

USING OF BABY POWDER BASED TALC AS A THIN LAYER CHROMATOGRAPHY ADSORBENT: TEACHING CHEMICAL EXPERIMENT

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Abstract. The aim of this paper is to check whether the thin layers prepared by powder containing talk and two different solvents are suitable for thin layer chromatography (TLC) and convenient to prepare slurries. The separability of the components of a commercial ink has been tested successfully.

Keywords: analytical chemistry, separation science, chromatography, TLC.

Introduction

Chromatography is one of the most important analytical techniques used to separate components of mixtures. In chromatographic separations and teaching chromatography the thin layer chromatography (TLC) is often used as a quick, easy and simple method. There are numerous applications of TLC for the qualitative and quantitative analysis of components of natural and artificial mixtures [1-7].

The effective separation by TLC depends on the properties of the sample, and on those of the mobile and stationary phases. The best representation of the relation between properties of the sample, mobile phase and stationary phase is given by Stahl's diagram in Fig. 1. In the diagram, the angles of the triangle correspond to the properties of the sample, and the stationary and mobile phases. The appropriate conditions for a good separation are determined by rotating the triangle [8-11]. The characteristics of the stationary phase are physical parameters such as particle size and distribution, particle shape, pore size and pore distribution and specific surface area (a_s), and chemical parameters such as surface hydroxyl group density, $\alpha_{OH(s)}$ [9, 10].

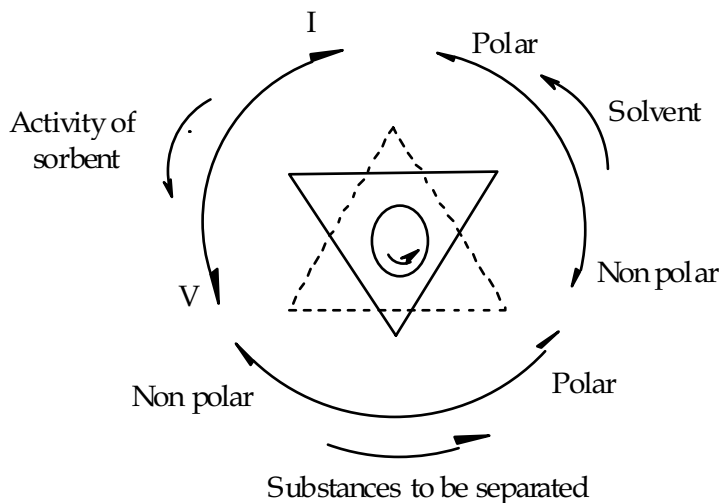


Figure 1. Stahl's diagram for choosing experimental conditions for TLC

A number of materials have previously been used as TLC adsorbents: activated bentonite [12], kaolinite [13], china clay [14], activated bleaching earth [15] and modified perlite [16], modified diatomite [9, 10]. Silica gel and alumina have been used most frequently as adsorbents for separation to the components of the mixtures in TLC applications. On TLC teaching, adsorbent materials should be inexpensive and easily available. Besides, commercial baby powders are easily available products, and they are mixtures based on talc or corn starch as major components. Some commercial baby powders and their contents are given in Tables 1 and 2. Talc as a major component of baby powder is a magnesium silicate mineral with the composition $Mg_3[Si_4O_{10}](OH)_2$ and a layered lattice structure. Its available surface for absorption markedly depends on particle size. Talc has been used as a TLC adsorbent to separate fatty acids, lanatosides, amino acids, the sugars and the flavonoids [11, 17]. Thus, it is reasonable to use baby powders based talc as TLC adsorbents. On the other hand, adsorbent slurries on TLC applications can be prepared with water or with any convenient solvent. For example, silica gel and alumina slurries are prepared using water [11].

Trademark of Baby Powder	Ingredients	
	Absorbent	Other Substance
Bebeten	Talc, ZnO kaolin, magnesium stearate	Fragrance
Baby Magic	Corn starch, NaHCO ₃ , Ca ₃ (PO ₄) ₂	Aloe Vera Gel, Fragrance
Johnson's Baby Powder	Corn starch, ZnO	Fragrance
Johnson's Baby Powder	Talc	Fragrance
Johnson's Baby Powder	Corn starch	
Johnson's Baby Powder	Corn starch, Ca ₃ (PO ₄) ₂	Fragrance
Johnson's Baby Powder	Corn starch, Ca ₃ (PO ₄) ₂	Aloe barbadnesis, Tocopherly Acetate (vitamin E), Fragrance
Caldesene	Talc, 81%, ZnO 15%	-
Eckerd	Talc	Fragrance
Eckerd	Corn starch, Ca ₃ (PO ₄) ₂	Fragrance
Eckerd	Corn starch 95.5%, Ca ₃ (PO ₄) ₂	Aloe barbadnesis, Tocopherly Acetate (vitamin E), Fragrance
Gold Bond	Corn starch, ZnO Kaolin	Fragrance, Silica

Composition	%
Talc	95.85
Zinc oxide	3.00
Magnesium stearate	0.50
Kaolin	0.35
Parfum capricci	0.30

In practice, the baby powder based talc has not been investigated yet. Therefore, the aim of this study is to check if the thin layers prepared by baby powder based talc

and two different solvents are suitable for TLC and convenient to prepare slurries. In addition, separability of commercial ink components on these layers has been tested.

Experimental

Chemicals, reagents, materials

Si-60GF₂₅₄, n-butanol, ammonia, acetic acid and ethanol were purchased from Merck (Darmstadt, Germany). Baby powder of Bebeten trademark was used to prepare thin layers. Red and blue inks of Pelikan 4001 were used as the sample on TLC applications.

2 mol L⁻¹ ammonia solution was prepared by adding distilled water to 150.4 mL of ammonia (d = 0.904 g/mL, 25%) on 1.0-L volumetric flask. Butanol-ethanol-2M ammonia (3:1:1, v/v) and butanol-acetic acid-water (12:3:5, v/v) mixtures were used as mobile phases. Si-60GF₂₅₄ and baby powder based talc were used as stationary phases. The plates were prepared using a Loughborough-Griffin&George, TLC Unikit (Leicestershire, England). All the chemicals were of analytical grade.

Chemical safety

All of the solvents except for water have high vapor pressure. Therefore, an extra care should be given for handling and storing those solvents. If a chemical fume hood is not available, the experiments should be done in an area with adequate ventilation. Both silica gel and baby powder are said to be finely powdered substances and their inhalation should be avoided.

Preparation of thin layer plates from baby powder with ethanol

Slurries of baby powder in ethanol (1:1.5, w/v) were spread onto clean glass plates (7.5x15 cm) with a thickness of 250 μm using a spreader kit. Non-activated plates were obtained by keeping the plates at room temperature for 2 h. They were activated by heating in an oven at 110°C for 1 h. For TLC applications, activated plates were used.

Preparation of thin layer plates from baby powder with distilled water

Slurries of baby powder in water (1:2, w/v) were spread onto clean glass plates (7.5x15 cm) with a thickness of 250 μm using a spreader kit. Non-activated plates were obtained by keeping the plates at room temperature for 12 h. They were activated by heating in an oven at 110°C for 2 h. Non active and activated plates were rough, cracked and beige. Therefore, they may not be used for TLC applications.

Preparation of thin layer plates from Si-60GF₂₅₄ with distilled water

Slurries of Si-60GF₂₅₄ in water (1:2, w/v) were spread onto cleaned glass plates (7.5x15 cm) with a thickness of 250 μm using a spreader kit. Non-activated plates were obtained by keeping the plates at room temperature for 12 h. They were activated by heating in an oven at 110°C for 2 h. For TLC applications, activated plates were used.

TLC applications

The red and blue ink samples and a mixture of both (1:1, v/v) were spotted with micropipettes on the starting line which was 2 cm from the bottom of the plate. The original spots on the layers were dried at room temperature for 5 min. A pencil line was marked 8 cm above the starting line of each plate. Two developing chambers measuring 10x50x20 cm were used. Sixty milliliters of butanol-ethanol-2M ammonia (3:1:1, v/v) was poured into one chamber and 60 mL of butanol-acetic acid-water (12:3:5, v/v) into the other. The lids of the chamber were closed and the chambers allowed standing for 25 min to ensure saturation of the air in each chamber with solvent vapors. Then, the Si-60GF₂₅₄ plates with their ink samples were carefully immersed in the chambers. The plates, which were taken out of the chambers when the solvent fronts reached 8.0 cm above the starting line of each plate, were dried. The migration distances of the solvent (Z_p) and of each spot (Z_x) were then measured. The retention factors (R_f) of the ink components were calculated from $R_f = Z_x/Z_p$ (9, 10). The same procedure was also applied to activated baby powder layers. From the chromatograms, the R_f values of ink components are given in Table 3 and 4.

Table 3. The R_f values for red and blue ink components and ΔR_f values for their couples obtained by using a butanol:acetic acid:water mixture (12:3:5, v:v:v) as the mobile phase on Si-60GF₂₅₄ and baby powder layers

R_f , Component	Si-60GF ₂₅₄	Baby powder	ΔR_f , Si-60GF ₂₅₄	ΔR_f , Baby powder
R_f , Pink	0.91±0.05	0.91±0.05	0.53	0.24
R_f , Yellow	0.38±0.02	0.67±0.03		
R_f , Green	0.56±0.03	0.67±0.03	0.07	0.59
R_f , Dark blue	0.49±0.03	0.08±0.01		

Table 4. The R_f values for red and blue ink components and ΔR_f values for their couples obtained by using a butanol:ethanol:(2M)ammonia mixture (3:1:1, v:v:v) as the mobile phase on Si-60GF₂₅₄ and baby powder layers

R_f , Component	Si-60GF ₂₅₄	Baby powder	ΔR_f , Si-60GF ₂₅₄	ΔR_f , Baby powder
R_f , Pink	0.71±0.04	0.86±0.04	0.31	0.14
R_f , Yellow	0.40±0.02	0.72±0.04		
R_f , Green	0.56±0.03	0.54±0.03	0.00	0.49
R_f , Dark blue	0.56±0.03	0.05±0.01		

Discussion and results

Samples from different natural and synthetic sources contain various compounds as major and minor components. Many of these compounds may have very similar physical and chemical properties. In such cases, sample components generate mutual interference spectra in qualitative, quantitative and structural analyses. Therefore, in analytical operations, interfering compounds with similar properties have to be well separated. TLC is extensively used for organic compounds but its use for inorganic cation separations is relatively uncommon [7, 9].

Successful TLC separation depends on the properties of the sample, and also those of the mobile and stationary phases. Finding suitable resolution for a TLC application involves usually by changing the properties of mobile phase only. It does not involve by changing the properties of stationary phase although a possibility sorbent is present to change the properties of stationary phase. In this study, the properties of baby powder based talc and Si-60GF₂₅₄ layers are investigated to understand the effects of kind and amount of solvent which is used to prepare adsorbent slurries as a contribution to undergraduate TLC teaching. Another aim of the study, the chromatographic behaviors of components of commercial ink samples are investigated to give a comprehensive understanding of the effects of changing of stationary phase properties and also those of the mobile phase such as polarity and acidity, on R_f values and separability of the components.

TLC applications were carried out through Si-60GF₂₅₄ and baby powders containing talc. Commercial red and blue ink samples were chosen because of their low cost and availability. In addition, their developed spots can be determined easily with the naked eye. Therefore, they are used in teaching TLC as samples. Due to the ink components being acidic, basic or neutral, and also soluble in water, basic butanol-ethanol-2M ammonia (3:1:1, v/v) and acidic butanol-acetic acid-water (12:3:5, v/v) mixtures were used as mobile phases.

The composition of baby powder used in this study has been given in Table 2. As is seen in Table 2, as a major adsorbent component of baby powder, the talc exists 95.85 %, as a minor adsorbent the zinc oxide, ZnO, exists 3.00 %. In spite of low amounts, magnesium stearate and kaolin are present, as well. In fact, in stationary phase, it is ideal to use only one component. However, in reality, this condition may not work. At least, the layers are desired not to react with components of the sample chemically. In this context, it is important to explain that a new TLC layer is not reacted with components of the sample with respect to prerequisites of TLC teaching. Since pure talc is used on TLC applications, it is plausible to use baby powder containing those main components on TLC application and teaching, as well.

The experimental practice shows that thin layers from slurries with ethanol dried shorter than those with distilled water at room temperature. The experiments have

been resulted in (1.5:1, w/v) value for ratio baby powder weight (g) to ethanol volume (mL). The pictures of activated layers from ethanol and distilled water were given in Figs. 2a and 2b, respectively.

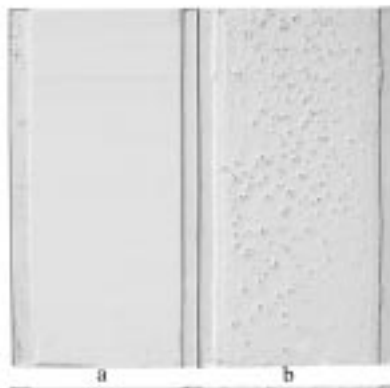


Fig. 2. a) Picture of thin-layer prepared by mixing baby powder with ethanol.
b) Picture of thin-layer prepared by mixing baby powder with distilled water.

As is shown in Figure 2a, activated layers from ethanol are smooth, homogeneous, crack-free, beige, and adhered to glass support. Also in Fig. 2b, activated layers from distilled water have been adhered to glass support, but they are non-homogeneous, rough with crackles. While gas bubbles occur in slurries based distilled water, they do not occur in those based ethanol. Observation of gas bubbles has indicated presence of surfactants (0.50 % magnesium stearate and parfum capricci 0.30 %) besides talc and ZnO in the baby powder. Surfactants in baby powder have resulted in reducing surface free energy and formation of gas bubbles. Gas bubbles on slurry surface have led to the formation of rough thin layers with crackles, which are not useful for TLC applications. Therefore, in order to prevent the formation of gas bubbles, surfactants should be removed from adsorbent surface by adding suitable solvent. Hence, surface free energy of slurries is increased. As a result, while thin layers from ethanol slurries are suitable for TLC, those from distilled water are not.

In this study, to investigate the chromatographic behavior of components, commercial ink samples were run on the selected stationary phases with acidic and basic mobile phases. The chromatograms are given in Fig. 3 and Fig. 4 for baby powder and Si-60GF₂₅₄ respectively.

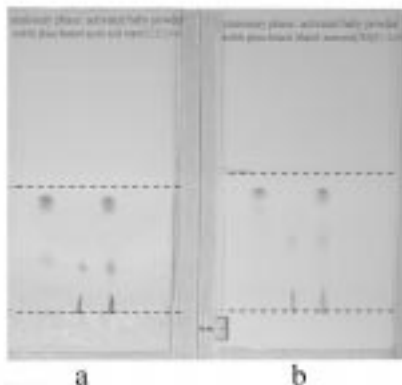


Fig. 3. Chromatograms of ink samples on activated baby powder plates, **(a)** with butanol:acetic acid:water mixture (3:1:1, by v/v). **(b)** with butanol:ethanol:ammonia (2M) mixture (12:3:5 by v/v). [1:red ink, 2:blue ink, 3:mixture of 1 and 2].

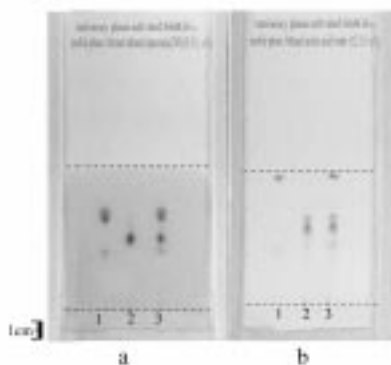


Fig. 4. Chromatograms of ink samples on activated Si-60GF₂₅₄ plates, **(a)** with butanol:ethanol:ammonia (2M) mixture (3:1:1, by v/v) **(b)** with butanol:acetic acid:water mixture (12:3:5 by v/v). [1: red ink, 2: blue ink, 3: mixture of 1 and 2].

As is seen in Figure 3a and 3b, in baby powder based talc layers, the red ink was separated into yellow and pink spots when the solvent front values were ≥ 2.0 cm for both acidic and basic mobile phases. The blue ink was separated into two main spots (dark blue and green) on running with the acidic and basic mobile phase when the solvent front was ≥ 8.0 cm also. However the dark blue spot has undergone to tailing, the other spots have not. The reason for tailing lies in the fact that it is related with both load capacity of the stationary phase and the amount of the components in the spots. Although the same amount of sample has been spotted to both baby powder and Si-60GF₂₅₄ layers, the dark blue spot on baby powder layer has been developed

with tailing, but the one on Si-60GF₂₅₄ has been developed without tailing. This situation indicates that the load capacity of Si-60GF₂₅₄ layer for dark blue is higher than those of baby powder layer. On the other hand, the area of dark blue spot is larger than those of green for both kinds of layers. This observation reveals that the amount of dark blue component on the sample is higher than those of green.

The chromatogram in Figure 3b is beige, whereas the bottom section of chromatogram in Figure 3a is tight and turns into dirty beige. Those spoilt structures and color changing are qualitative indicators of chemical interaction of the stationary phase with mobile phase. The spoilt structure and color change are results of chemical interaction between the talc, Mg₃[Si₄O₁₀](OH)₂, on thin layer and the CH₃COOH in mobile phase. Consequently, the layer has undergone to chemical decomposition on the application with the mobile phase containing CH₃COOH. However, it is possible to conclude that layers of baby powders based talc have been successfully applied to the separation of components of ink samples.

As is seen in Figure 4a and 4b, on Si-60GF₂₅₄ layers, the red ink was separated into yellow and pink spots when the solvent front values were ≥ 2.0 cm for both acidic and basic mobile phases. The blue ink was separated into two main spots (dark blue and green) on running with the acidic mobile phase when the solvent front was ≥ 8.0 cm. However, in the basic mobile phase application, blue ink components were not separated even when the solvent front was ≥ 8.0 cm. On the other hand, the components of blue ink on Si-60GF₂₅₄ layers has been developed wholly, but no physical deformation and color change have been observed at layers qualitatively. From these qualitative observations, it can be said that the Si-60GF₂₅₄ layers do not react with acidic and basic mobile phases. Consequently, Si-60GF₂₅₄ layers are successful for separation of the red and blue ink components with acidic mobile phase. They are not successful for separation of blue ink components with basic mobile phase, whereas they are successful for those of red ink components.

The R_f values for red and blue ink components and ΔR_f values of their couples for Si-60GF₂₅₄ and baby powder layers with acidic and basic mobile phases have been given in Table 3 and 4 respectively. In order to evaluate separability of ink components, ΔR_f values of ink component couples have been calculated.

Based on the data in Table 3, the R_f values of pink and yellow spots belong to red ink on TLC applications with baby powder and acidic mobile phase are 0.91 ± 0.05 and 0.67 ± 0.03 respectively, whereas corresponding values are 0.91 ± 0.05 and 0.38 ± 0.02 for Si-60GF₂₅₄ layers. The data in Table 3 show that ΔR_f is 0.24 for yellow-pink couple on baby powder layer. Besides, ΔR_f is 0.53 for the same couple on Si-60GF₂₅₄ layers. Because the values of ΔR_f are >0.1 for yellow-pink couple, both layers are effective to separate this couple.

Based on the data in Table 4, R_f values of pink and yellow spots belong to red ink on TLC application with baby powder and basic mobile phase are 0.86 ± 0.04 and

0.72 ± 0.04 respectively, whereas corresponding values are 0.71 ± 0.04 and 0.40 ± 0.02 for Si-60GF₂₅₄ layers. The data in Table 4 show that ΔR_f is 0.14 for yellow-pink couple on baby powder layer. Also ΔR_f is 0.31 for same couple on Si-60GF₂₅₄ layer. Because the values of ΔR_f are >0.1 for yellow-pink couple, both layers are effective to separate this couple.

Based on the data in Table 3, the R_f values of green and dark blue spots belong to blue ink on TLC application with baby powder and acidic mobile phase are 0.67 ± 0.03 and 0.08 ± 0.01 respectively, whereas corresponding values are 0.56 ± 0.03 and 0.49 ± 0.03 for Si-60GF₂₅₄ layers. The data in Table 3 show that ΔR_f is 0.59 for green-dark blue couple on baby powder layer. Also ΔR_f is 0.07 for same couple Si-60GF₂₅₄ layer. Because ΔR_f is >0.1 for green-dark blue couple, the baby powder layer is successful to separate this couple, but because of $\Delta R_f < 0.1$ ($\Delta R_f = 0.07$), Si-60GF₂₅₄ layer is not successful to separate this couple. This result may be an advantage of baby powder based talc on TLC application compared to Si-60GF₂₅₄.

Based on the data in Table 4, the R_f values of green and dark blue spots belong to blue ink on TLC application with baby powder and basic mobile phase are 0.54 ± 0.03 and 0.05 ± 0.01 respectively. Yet the components of blue ink have developed only one spot without separation on Si-60GF₂₅₄ layers. The data in Table 4 show that ΔR_f is 0.49 for dark blue-green couple on baby powder layer. Because ΔR_f is > 0.1 for dark blue-green couple, the baby powder layers are successful to separate this couple, but because of spot overlapping, Si-60GF₂₅₄ layer is not successful to separate this couple. This result may be an advantage of baby powder based talc on TLC application compared to Si-60GF₂₅₄.

According to Tables 3 and 4, for Si-60GF₂₅₄ layers, when the acidic mobile phase was replaced by the basic mobile phase, R_f values changed from 0.91 ± 0.05 to 0.71 ± 0.04 for the pink component, from 0.38 ± 0.02 to 0.40 ± 0.02 for the yellow component, from 0.56 ± 0.03 to 0.56 ± 0.03 for the green component and from 0.49 ± 0.03 to 0.56 ± 0.03 for the dark blue component. Replacing the acidic mobile phase with the basic phase changed the R_f value significantly for the pink component only. R_f values for the yellow, dark blue and green components did not change. On the basis of the experimental data and their changing patterns, the polarity of the mobile phase was more effective in contributing to the chromatographic behavior of all the dye components. Considering all components are water soluble dyes, it is possible to attribute this behavior to the acid-base properties of components. In this study, the pH of the acidic mobile phase was 3.00, and for the basic mobile phase was 11.00 (9). The R_f value for the pink component in the acidic mobile phase was higher than that of the basic mobile phase. This means that the pink component was favored by the mobile phase due to its basic chemical nature. Since the R_f values of the other ink components were affected in both acidic and basic mobile phases, it is suggested that they have a neutral character with respect to their chromatographic behavior pattern.

According to Tables 3 and 4, on baby powder layers, when acidic mobile phase is replaced by basic one, R_f values change from 0.91 ± 0.05 to 0.86 ± 0.04 for pink component, from 0.67 ± 0.03 to 0.72 ± 0.04 for yellow component, from 0.67 ± 0.03 to 0.54 ± 0.03 for green component from 0.08 ± 0.01 to 0.05 ± 0.01 for dark blue component. These data and chromatographic behavior patterns could not be explained as easily as on Si-60GF₂₅₄ layers, because the chemical composition, pH and physical properties of baby powder based talc are significantly different from on Si-60GF₂₅₄. Hence in order to mention give details in this matter, it is necessary to carry out further studies, such as chemical and spectroscopic characterization.

Stahl (11) suggest that the activity of stationary phase, polarity of mobile phase and polarity of molecule in sample are interrelated on normal TLC. When Si-60GF₂₅₄ layers were replaced by baby powder layers as stationary phases, in running operations with butanol- acetic acid-water mixture (12:3:5, v:v:v), the data on Table 3 show that the R_f values have changed from 0.91 ± 0.05 to 0.91 ± 0.05 for pink, from 0.38 ± 0.02 to 0.67 ± 0.03 for yellow, from 0.56 ± 0.03 to 0.67 ± 0.03 for green and from 0.49 ± 0.03 to 0.08 ± 0.01 for dark blue. The same pattern is valid for applications with butanol-ethanol-(2M) ammonia mixture (3:1:1, v:v:v). The retention of various molecules on stationary phase is generally explained by considering the interactions between polar Si-OH groups on surface of layer and molecules in sample, e.g., hydrogen bridging, dipole-dipole and Van der Waals forces. The compositions of Si-60GF₂₅₄ and baby powder based talc are $\text{SiO}_2 \cdot n\text{H}_2\text{O}$ and $\text{Mg}_3[\text{Si}_4\text{O}_{10}](\text{OH})_2$, respectively. Thus, while Si-60GF₂₅₄ has neutral character, talc is basic. The change of R_f values of ink components on TLC applications on both adsorbents is related to surface activity of the layers.

Conclusions

This work was carried out to better understand the effects of kind and amount of solvent on properties of baby powder based talc and Si-60GF₂₅₄ layers. In addition, the chromatographic behaviors of components of commercial ink samples were investigated to give a comprehensive understanding of the effects of changing of stationary phase properties and also those of the mobile phase such as polarity and acidity, on R_f values and separability of the components. In light of these studies, conclusions are as follow:

(a) It is shown that among baby powder layers containing talc prepared from both distilled water and ethanol, while the layers from ethanol are suitable for TLC application, those from distilled water are not;

(b) On TLC applications, the components of commercial red and blue inks were successfully separated into two main spots (yellow and pink) on the activated layers of baby powder based talc with acidic and basic mobile phases;

(c) On activated layers of Si-60GF₂₅₄, the components of commercial red ink were

successfully separated into two main spots (yellow and pink) by TLC with both acidic and basic mobile phases also. The blue ink was separated into two main spots (dark blue and green) on activated layers of Si-60GF₂₅₄ with the acidic mobile phase. However, blue ink components did not separate on Si-60GF₂₅₄ with the basic mobile phase;

(d) TLC applications which are done with baby powder layers and acidic and basic mobile phases are more successful to separate green-dark blue couple than Si-60GF₂₅₄ layers. This result may be an advantage of baby powder based talc on TLC application compared to Si-60GF₂₅₄.

(e) Replacing of the acidic mobile phase with the basic phase for Si-60GF₂₅₄ layers, changed the R_f value significantly for the pink component only, with R_f values for the yellow, dark blue and green components unchanged. Considering that all the components are water soluble dyes, it may be possible to attribute this behavior pattern to acid-base properties of the components;

(f) The chemical composition, pH and physical properties of baby powder based talc are significantly different from on Si-60GF₂₅₄. Replacing of the acidic mobile phase with the basic phase for baby powder layers, these data and chromatographic behavior patterns could not be explained as easily as on Si-60GF₂₅₄ layers. In order to mention give details in this matter, it is necessary to carry out further studies, such as chemical and spectroscopic characterization;

(g) The retention of various molecules on stationary phase is generally explained by considering the interactions between polar Si-OH groups on surface of layer and molecules in sample, e.g., hydrogen bridging, dipole-dipole and Van der Waals interactions. The compositions of Si-60GF₂₅₄ and baby powder based talc are SiO₂·nH₂O and Mg₃[Si₄O₁₀](OH)₂, respectively. Thus, while Si-60GF₂₅₄ has neutral character, talc is basic. The change of R_f values of ink components on TLC applications on both adsorbents is related to surface activity of the layers;

(h) The baby powder is a suitable adsorbent for TLC teaching due to its availability, inexpensiveness and being damage-free for health. In spite of being a composite material, its achievements on TLC applications belong to commercial ink samples that made it a preferred material in teaching TLC for undergraduate students studying chromatography.

REFERENCES:

1. **Curtright, R.D., R. Emry, J. Markwell.** Student Understanding of Chromatography: A Hands-On Approach. *J. Chem. Educ.* **76**, 249 (1999).
2. **Baum, D.E., R.A. Shanks.** A Novel Method for Quantitative Thin Layer Chromatography. *J. Chem. Educ.* **52**, 738 (1975).
3. **Anwar, M.H.** Separation of Plant Pigments by Thin Layer Chromatography. *J. Chem. Educ.* **40**, 29-30 (1963).
4. **Goller, E.J.** Cation Analysis with Thin Layer Chromatography. *J. Chem. Educ.* **42**, 442-443 (1965).

5. **Rollins, C.** Thin Layer Chromatographic Separation of Leaf Pigments: A Rapid Demonstration. *J. Chem. Educ.* **40**, 32 (1963).
6. **Frodyma, M.M., R.W. Frei.** Reflectance Spectroscopic Analysis of Dyes Separated by Thin Layer Chromatography. *J. Chem. Educ.* **46**, 522-524 (1969).
7. **Ergül, S.** Qualitative Analysis of Cu^{2+} , Co^{2+} , and Ni^{2+} Cations Using Thin-Layer Chromatography. *J. Chromatographic Sci.* **42**, 121-124 (2004).
8. **Akhrem, A.A., A.I. Kuznetsova.** *Thin Liquid Chromatography, A Practical Laboratory Handbook*. Israel Program for Scientific Translations Ltd., Jerusalem, 1965.
9. **Ergül, S.** PhD Thesis. University of Balıkesir, Balıkesir, 2003.
10. **Ergül, S., I. Kadan, S. Savasci, S. Ergül.** Diatomaceous Earth as a Principle Stationary Phase Component on TLC. *J. Chromatographic Sci.* **43**, 394-400 (2005).
11. **Sthal, E.** *Thin-Layer Chromatography*. Springer, New York, 1969.
12. **Popov, A., K. Stefanov.** Einsatz des aktivierten Bentonits als Adsorbens bei der Dünnschichtchromatographie. *Compt. R. Acad. Bulg. Sci.* **21**, 673-675 (1968).
13. **Fayez, M.B.E., G. Gad, I. Nasr, A.S. Radvan.** Sinai Clay, a New Adsorbent for Thin Layer Chromatography. *J. Chem. UAR* **10**, 49-54 (1967).
14. **Sheen, B.** Chine Clay - A Sorbent for Thin-Layer Chromatography. *J. Chromatography* **60**, 363-370 (1971).
15. **Hashimoto, A., A. Hitorani, K. Mukai.** Separation of Alcohols by Thin Layer Chromatography on Activated Bleaching Earth. *J. Chromatography* **14**, 343-347 (1965).
16. **Karakaş, R., U. Yüksel.** Modification of Perlite for Use as a Thin-Layer Chromatography on Activated Bleaching Earth. *J. Chromatographic Sci.* **36**, 499-504 (1998).
17. **Walsch, B.J.M.** The Use of Talc as a TLC Adsorbent. *J. Chem. Educ.* **44**, 294-296 (1967).

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