% papain for 3 h and 0.5% bacteria (Bacillus subtilis) for another 1 h at an optimal pH and temperature. Hydrolysates were stirred and heated in a boiling water for 10 min to inactivate enzyme. The hydrolysates were centrifuged at 10,000*g* for 15 min. The supernatants were taken out and dried by spray dryer to become collagen powder and stored at 4 ℃ for future use.

The 10% mass fraction of collagen peptides solution was ready and blended well with viscous solution during the process of producing regular rayon, and finally the novel rayon fiber was obtained, which was also from FCFC [58]. Moreover, the ring spun yarns were made of the novel rayon fiber and the regular rayon fiber, respectively. Both fibers were all 1.25D $\times$ 38 mm, and the strength of the fibers was all 2.90 ± 0.15 g/d. The elongation (%) of the novel fiber was 22 ± 3.0, and that of the regular fiber was 20 ± 4.0. The whiteness of appearance (WB) of the novel fiber was 84, which was almost the same as the regular rayon fiber [58, 59].

The ring spun yarns were made of the novel rayon fiber and the regular rayon fiber, respectively. Both yarns had a yarn count of Ne32 (or Nm54.2) [60] and were spun on a same machine that were obtained from the Taiwan Textile Research Institute. Two knitted fabrics were made of novel rayon yarn and regular rayon yarn, respectively. The weight of both fabrics was 263 g/sm. Both fabrics contained 4.2% spandex, and were obtained from Oriental Institute of Technology.

2.2 Protein Content in the novel rayon fiber

The protein content in both novel rayon fiber and regular rayon fiber was measured by Sodium Hypochlorite Method (paten no. CN104020075A) [61]. Briefly, both 1.00 g of the novel fiber and the regular fiber were weighted and taken after drying at 105 °C for 2 h, respectively. Then, the dried specimens were put into the 1 N sodium hypochlorite 100 ml solution and stirred at 75 rpm for 45 min at room temperature.

The specimens were taken out and soaked into the 1 N sodium hypochlorite 100 ml solution, stirred for 3 min to remove the protein residues on the fiber, immersed into the distilled water 100 ml to clean, stirred for 5 min, and then put into 10% acetic acid 100 ml solution and stirred 3 min, and then cleaned with 100 ml distilled water twice.

Finally, the specimens were centrifuged at 6000*g* for 10 s twice and the weight of precipitates was measured after drying at 105 °C for 24 h. Then the protein content of each specimen was determined by calculating the rate of weight loss in chemical solution [61].

2.3 LC–MS/MS Analysis

In order to verify the collagen content in the novel rayon, the further analysis was conducted using liquid chromatography coupled with tandem mass spectrometry (LC–MS/MS) [62].

The novel rayon was diluted and injected onto a hydrophilic interaction column (HILIC) coupled with a LC/MS/MS system operated in positive and negative polarity. Multiple reaction monitoring (MRM) by mass spectrometry was used for detection because of its high selectivity and sensitivity [62].

2.4 Physical properties of yarns

The physical properties of yarns were measured for yarn count by ISO 2060, twist by ISO 2061, strength and elongation by ISO 2062, and evenness by USTER® Tester.

2.5 The moisture regains of adsorption and moisture regains of desorption of fabric

In general, the fabric can adsorb moisture from a moist atmosphere, and conversely the fabric can give up moisture to a dry atmosphere. The former is the adsorption effect, and the latter is the desorption effect [63].

Three environmental humidity situations were assumed in this study, i.e., low relative humidity (RH), medium RH and high RH, such as 40% RH, 60% RH and 80% RH in order. Therefore, there were two factors, i.e., fabric and relative humidity were tested for the moisture regains of adsorption (AR) and the moisture regains of desorption (DR) of fabric in this study. In other words, there were two levels for factor fabric, such as the novel rayon fabric (Novel) and the regular rayon fabric (Regular) as well as three levels for factor relative humidity, such as 40% RH, 60% RH, and 80% RH, respectively.

The operating procedures of AR were descripted as follows [64]. Three pieces (3 replicates) of 1.00 g novel rayon fabric and regular rayon fabric, respectively were taken and weighted after drying at 105 ± 2 °C for 2 h in heating chamber (Type 9010–0295, Binder GmbH, Germany) in order to get the absolutely dried weight for each specimen.

Each dried specimen was put into a constant temperature and humidity machine (CTHM) (Model MHG-225RF, Terchy Environmental Technology Ltd, Taiwan) under the temperature at 20 ± 0.5 °C and the air speed at 0.4 ± 0.1 m/s conditions, and weighted after 2 h at 40 ± 3% RH. Next, each specimen was put into the CTHM again and weighted after 2 h at 60 ± 3% RH. Then, each specimen was put into the CTHM again and weighted after 2 h at 80 ± 3% RH. Finally, each specimen was put into the CTHM again and weighted after 2 h at 97 ± 3% RH. The 97 ± 3% RH was assigned as the highest relative humidity owing to the instrument restrictions. Once the weights of final condition of 97 ± 3% RH were measured, the procedures of adsorption were all completed.

Then, started measuring the weight during desorption. i.e., each specimen was put into the CTHM again and weighted after 2 h at 80 ± 3% RH. Next, each specimen was put into the CTHM again and weighted after 2 h at 60 ± 3% RH. Then, each specimen was put into the CTHM again and weighted after 2 h at 40 ± 3% RH. Once the weights of final condition of 40 ± 3% RH were measured, the procedures of desorption were all completed.

The AR and DR are defined as follows.

$$\mathrm{AR}(\%) = \frac{W1 - W0}{W0}100 \tag{1}$$

$$\mathrm{DR}\ (\%) = \frac{W2 - W0}{W0}100 \tag{2}$$

where W_0 was the absolute dry weight each specimen; W_1 was the weight under the specific RH during adsorption each specimen; W_2 was the weight under specific RH during desorption each specimen.

2.6 Statistical Analysis

Analysis of variance (ANOVA) test, which is a statistical method and can be used to compare the arithmetic mean of multiple treatments, was adopted in this study. The treatment included two classes. One was the fabric and the other was relative humidity. It was a factorial experiment with two factors, i.e., a two-stage nested or hierarchical design experiment [65]. The first-stage factor such as the fabric has 2 levels and the second-stage factor such as the relative humidity with 3 levels nested under each level of the first-stage factor. Since every level of the first-stage factor did not appear with every level of the second-stage factor, there can be no interaction between first-stage factor and second-stage factor.

Therefore, the moisture regains of adsorption and desorption were performed in a linear statistical model as follows:

$$x_{ijk} = \mu + \alpha_i + \beta_{(i)j} + \epsilon_{(ij)k} \tag{3}$$

where μ was mean, α was the first-stage factor and i = 1, 2 level, i.e., novel rayon fabric and regular rayon fabric; β was the second-stage factor and (i) j = 1, 3 level, i.e., 40% RH, 60% RH and 80% RH; ϵ was the error term with (ij) k = 1, 3 (replicate). ANOVA test was performed and Duncan new multiple range test was further used to test pairwise difference (α = 0.05) between treatments if the factor was significant difference.

3 Results and discussion

3.1 Protein content in the novel rayon fiber

The rate of weight loss in chemical solution was 1.82% ± 0.12% for the novel rayon fiber and 0.90% ± 0.20% for the regular rayon fiber, respectively (Table 1). Both rates were significantly different ($p < 0.05$).

In theory, no weight loss should occur for the regular rayon fiber after sodium hypochlorite treatment; however, unknown materials or fatty agents [66, 67] on the fibers may have been dissolved by the sodium hypochlorite solution. Therefore, the protein content in the novel rayon fiber was 0.92% (1.82%–0.90%).

3.2 LC–MS/MS analysis

Peptide tests in novel rayon were conducted using LC–MS/MS [62]. A LC–MS/MS test performed by the SGS company (Report No. PUG21600154) revealed 5800.0 mg/kg collagen content which was calculated based on hydroxyproline content.

The ratio of hydroxyproline to collagen was 13.4%. The results confirmed the novel rayon fiber does contain collagen peptides.

3.3 The physical properties of yarns

The physical properties of both the novel rayon yarn and the regular rayon yarn were shown as follows. The yarn count was 32.3 (or Nm54.7) for the novel rayon yarn and 32.4 (or

Table 1 The rate of weight loss in chemical solution for the novel rayon fiber and the regular rayon fiber

Rayon fiber	Dry weight before treatment (g) (A)	Dry weight after treatment (g) (B)	The percentage of reduced weight in chemical solution (%) ($\frac{A-B}{A} \times 100$)
Novel	0.983	0.966	1.73
	1.020	1.000	1.96
	1.186	1.165	1.77
			1.82 ± 0.12*
Regular	1.052	1.045	0.67
	1.078	1.067	1.02
	1.005	0.995	1.00
			0.90 ± 0.20

*$P < 0.05$

Table 2 The physical properties of the novel rayon yarn and the regular rayon yarn

Rayon yarn	Yarn count (Ne*)	Twist per inch	Single yarn strength (cN/tex)	Single yarn elongation (%)	Unevenness (CV %)
Novel	32.3	17.3	13.59	10.36	13.31
Regular	32.4	17.2	13.80	10.51	12.02

*Ne: English count system, for instance Ne32 means 32 hanks per pound, and 840 yards per hank

Nm54.9) for the regular rayon yarn. The twist per inch was 17.3 (or twist per meter [TPM]:681) for the novel rayon yarn and 17.2 (or 677) for the regular rayon yarn. The single yarn strength (cN/tex) was 13.59 for novel and 13.80 for regular. The single yarn elongation (%) was 10.36 for novel and 10.51 for regular, and the unevenness (CV %) was 13.31 for novel and 12.02 for regular (Table 2).

The strength and elongation of novel rayon yarn were a little bit lower than that of the regular rayon yarn, and the unevenness of the former was also worse than that of the latter. The components of novel rayon fiber may have been too smooth [68] to spin well.

The properties of yarn and fiber are strongly connected, i.e., the strong fiber leads to the strong yarn. In general, introducing proteins into viscose solution will weaken the tensile properties of the resulting viscose rayon fibers [68] due to a decrease in crystallinity, and the more collagen content in cellulose/collagen blend, the less tenacity of the fibers [69].

Moreover, the collagen and cellulose are compatible, resulting in a more uniform and smoother surface of the collagen/cellulose blended fiber [69–71]. Therefore, the surface of the novel rayon is smoother than that of the regular rayon, resulting in less cohesive force and great unevenness.

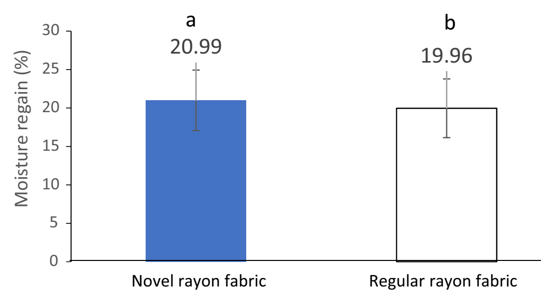

Fig. 1 The mean of moisture regains of two fabrics during adsorption. The different superscripts are significant difference (ANOVA test, $p < 0.05$)

3.4 The moisture regains of adsorption and desorption for fabric

The mean moisture regains of adsorption for the novel rayon fabric and the regular rayon fabric were 20.99% and 19.96%, respectively, i.e., the hygroscopicity of the former was 5.16% more than that of the latter (= 20.99%/19.96%—1) during absorption (Fig. 1).

ANOVA test showed that the two means were significant difference ($p < 0.05$) (Table 3) as well as the mean moisture regains of adsorption for relative humidity under the two nests were also showed significant difference ($p < 0.05$) (Table 3).

The mean moisture regains of adsorption under the nest of novel rayon fabric were 16.61% for 40% RH, 21.01% for 60% RH, and 25.35% for 80% RH, respectively. The pairwise comparisons between relative humidity showed 80% RH > 60% RH > 40% RH, as well as the mean moisture regains of adsorption under the nest of regular rayon fabric were 15.83% for 40% RH, 19.51% for 60% RH, and 24.56% for 80% RH, respectively. The

Table 3 Nested analysis of variance for adsorption on novel fabric and regular fabric as well as 40%, 60%, and 80% relative humidity

Sources	DF	Sum of squares	Mean squares	F value	$F_{0.05}$	$p(F)$
Fabric	1	4.7432	4.7432	5.3241	4.7470	< 0.05
Relative humidity	4	229.8303	57.4576	64.4939	3.2590	< 0.05
Error	12	10.6913	0.8909			
Total	17	245.2648				

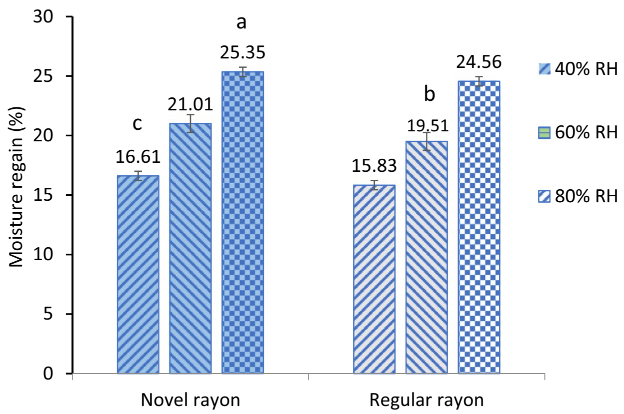

Fig. 2 The moisture regains of two fabrics at various relative humidity during adsorption. The same superscripts are not significant difference (Duncan's new multiple range test, $p > 0.05$)

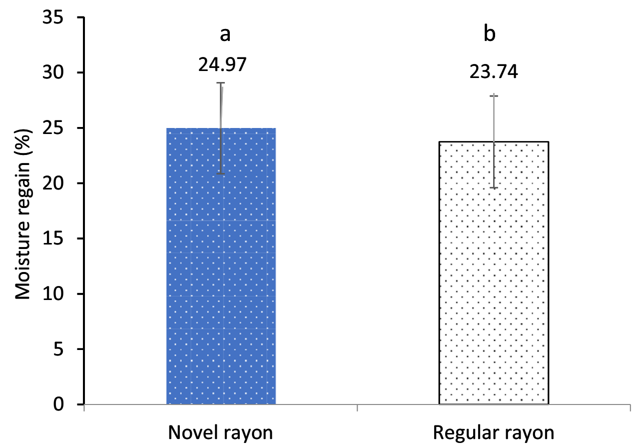

Fig. 3 The mean of moisture regains of two fabrics during desorption. The different superscripts are significant difference (ANOVA test, $p < 0.05$)

pairwise comparisons between relative humidity also showed 80% RH > 60% RH > 40% RH. However, the two means for the novel rayon fabric and the regular rayon fabric under same relative humidity were not significant difference (Fig. 2) ($p > 0.05$).

The mean moisture regains of desorption for the novel rayon fabric and the regular rayon fabric were 24.97% and 23.74%, respectively, i.e., the hygroscopicity of the former was 5.18% more than that of the latter (= 24.97%/23.74%—1) during desorption (Fig. 3).

ANOVA test showed that the two mean were significant difference ($p < 0.05$), and the mean moisture regains of desorption for relative humidity under the two nests were also showed significant difference ($p < 0.05$) (Table 4).

The mean moisture regains of desorption under the nest of novel rayon fabric were 20.24% for 40% RH, 25.07% for 60% RH, and 29.59% for 80% RH, respectively. The pairwise comparisons between relative humidity showed 80% RH > 60% RH > 40% RH, and the mean moisture regains of desorption under the nest of regular rayon fabric were 19.16% for 40% RH, 23.38% for 60% RH, and 28.69% for 80% RH, respectively. The pairwise comparisons between relative humidity also showed 80% RH > 60% RH > 40% RH. However, the two means for the novel rayon fabric and the regular rayon fabric under same 80% RH were not significant difference, while they were still different under same 40% RH and 60% RH (Fig. 4) ($p < 0.05$).

According to the reports of FCFC, the properties of novel rayon fiber were almost the same as regular rayon fiber. However, the moisture of adsorption and retention of the former is better than that of the latter.

The moisture regains of adsorption and desorption of the novel rayon fiber may have been improved by the collagen peptides, which possess a carboxyl group (-COOH) and an amino group (–$CONH_2$), and the configuration can be changed with a supramolecular bond that reduces the evaporation of water [72]. In addition, the crystallinity of the novel rayon fiber is lower than that of regular rayon fiber, which indicates that the amorphous regions of novel rayon fiber became bigger than that of regular rayon fiber [69]. Therefore, the hygroscopicity of novel

Table 4 Nested analysis of variance for desorption on novel fabric and regular fabric as well as 40%, 60%, and 80% relative humidity

Sources	DF	Sum of squares	Mean squares	F value	$F_{0.05}$	$p(F)$
Fabric	1	6.7350	6.7350	20.3045	4.7470	< 0.05
Relative humidity	4	237.9950	66.9988	201.9861	3.2590	< 0.05
Error	12	3.9800	0.3317			
Total	17	248.7100				

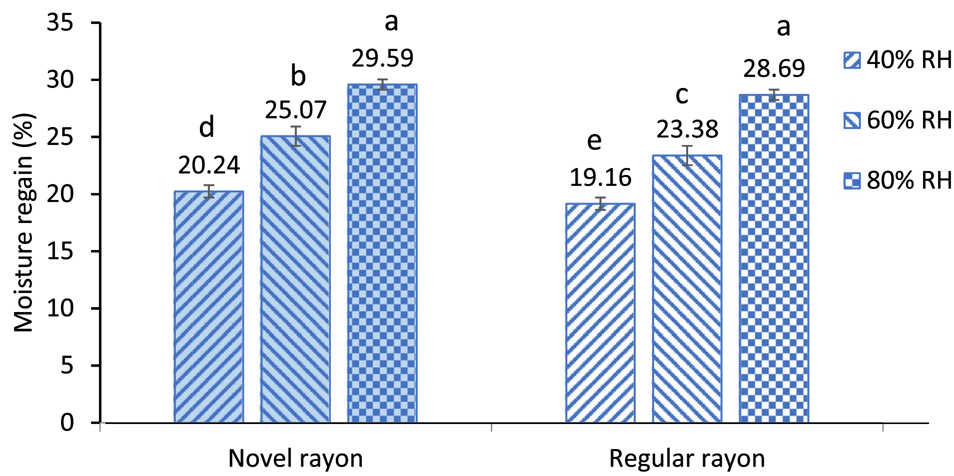

Fig. 4 The moisture regains of two fabrics at various relative humidity during desorption. The same superscripts are not significant difference, but the different superscripts are significant difference (Duncan's new multiple range test, $p < 0.05$)

rayon fiber was better than that of regular rayon fiber. Similar results, which were shown for acrylic fiber [73] and polyester DTY [56] indicated the moisture regains of fibers with collagen modification were higher than that of regular fibers.

For most textile fibers, the value of DR is higher than that of AR at the same temperature and RH generally, and this phenomenon is called hydroscopic hysteresis [74]. It means that not all moisture which is adsorbed by the textile fiber would be evaporated during desorption but some moisture can be retained in the fiber during the process [75].

The moisture regain of desorption is higher than that of adsorption, which was indicated for some common fibers, such as viscose rayon, cotton, nylon, acrylic and polyester [74]. Similar results for both novel rayon fabric and regular rayon fabric in this study were presented again.

Several explanations for the hydroscopic hysteresis of cellulosic materials or other biomaterials have been proposed. A theory of the change in availability of active polar sites for the bonding of water molecules suggested that the polar sites in the molecular structure of the material were almost satisfied by adsorbed water in the original wet condition. Upon drying and shrinkage, the molecules and their water-holding sites were drawn closely enough together to satisfy each other. This reduced the water-holding capacity of the material upon subsequent adsorption [76, 77], so that the moisture content of desorption was higher than that of adsorption.

Regarding the moisturizing effect of textiles, there were two main factors to determine the degree of moisturizing effect. One was whether the textiles were high hygroscopic, and the other was whether the textiles had the strong water holding capacity [78]. In order to present the combining effects of both AR and DR, a new variable of moisturizing value (MV%) was defined as follows:

$$MV\ (\%) = AR\ (\%) + DR\ (\%) \tag{4}$$

However, both AR (%) and DR (%) of novel rayon fabric were higher than that of regular fabric at same RH (%) (Table 5), so the MV (%) of novel rayon fabric was obviously better than that of regular rayon fabric. Interestingly, these two kinds of fabrics were almost the same composition ratio of MV (%): 45.60% of AR and 54.40% of DR (Table 5).

Table 5 Percentage of absorption (AR), desorption (DR), moisturizing value (MV) and its relative percent with relative humidity for novel rayon fabric and regular rayon fabric

Relative humidity (%)	Novel rayon fabric					Regular rayon fabric				
	AR% (*A*)	DR% (*B*)	MV% (*C*)	$\frac{A}{C}\times 100$	$\frac{B}{C}\times 100$	AR% (*A*)	DR% (*B*)	MV% (*C*)	$\frac{A}{C}\times 100$	$\frac{B}{C}\times 100$
40	16.61	20.24	36.85	45.07	54.93	15.83	19.16	34.99	45.24	54.76
60	21.01	25.07	46.08	45.59	54.41	19.51	23.38	42.89	45.49	54.51
80	25.35	29.59	54.94	46.14	53.86	24.56	28.69	53.25	46.12	53.88
Average	20.99 ± 4.37	24.97 ± 4.68	45.96 ± 9.05^a	45.60 ± 0.54	54.40 ± 0.54	19.97 ± 4.38	23.74 ± 4.78	43.71 ± 9.16^b	45.62 ± 0.45	54.38 ± 0.45

The different superscripts indicate significant difference ($p < 0.05$)

Furthermore, comparing MV (%) between these two kinds of fabrics, the mean MV (%) of the novel rayon fabric and the regular rayon fabric was 45.96% and 43.71%, respectively, i.e., the degree of MV (%) of the former was 5.15% more than that of the latter (Fig. 5).

ANOVA test showed that the two means were significant difference ($p < 0.05$), and the mean moisturizing value for relative humidity under the two nests were also showed significant difference ($p < 0.05$) (Table 6).

The mean moisturizing value under the nest of novel rayon fabric were 36.86% for 40% RH, 46.07% for 60% RH, and 54.95% for 80% RH, respectively. The pairwise comparisons between relative humidity showed 80% RH > 60% RH > 40% RH, and the mean moisturizing value under the nest of regular rayon fabric were 34.99% for 40% RH, 42.89% for 60% RH, and 53.25% for 80% RH, respectively.

The pairwise comparisons between relative humidity also showed 80% RH > 60% RH > 40% RH. However, the means of the novel rayon fabric and the regular rayon fabric at same 40% RH and 80% RH were not significant difference, while there was still significant difference at same 60% RH (Fig. 6) ($p < 0.05$).

However, it also indicated the degree of moisturizing value of the novel rayon fabric was 5.34% (= 36.86%/34.99%—1) more than that of the regular rayon fabric at 40% RH, and the former was 7.41% (= 46.07%/42.89%—1) and 3.19% (= 54.95%/53.25%—1) more than that of the latter at 60% RH and 80% RH, respectively.

Furthermore, fish scales have little value in general and are usually discarded. Making use of them in the manufacturing of clothing reduces waste, thereby protecting the environment. In addition, fisheries may benefit from the value added to their product.

Studies investigating moisturizing effects under much drier environments and testing wearer comfort are warranted.

4 Conclusions

A new variable, fabric MV, that combines the moisture regains of adsorption and desorption was suggested in this study.

The MV of the novel rayon fabric and the regular rayon fabric increased with the increase in RH. The moisturizing effect of the novel rayon fabric with collagen peptides was better than that of the regular rayon fabric. Therefore, the novel rayon fabric may be suitable for preventing dry skin in winter.

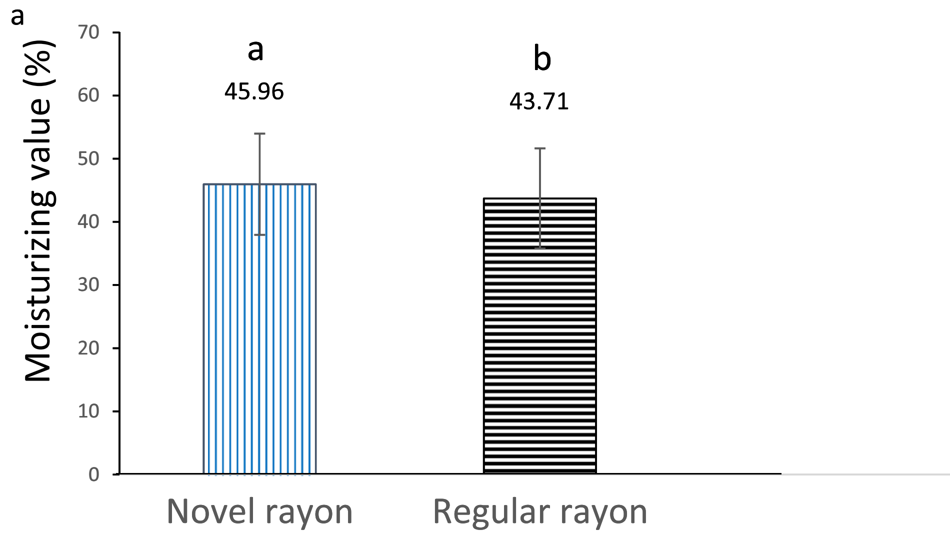

Fig. 5 The mean of moisturizing value of two fabrics. The different superscripts are significant difference (ANOVA test, $p < 0.05$)

Table 6 Nested analysis of variance for moisturizing value on novel fabric and regular fabric as well as 40%, 60%, and 80% relative humidity

Sources	DF	Sum of squares	Mean squares	F value	$F_{0.05}$	$p(F)$
Fabric	1	22.7800	22.7800	11.2050	4.7470	< 0.05
Relative humidity	4	994.0640	248.5160	122.2410	3.2590	< 0.05
Error	12	24.3900	2.0330			
Total	17	1041.2340				

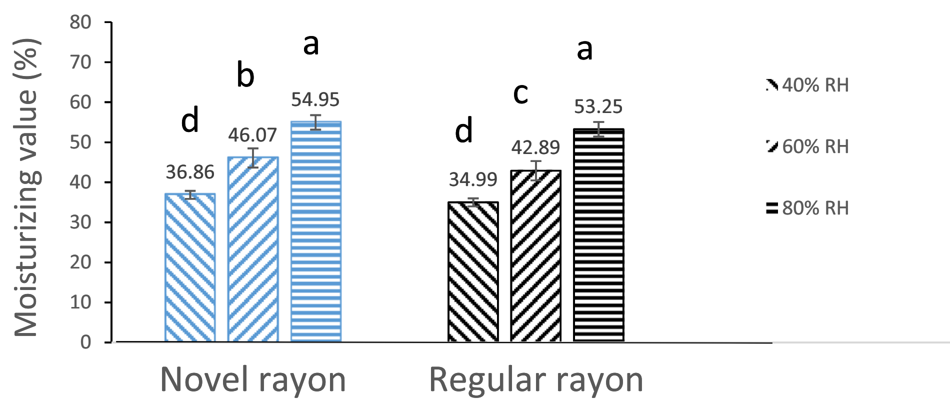

Fig. 6 The moisturizing value of two fabrics at various relative humidity. The same superscripts are not significant difference, but the different superscripts are significant difference (Duncan's new multiple range test, $p < 0.05$)

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Declarations

Conflicts of interest The authors declare that there are no conflicts of interest. The authors are responsible for the contents of this paper.

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