Research Article *Science, Engineering and Health Studies 2018, 12(2), 103-110*

Performances of fixative polymers for the virgin Thai hair

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Received: December 27, 2017; Accepted: July 18, 2018

ABSTRACT

Hair fixative gels are widely used to create and maintain a variety of hairstyles. The fixative polymer plays a crucial role in the formulation to provide hair styling performances which are hardness (stiffness) and hold (curl retention). Many generations of polymers have different humidity resistance properties, which determine both the holding power and the lack of tack in humid climates. This study was, therefore, to evaluate the performances of the fixative polymers which were frequently used in commercial hair gels in Thailand. In addition, the impact of humidity on the polymers was investigated. The polymers were chosen based on the survey of hair gel ingredients. Fixative performances i.e. stiffness and curl retention were tested in the virgin Thai hair. Among 25 hair styling products, polyacrylic acid and polyvinylpyrrolidone (PVP) were the most popular followed by acrylates copolymer, polyvinylpyrrolidone/vinyl acetate (VP/VA) copolymer, polyquaternium-86, respectively. Polyacrylic acid showed the highest stiffness and curl retention referring to the best performances for hair styling products. PVP K-90 was another interesting polymer that provided a good stiffness for Thai hair while polyquaternium-86 was good at curl retention. Furthermore, the polymer characteristics were changed by the high humidity condition depended on resistance ability to water of each polymer. The humidity resistance was found in the hair treated with VP/VA copolymer or VP/methacrylamide/vinyl imidazole copolymer.

Keywords: fixative polymer; gels; Thai hair; stiffness; curl retention

1. INTRODUCTION

The hair styling market has realized steady growth every year and is expected to reach 90 billion U.S. dollars by the end of the decade. Hairstyle trends dictate the consumption behavior of consumers who prefer a hair styling product which fulfils their needs. Nowadays, the styling product with stiff texture and strong hold is one of the most popular products. Hair fixative gels are widely used to create and maintain a variety of hairstyles. The fixative polymer plays a crucial role in the formulation to provide hair styling performance which are hardness (stiffness) and hold (curl retention). When a gel is applied to the hair, a polymer–fiber composite is created that is similar to high performance fiber composites which are used in load-bearing applications (Rafferty et al., 2008). However, many fixative polymers are sensitive to moisture from humidity, rain or sweat and this causes the hair to lose its style prematurely. The development and improvement of hair fixative polymers were continuously studied (Martiny, 2002; Wood et al., 2004; Rigoletto et al., 2007; Rafferty et al., 2008;

ISSN Online 2630-0087 DOI: https://doi.org/10.14456/sehs.2018.7

Hoessel et al., 2014; Lochhead, 2017). Among these publications, most of them investigated fixative performances on Caucasian hair. The findings might not directly and practically imply to Asian or Thai hair which is much thicker. Franboug et al. measured the cross section area of African, Asian and Caucasian hair (Franbourg et al., 2003). The cross section area was found to be 4274 ± 215, 4804 ± 159 and 3857 ± 132 µm2, respectively. Additionally, the weather is warm and humid in Thailand. The information about fixative performance on the Asian or Thai hair is necessary for research and development of hair care products. Therefore, this study was aimed to evaluate the major fixative performances, stiffness and curl retention properties, of fixative polymers that were available in commercial hair gels in Thailand. This study was proceeded with the condition that imitated Thailand's climate. The polymers were also investigated the fixative performance based on the virgin Thai hair. The stiffness was carried out by a three-point bending method in the ambient condition and high humidity. Curl retention and water absorption were proceeded in the cabinets controlled humidity at 75% RH and 95% RH.

2. MATERIALS AND METHODS

2.1 Materials

Polyacrylic acid was purchased from Lubrizol Advanced Materials, Inc. (Carbopol® 940, Ohio, USA). The following chemicals were obtained from the commercial supplier (The Sun Chemical Co., Ltd., Thailand) and used as received: polyvinylpyrrolidone (PVP K-30, PVP K-90) (Luviskol® Pulver, BASF SE, Ludwigshafen, Germany); vinylpyrrolidone (VP) vinyl acetate copolymer (VA) (Luviskol® VA 37E, BASF SE, Ludwigshafen, Germany); acrylates copolymer (Luvimer® 100 P, BASF SE, Ludwigshafen, Germany); polyquaternium-86 (Luvigel® advanced, BASF SE, Ludwigshafen, Germany); VP/Methacrylamide/vinyl imidazole copolymer (Luviset® Clear AT 3, BASF SE, Ludwigshafen, Germany); and 2-amino-2-methyl-1-propanol (AMP-90, The Sun Chemical Co., Ltd., Thailand)

2.2 Selection of fixative polymers

Hair styling gels commercially available in the hypermarket were surveyed. Product information of each gel product was obtained. Each fixative polymer was counted and reported as frequency of using. The polymers frequently used in these commercial gels were selected to evaluate the performance including stiffness and curl retention in this study.

2.3 Fixative gel preparation

The fixative polymers were prepared to water-based gel preparation at a concentration of 3% w/w of solid polymer. Each polymer was accurately weighted in 3 g and dispersed into the water. Acrylates copolymer was insoluble in water. The neutralizer, AMP, was used to react with acidic moieties in the polymer molecule to form salt, resulting in clear gel preparation. Weight of all formulations was adjusted to 100 g using water.

2.4 Hair sample and hair preparation

The study protocol was approved by Naresuan University Human Ethics Committee (Approval No. NU-IRB0633/60). Hair sample used in this study was virgin straight hair and was obtained from voluntary Thai woman with age of 20 years old. The hair of twenty centimeters in length was collected, cleaned with shampoo, rinsed in 25°C tap water and dried at room temperature.

2.5 Stiffness test

The stiffness test was adapted from the previous study (Rafferty et al., 2008). The stiffness of the fixative–hair composite samples was performed using a texture analyser (TA.XT.plus®, Stable Micro Systems, Godalming, UK) in a three-point bending configuration. Composite samples for this test were prepared by applying 3 g of the fixative gel to the hair tresses (2 g in weight and 16 cm in length). Application and distribution of the gel was done with the tress on a balance to ensure accurate loading. The prepared tresses were placed on the Teflon-coated plates to maintain a flat, rectangular geometry while the samples were dried for 24 h at 35°C, 65±5% RH. Furthermore, to study on the influence of humidity condition, the dried tresses were stored 24 h at 35°C, 95±2% RH. Testing of hair tresses from two conditions was done by texture analyser with support span of 3 cm and a flexure rate of 40 mm/s (Figure 1). Peak force was used as a measure of stiffness. The graphs were plotted between forces versus time. The stiffness test was performed in triplicate.

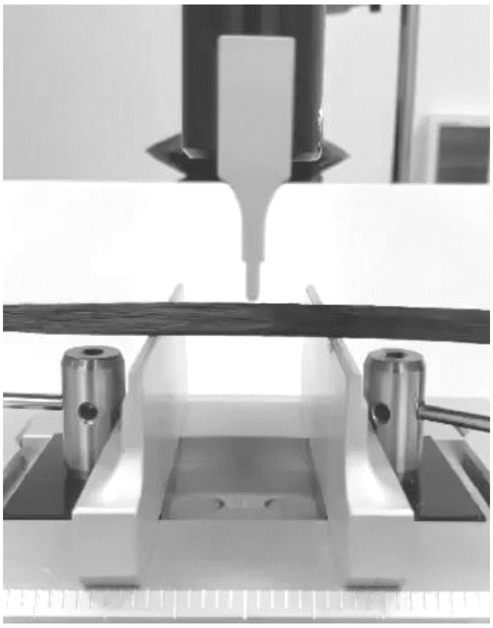

Figure 1 Stiffness test of fixative–hair composite samples by TA.XT. Plus® Texture Analyser with three-point bending rig

2.6 Curl retention

Spiral curl retention testing was adapted from the high-humidity spiral curl retention testing (Rafferty et al., 2008). The test was performed on fixative–hair composite samples. The fixative gel samples (2 g) were applied to the hair tress 1.5 g in weight and 16.5 cm in length. To ensure accurate loading, gel was applied and distributed to the tress on a balance. The treated tresses were wrapped onto curlers with a spiral groove, secured, and dried for 24 h at 35°C, 65±5% RH (Figure 2A). The dried tresses were tenderly unwrapped (Figure 2B) and hung on a ruled peg board. The initial length of the curls was recorded, and the peg board assembly was placed into humidity cabinets (75% RH and 95% RH), controlled temperature at 35°C. At predetermined time points, the length of the curls was measured. The curl retention was calculated using the following equation:

$$\% \text{ Curl retention} = [(L - L_t) / (L - L_o)] \times 100 \qquad (1)$$

where L is the length of the uncurled tress, L_t is the length of the curl at the time of the reading, and L_o is the length of the curl at the start of the experiment. The length of the tress is denoted as the lowest line number (on the peg board) that is below the entire tress. Ten replicates were tested, and the averages were reported.

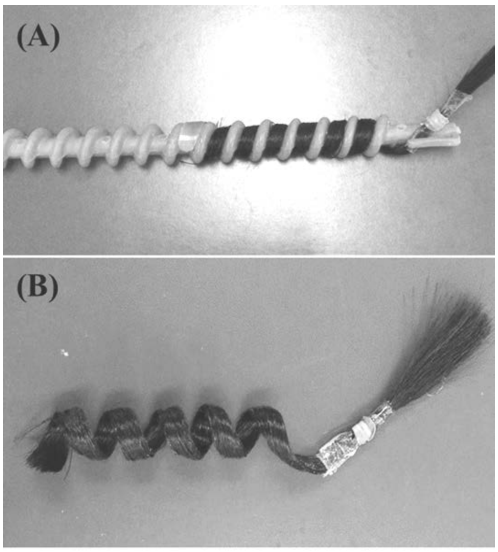

Figure 2 (A) Tresses curled around spiral curlers for the curl retention test and (B) curled tresses after removing from the spiral curling rods

2.7 Water absorption

Water absorption of fixative–hair composite samples were carried out during the curl retention testing. The initial weight of the curls was recorded, and the peg board assembly was placed into humidity cabinets (75% RH and 95% RH) controlled temperature at 35°C. The weight of the curls was measured at predetermined time points. The water absorption was calculated using the following equation:

$$\% \text{ Water absorption} = [(W_t - W_0) / W_0] \times 100 \qquad (2)$$

where W_t is the weight of the curl at the time of the measuring, and W_0 is the weight of the curl at the start of the experiment. Ten replicates were tested, and the averages were reported.

3. RESULTS AND DISCUSSION

Hair styling gels commercially available in the hypermarket were surveyed. The frequently used fixative polymers in these products were selected to evaluate the performance in this study. From the surveyed, 25 products of hair styling gels under 15 brands were found. The fixative polymers commonly used in these products are presented in Figure 3. Polyacrylic acid was used at the highest rate (22 in 25 products). One of important role of this polymer is to provide a good gel formulation. It has great ability to thicken, suspend and stabilize aqueous formulations (Lochhead, 2017). The use of PVP was the second highest as the fixative polymer for hair styling product in the market. PVP is compatible with all commonly used personal care ingredients, stable across the pH range and tolerant to salt (Martiny, 2002). However, acrylates copolymer, VP/VA copolymer and polyquaternium were used at the lower frequency compared to polyacrylic acid and PVP. These three fixative polymers are new types of hair styling polymer to achieve improved performance of gels. All fixative polymers were investigated for their performance in this study. In addition, VP/methacrylamide/vinyl imidazole copolymer, a another polymer which exhibited a good performance for hair styling products (Wood et al., 2004) was also included in this study.

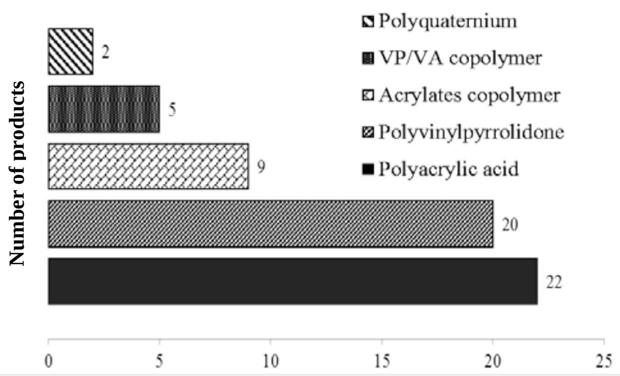

Figure 3 Frequency plot of the commonly used fixative polymers in 25 commercial products of the hair styling gels

3.1 Stiffness test

In stiffness tests, fixative–hair composite samples of each polymer were evaluated and compared when applying on virgin Thai hair tresses and kept at dry and high humidity condition (stored at 35°C and 95±2% RH for 24 h). Stiffness of a sample was evaluated and reported as the peak force (N). High peak force represents the performance of fixative polymers to style and/or hold a hair set. The results in Figure 4 showed that at the concentration of a polymer at 3% w/w, PVP K-90 and polyacrylic acid provided the greatest peak force compared to other fixative polymers at ambient condition. This implied that PVP K-90 and polyacrylic acid could give the highest stiffness to the virgin Thai hair tress. The stiffness of fixative polymer was in the order PVP K-90 > polyacrylic acid > VP/VA copolymer > VP/methacrylamide/vinyl imidazole copolymer ~ acrylates copolymer > polyquaternium-86 > PVP K-30. However, the stiffness of PVP K-90 and polyacrylic acid dramatically dropped in the high humidity condition. This may be explained by the fact that hydrophilic polymer is hygroscopic: therefore, it absorbs moisture from the atmosphere (Martiny, 2002). The polymer films on hairs become soft and sticky due to the plasticizing effect of the water molecule in the polymer films. Thus, the ability to style and/or hold the hair tresses is decreased. The stiffness of the hair tresses applied with VP/VA copolymer and VP/methacrylamide/vinyl imidazole copolymer exhibited the highest peak force under high humidity condition. This might be explained by the humidity resistant property of these two polymers (Wood et al., 2004; Lochhead, 2017). Different fixative polymers have different film hydrophobicity. When fixative gels are dried, the polymer becomes coated film on the hair surface which provides humidity resistant effect.

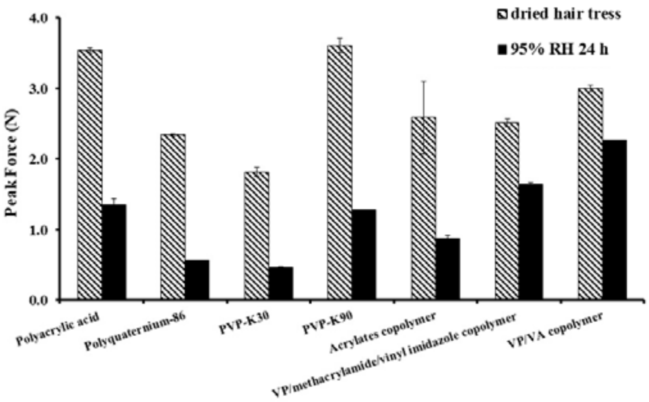

Figure 4 Effect of humidity on stiffness of the hair tresses treated with gels prepared using 3% w/w of fixative polymers

3.2 Curl retention

High humidity resistance is a necessary property of fixative polymers for creating and maintaining a hairstyle (i.e. curl retention). This study was conducted to determine the humidity resistance of a hair gel containing 3% w/w fixative polymers. The study involved treating the curls with the selected fixative polymers. The curls were stored in humidity cabinets (75% RH and 95% RH) and monitored at 35°C. The curl retention of fixative–hair composite samples with various polymers was investigated. High percentage of curl retention is directly related to the good hold properties of the fixative polymer. As shown in Figure 5A, polyacrylic acid and polyquaternium-86 gave the best curl retention followed by VP/methacrylamide/vinyl imidazole copolymer > VP/VA copolymer ~ PVP K-90 > Acrylates copolymer > PVP K-30. The curl retention substantially decreased as a function of time due to weight of the hair tress itself. Additionally, the humidity was another main factor on the holding property. Increasing humidity to 95% RH clearly showed faster decrease of curl retention value (Figure 5B and 6). This finding might be explained by heavier curls by the water. The water in the air can penetrate and act as plasticizer for the proteins at the hair surface and cause hair to heavier and droop (Robbins, 1994). In addition, water was a plasticizer for fixative polymers led to soften polymer film and low holding ability. The high performance in curl retention of polyquaternium was reported in an earlier publication (Rigoletto et al., 2007), polyquaternium-69 provided hydrophilic-hydrophobic balance which led to a high humidity curl retention, increased durability of hold, and anti-frizz effects under high humidity.

3.3 Water absorption

Since the humidity was the one of main factors for hair polymer performances, the water absorption fixative–hair composite samples was measured. The obtained results are shown in Figure 7. The increasing weight represents water absorption on the hair tresses. Weight of the hair tresses was increased to 3-4% at 75% RH and 7-8% at 95% RH. These findings were in agreement with the decrease of stiffness and curl retention as discussed above. Interestingly, VP/VA copolymer exhibited the lowest water absorption because of its hydrophobic property. The hydrophobicity of the polymer provides a water resistant film which retards the negative effect of water absorptivity (Rigoletto et al., 2007). There finding was in agreement with the stiffness test which showed the lowest stiffness change when the humidity increased from 75% RH to 95% RH (Figure 4).

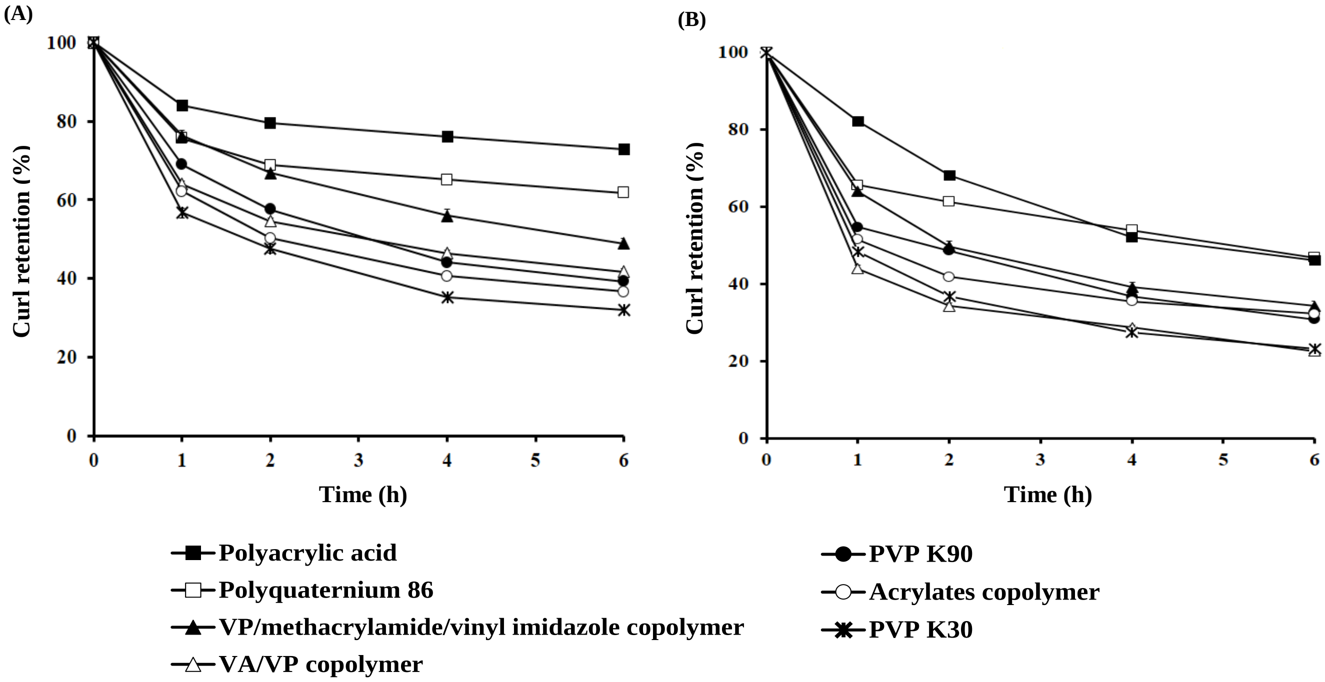

Figure 5 Curl retention of hair tresses treated gels prepared using 3% w/w of fixative polymers and kept under 75% RH condition (A) and 95% RH condition (B), controlled temperature at 35°C

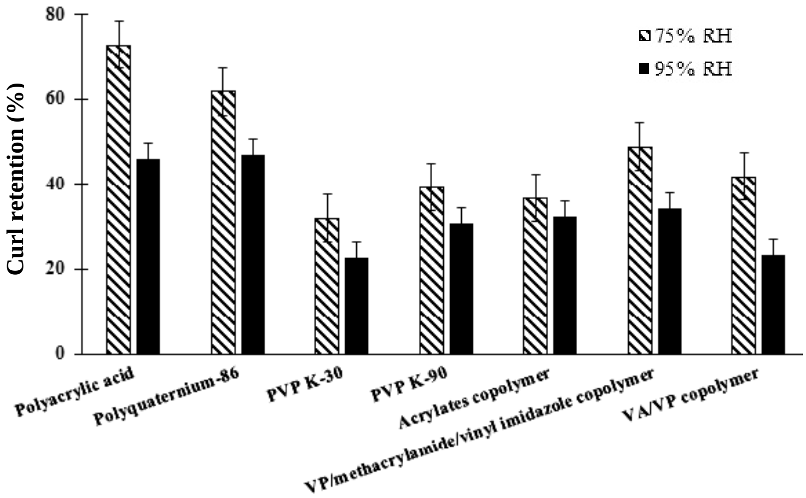

Figure 6 Effect of humidity on curl retention of hair tresses treated with gels prepared using 3% w/w of fixative polymers stored in the controlled humidity chamber at 35°C for 6 h

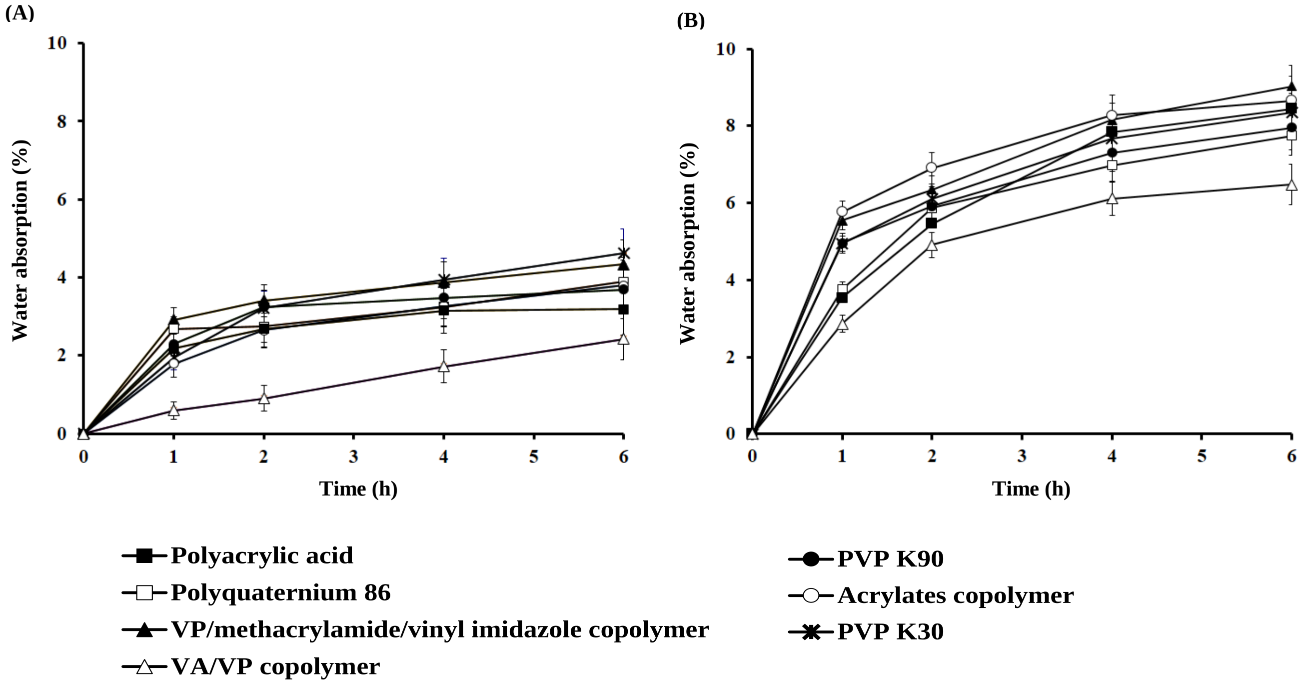

Figure 7 Effect of humidity on water absorption of hair tresses treated with gels prepared using 3% w/w of fixative polymers stored under 75% RH condition (A) and 95% RH condition (B), controlled temperature at 35°C

3.4 Fixative polymer characteristic

The most important fixative characteristic could be described by the correlations of stiffness and curl retention. Stiffness value represents the ability of a fixative polymer to style and /or hold the hair tress after applying with the gels prepared by each fixative polymer. While, curl retention represents the ability of a polymer to maintain the style for a period of time. Figure 8 exhibits characteristic of the fixative polymer at 3% w/w solid. At low-humidity condition (Figure 8A), polyacrylic acid showed the highest stiffness and curl retention which refer to the best performances for hair styling products. However, the limitation of this polymer was high viscosity of gel formulation when adding at high concentration. PVP K-90 was another interesting polymer that provided a good hardness for Thai hair while polyquaternium-86 was good at holding hair. In the high humidity condition, the polymer characteristic was changed due to the resistance ability to water of each polymer. The impact of the humidity is summarized in Figure 8B.

4. CONCLUSION

Among 25 commercial hair styling gels, polyacrylic acid and PVP were commonly used as a fixative polymer. Polyacrylic acid exhibited good fixative performances for hair styling products, high stiffness and curl retention. PVP K-90 was polymer that provided a good hardness for Thai hair while Polyquaternium-86 showed a good hold property. The high humidity condition could make some fixative polymer soft and sticky led to decrease in stiffness and curl retention. These finding in this study will benefit to the research and development of hair styling product manufacturing in Thailand.

5. CONFLICT OF INTEREST

The Sun Chemical Co., Ltd. is one of the financial supports of this research. The study has been handled independently of the Sun Chemical Co., Ltd.

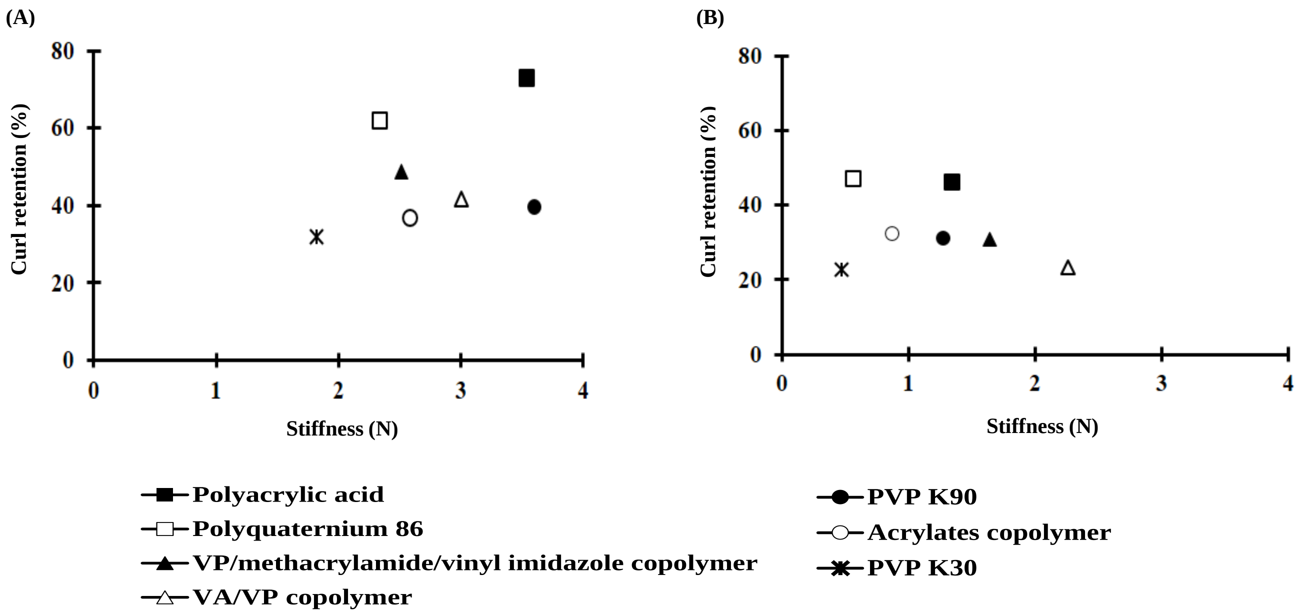

Figure 8 Fixative polymer characteristic on virgin Thai hair under 75% RH condition (A) and 95% RH condition (B), controlled temperature at 35°C

ACKNOWLEDGEMENTS

This work was financially supported by research funds from Faculty of Pharmaceutical Sciences, Naresuan University and the Sun Chemical Co., Ltd. The authors also wish to thank the Sun Chemical Co., Ltd. for providing the fixative polymers.

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