Improving barrier performance of coated paper and paperboard using a multi-layer approach

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ABSTRACT: Market demand for barrier coated packaging paper and paperboard has been on a steady rise and is forecasted to further increase. As a result, there is a continued interest in improving barrier coating functionalities, which is currently an active area of investigation.

In this work, a multi-layer approach was adopted that involved applying a biowax emulsion, latex, or a combination of biowax and latex top coating layer onto the kaolin/latex (20/80, 50/50, 65/35, or 70/30) precoated solid bleached sulfate (SBS) paperboard. Our main objective was to demonstrate the effect of these top coating layers on various barrier properties, especially water vapor transmission rate (WVTR) at high relative humidity (RH) and high temperature (90% RH; 38°C), known as tropical/jungle test conditions.

While the top coat with latex and/or biowax showed dramatic improvement in both water resistance (Cobb) and WVTR, the biowax coating increased contact angle significantly compared to the latex top coat. Contact angle increased from about 65° for the latex top coat to as high as 96° for the biowax top coat. Generally, it is much more difficult to improve WVTR at the jungle conditions below 100 g/m^2/day, even with the high aspect ratio platy pigment. However, using the coating strategies adopted in this study, we were able to achieve WVTR values notably below 50 g/m^2/day at the tropical test conditions, as well as significant improvements in regard to fold crack barrier integrity at high kaolin clay usage.

Application: The findings presented in this study highlight the importance of maintaining a high degree of water resistance in barrier coatings when targeting extremely low WVTR values under severe atmospheric conditions. A multi-layer coating approach was employed in which a platy pigment (kaolin) in the base layer and a bio-based wax in the top layer partially, yet significantly, replaced synthetic latex to enhance barrier performance while supporting sustainability objectives. This work provides a practical framework for advancing more sustainable barrier coating systems without compromising performance.

A barrier coating layer is applied to paper and paperboard packaging materials to protect and preserve the quality of food and non-food contents from transmission of oil and grease, solvent, liquid water, water vapor, oxygen, and other unwanted substances. Conventionally used waxes, per- and polyfluoroalkyl substances or PFAS (forever chemicals), and polyethylene (PE) films are being phased out due to health, environmental, recyclability, repulpability, and compostability concerns. Single-use plastics are creating havoc on our planet. Paper-based packaging coated with aqueous barrier dispersions is a viable alternative to the single-use plastics and is gaining more prominence for sustainability reasons. Inclusion of platy pigments such as kaolin in aqueous dispersion coatings provides cost-effective and, in many instances, improved performance.

The use of minerals such as talc and kaolin clays in aqueous barrier coatings has been widely published and known to produce block-free coated surface and improve water vapor transmission rate (WVTR) [1-8]. In addition to cost effectiveness and quality enhancements, the minerals added in aqueous barrier dispersions aid in process operations. Adding pigment increases coating solids and allows for quicker immobilization after application. That is then manifested in better holdout and coverage. Pal et al. [1] showed that the platy shaped mineral particles are said to improve WVTR due to layered coating structure and high tortuosity. In our earlier work based on coating formulations with kaolin clay and latex binders, an increase of high aspect ratio kaolin clay loading in a single layer coating improved WVTR at TAPPI standard test conditions of 23°C and 50% relative humidity (RH) compared to the 100% latex coating, while the results at tropical test conditions (38°C; 90% RH) showed a decrease of WVTR with an increase of clay. Water resistance properties also deteriorated with increases in clay loading [2]. Therefore, further research is required to gain a full understanding of the role of minerals in barrier coatings, especially in terms of the linkage between water resistance and WVTR both in single- and multi-layer coating systems.

Folding is an essential part of any packaging and converting operations, and the substrate experiences cracking due to folding stresses as a natural part of packaging operations, which can be harmful to the barrier quality and

aesthetics. Therefore, information regarding fold crack resistance is crucial and should be part of any barrier coating study. The factors influencing coating cracking during folding have been reported in several publications in the recent past [9-16]. Rättö et al. suggested that kaolin clays are prone to more cracking than ground calcium carbonate, and a carbonate with narrow particle size distribution is prone to more cracking than a broader particle size distribution carbonate when compared at equal binder levels [11]. Base paper dominates most of the mechanical properties of the whole coated substrate. However, coating layers play a dominant role with regards to stiffness in bending mode. That is because the strain undergone by the outermost layers is much larger [10]. Generally speaking, fold crack resistance and bending stiffness are inversely related. Formulations with materials of lower elastic modulus produce coating films that are more flexible due to an increase in elongation strength [9].

Many authors have focused on optimizing stiffness and fold crack resistance through a multi-layer coating approach by placing stiffer undercoating layers and a thin flexible coating on the outermost layer [13-16]. Najafi et al. [13] and Alam et al. [16] indicated that an optimum way to balance stiffness and fold crack resistance is to include stiffer under layers and a thin flexible outer coating layer. Preston et al. [14] and Pokharel et al. [15] reported a decrease in barrier properties due to folding. Devisetti et al. [2] showed that barrier performance improves with an increase of kaolin clay aspect ratio, pigment loading, and coat weight. However, they did not discuss the influence of folding on barrier integrity. Zuo et al. [12] showed that the coating with high pigment loading and coat weight is prone to more cracking and deterioration of barrier performance after folding. Preston et al. [14] showed that barrier properties across a fold decreased more with an increase in aspect ratio of the clay filler. Their results also suggested that tendency to crack was higher due to folding with coating outside (elongation) as opposed to folding with coating inside (compressions). In reality, it is an advantage that most of the barrier packaging involves folding the coated surface inside.

The majority of publications on aqueous barrier dispersion coatings used synthetic polymer binders such as styrene butadiene (SB) or styrene acrylic (SA) latex for quality reasons [1-8,17-20]. There is a need for continued research on how to effectively incorporate sustainable bio-based materials into packaging without compromising quality requirements. Recently, the use of bio-based alternatives in coatings for food packaging grades is trending. Biowax is one such material [21-25]. Benz et al. [25] showed an improvement in barrier properties (against water, water vapor, and oil and grease) of coated paper by using biowax at additive levels with SB and SA binders. While the use of biowax in aqueous barrier coatings is gaining importance, the information available is still limited. It is thus worthwhile investigating further, especially in multi-layer coating systems. The main objective of this work is to improve the barrier performance and fold cracking at different kaolin clay levels by applying a latex, biowax, or a combination of latex and biowax top coating.

MATERIALS AND METHODS

The coating formulations in this study were prepared using a high aspect ratio delaminated kaolin clay and SB latex with glass transition temperature (Tg) of ~12°C. Additionally, a biowax emulsion was used as one of the top coat materials, in addition to SB latex. The kaolin clay utilized in the study had the following typical properties: 1) mean particle size 2.60 µm; 2) median particle size 1.28 µm; 3) 65% < 2µm in particle size distribution (as determined by sedimentation – Sedigraph method); and 4) shape factor in the 88–100 range.

The experimental design for precoated single layer coating systems resulted in a total of six coating runs (C1 to C6), as shown in **Table I**. All clay/latex coating formulations utilized in single layer coating application were prepared at 54% target solids by adding latex binder and carboxymethyl cellulose (CMC) thickener to the pigment

Coating Run No.	SB Latex, %	Clay, %	PVC, %	CPVC, %
C1	100	0	0	49.8
C2	80	20	8.8	
C3	50	50	28	
C4	35	65	41.9	
C5	30	70	47.5	
C6	15	85	68.7	

SB: styrene butadiene; PVC: pigment volume concertation; CPVC: critical pigment volume concentration.

I. Experimental design showing coating runs for precoated single layer coating systems.

Multi-Layer Coating Run No.	First High Coat Weight Under Layer Details (Coating Runs from Table I)			Thin Top Coat Layer Details		
	Precoat Run No.	Clay/Latex Ratio	Coat Weight, g/m²	Material Utilized	Coat Weight, g/m²	Total, g/m²
C7	C2	20/80	12.0	100% Latex (SB)	3.0	15.0
C8	C3	50/50	12.2		3.1	15.3
C9	C4	65/35	12.4		3.3	15.7
C10	C5	70/30	12.3		3.0	15.3
C11	C2	20/80	12.0	100% Biowax	3.1	15.1
C12	C3	50/50	12.2		3.2	15.4
C13	C4	65/35	12.4		3.2	15.6
C14	C5	70/30	12.3		3.2	15.5
C15	C2	20/80	12.0	(70/30) Latex (SB)/ Biowax	-	-
C16	C3	50/50	12.2		3.0	15.2
C17	C4	65/35	12.4		-	-
C18	C5	70/30	12.3		3.2	15.5
C19	C6	85/15	12.0	100% Latex (SB)	3.0	15.0

II. Experimental design showing coating runs for multi-layer coating systems (SB: styrene butadiene).

slurry. The thickener was adjusted to maintain a low shear viscosity of about 300 cP (Brookfield at 20 rpm). Coating dispersions were applied to SBS paperboard to the back side rougher surface (commercially available, 250 g/m² basis weight, PPS roughness at 10 MPa: ~5.25 µm) at coat weights of 12 g/m² (and 16 g/m² in some cases) using a laboratory pilot coater (Dow Modern Metal Craft) and wire-wound Mayer rods. All coated substrates were dried using a heated cylinder drum surface of the coater (uncoated surface contacting the heated drum) for 1 min and then cured for 5 min in the convection oven set at 110°C, unless otherwise specified. The coated sheets were then conditioned at standard TAPPI controlled humidity and temperature conditions (50% RH; 23°C) for about 7–10 days prior to the evaluation.

The experimental design for multi-layer coating systems resulted in a total of 13 coating runs (C7 to C19), as shown in **Table II**. The coating materials utilized in top coat application were 100% latex, 100% biowax emulsion, and 70/30 latex/biowax blend without clay. These top coats were applied by adjusting their solids concentration as necessary to obtain a low coat weight of around 3 g/m², also using a wire wound rod applicator as earlier.

A total of five coated sheets were evaluated and averaged for Kit rating, while three tests were averaged in the case of WVTR, Cobb, and contact angle measurements, as described in the following sections.

Coat weight

Coat weight (g/m²) was determined gravimetrically by comparing the grammage of oven dried uncoated and coated substrates tested as per TAPPI Standard Test Method T 410 om-19 "Grammage of paper and paperboard (weight per unit area)." Liquid water barrier was measured by Cobb test procedure for 30 min as per TAPPI T 441 "Water absorptiveness of sized (non-bibulous) paper, paperboard, and corrugated fiberboard."

Oil/grease barrier

The oil/grease barrier was measured by Kit test procedure following TAPPI T 559 cm-12 "Grease resistance test for paper and paperboard." This test assigns a score rating of 1 to 12 depending on the oil and grease resistance barrier performance, and 12 is the highest ranking.

Water vapor barrier

The WVTR was measured as per TAPPI T 448 "Water vapor transmission rate of paper and paperboard at 23°C and 50% RH" and TAPPI T 464 "Water vapor transmission rate of paper and paperboard at high temperature and humidity" (90% RH and 38°C) methods. The test involves gravimetric determination of the water vapor transmission of the sheet material exposed to a specified environment for 72 h and then expressing the results in terms of g/m²/day.

Fold crack

Fold crack was conducted using the following procedure. Coated samples that were marked in machine direction (MD) and cross-machine direction (CD) were folded to 180° with the coated side facing inside the fold. The fold crack tests were performed without any creasing or scoring. For this, the coated sample was first partially folded by bringing the edges together and creating an overlap of the ends with coated side facing inside. The partially folded sample was then subjected to a predetermined pressure of 2 bar for 1 min using an AA-GWR water retention meter (Kaltec Scientific; Novi, MI, USA) upon inserting sample under clamps by holding the overlapping ends. Barrier integrity of the folded samples (unfolded to original flat shape) was examined by evaluating them for WVTR at standard conditions.

RESULTS & DISCUSSION

Effect of clay-to-latex ratio on water resistance barrier

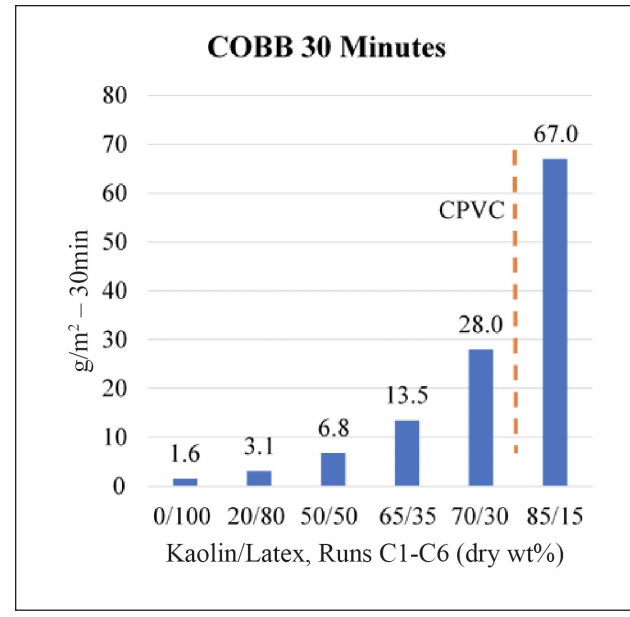
The water resistance barrier results (Cobb 30 min) generated for the single layer coatings at different clay loadings are provided in **Table III** and **Fig. 1**. The 100% latex coating without any clay showed extremely good water resistance with the lowest Cobb value. Addition of clay from 20% to 80% progressively showed an increase in Cobb value, indicating a decrease of water resistance with increases in clay level. A sharp increase in Cobb was noted as the clay level exceeded the critical pigment volume concentration (CPVC) point (between 65% and 70% loading).

Effect of clay-to-latex ratio on WVTR barrier

The water vapor transmission barrier results (WVTR) measured at 50% RH and 23°C (standard conditions) for the single layer coatings at different clay loadings are given in Table III and **Fig. 2**. The results gradually improved with the addition of clay up to 50% (50/50 clay/latex) as compared to the 100% latex coating, and then leveled off with clay loading up to 70% (70/30 clay/latex). Once again, the results were extremely poor above the CPVC (85% clay), most likely due to the gain in coating porosity.

The water vapor barrier results obtained at tropical conditions (WVTR at 90% RH and 38°C) for the coatings at different clay levels are given in **Fig. 3**. Since the data above CPVC was much poorer than the rest at standard conditions, it was not included in Fig. 3.

As can be seen, the results at the high humidity and temperature tropical conditions deteriorated gradually with

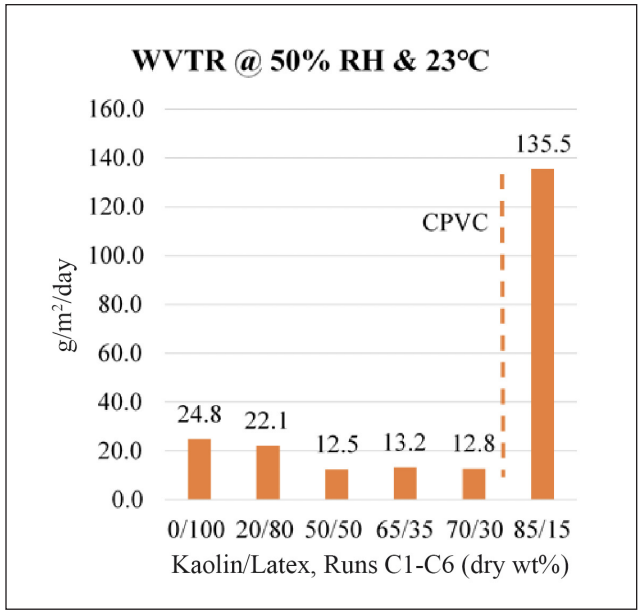


1. Cobb data for single layer coatings (CPVC: critical pigment volume concentration).

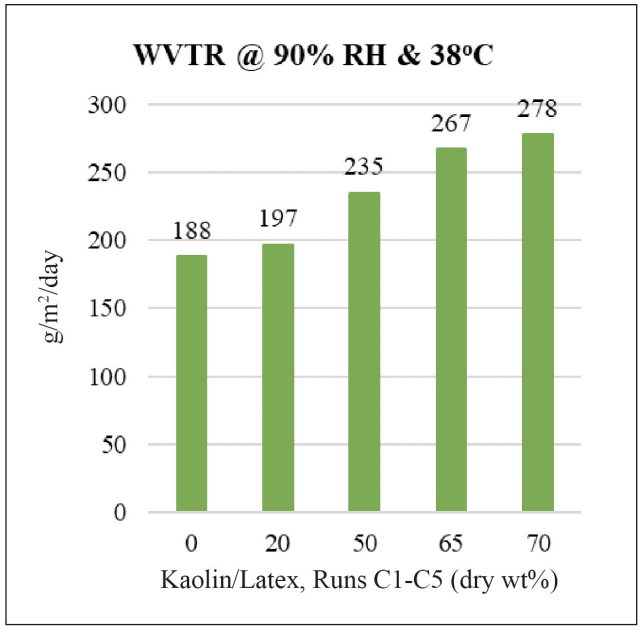
	Coat Weight g/m²	Kit Test Rating, 1–12		Cobb 30 min, g/m²		WVTR, g/m²/day			
						50% RH, 23°C		90% RH, 38°C	
		AVG	SD	AVG	SD	AVG	SD	AVG	SD
C1	12.4	9.0	0.8	1.6	0.2	24.8	1.2	188	5.8
C2	12.0	12.0	–	3.1	0.3	22.1	0.4	197	4.8
C3	12.2	12.0	–	6.8	1.6	12.5	0.5	235	5.2
C4	12.4	12.0	–	13.5	2.7	13.2	0.5	267	7.2
C5	12.3	12.0	–	28.0	2.2	12.8	0.3	278	7.4
C6	12.5	6.6	0.3	67.0	2.0	135.5	2.5	–	–

AVG: average; SD: standard deviation; WVTR: water vapor transmission rate; RH: relative humidity.

III. Effect of clay/latex ratio on various barrier properties of single layer coated sheets.

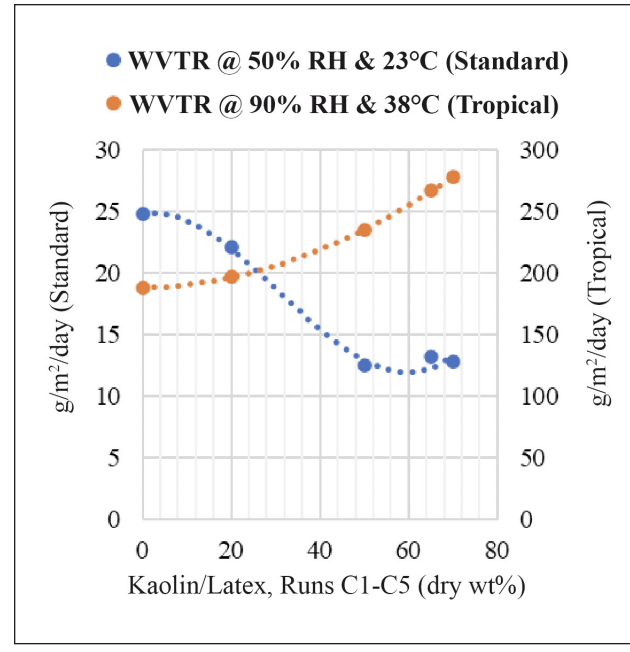


2. Water vapor transmission rate (WVTR) data for single layer coatings.



3. The WVTR at tropical conditions for single layer coatings.

an increase in clay level. The data at 50% RH and 23°C (standard conditions) are included for direct comparison in **Fig. 4**, which indicates an opposite trend as previously reported [2]. In essence, the trend observed for WVTR at tropical conditions (90% RH and 38°C) was analogous to the trend observed with Cobb results. It is probably because the coatings with the higher clay level were not able to reduce permeation of water vapor under the harsher tropical conditions in which water vapor tends to condense to liquid form. This can be considered a condition similar to the condition under Cobb testing. The condensation of water vapor likely weakens the coating layer, and more so for the coating containing a higher level of pigment (or a lower level of latex), thereby breaching coating layer integrity. In addition, diffusion of water molecules at a higher temperature is much more rapid due to the increase in its kinetic energy compared to a lower temperature.



4. The WVTR at standard vs. tropical conditions for single layer coatings.

Thus, a higher level of latex binder on the surface is more desirable for improved WVTR at the high humidity and high temperature conditions and plays a dominant role in controlling the water vapor or liquid water permeation.

Water resistance and oil and grease barrier for the multi-layer coating systems

All the multi-layer coated sheets resulted in excellent flat Kit test values, with a rating of 12 as shown in **Table IV**. Notice that the single layer coated sheets before applying top coats (runs C2 to C5 at 20%, 50%, 65%, 70%, and 85% clay levels) already had extremely good Kit ratings of 12, as shown in Table III. Consequently, after applying different top coats, these same coating systems all maintained the highest Kit ratings. In addition, the single layer coating with 85/15 clay/latex that showed a Kit rating of 6.6 also improved to 12 after top coatings.

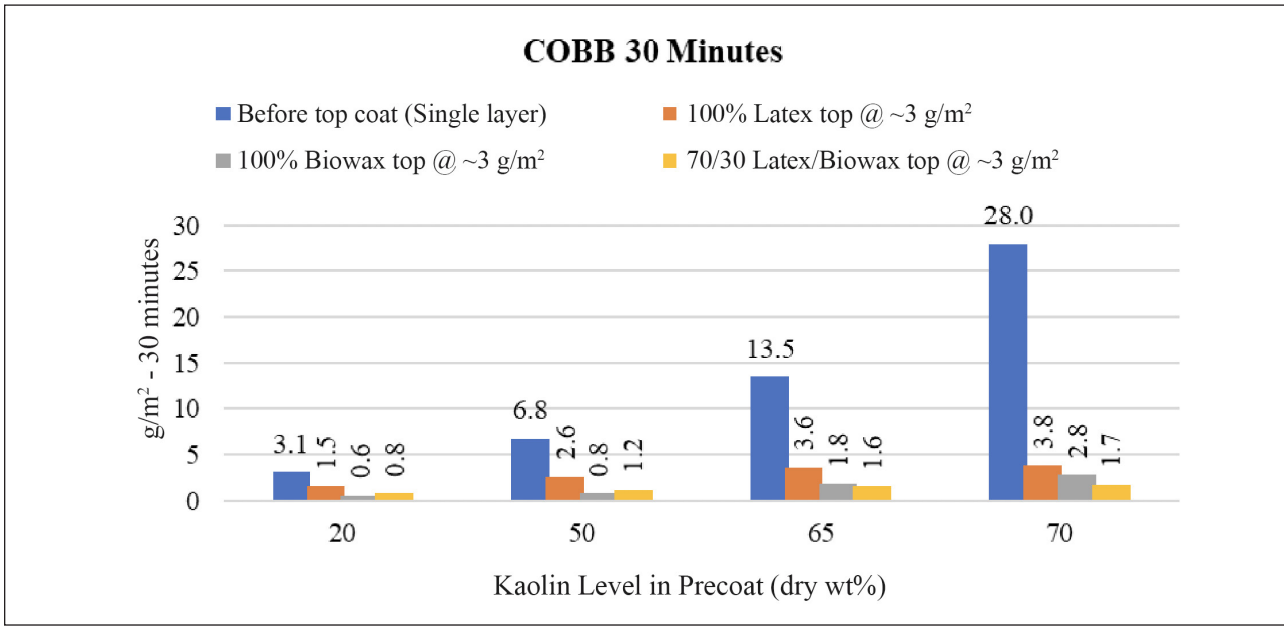
The Cobb values obtained before and after applying various top coats are presented in **Fig. 5**. The top coat materials (formulations) of 100% latex, 100% bio wax, and 70/30 latex/biowax, were applied on to the precoated sheets at each of the clay levels (20%, 50%, 65%, and 70%).

As can be seen in Fig. 5, irrespective of the top coat formulation, the Cobb values greatly improved compared with the coated sheets without top coat. It is important to note that the clay/latex coated sheets at a total coat weight of 15 g/m² or higher (matching the total coat weight of the

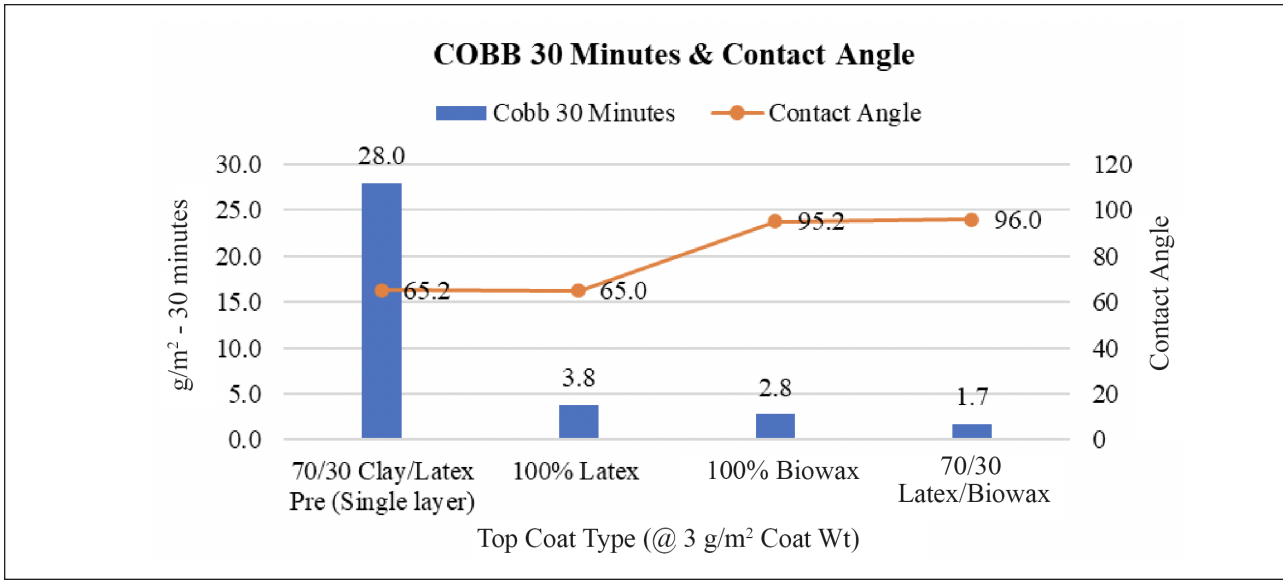
Multi-Layer Coating Run No.	Precoat Type, ~12 g/m²	Top Coat Type, ~3 g/m²	Kit Test Rating, 1–12		Cobb 30 min, g/m²		WVTR, g/m²/day				Contact Angle, θ
							50% RH, 23°C		90% RH, 38°C		
			AVG	SD	AVG	SD	AVG	SD	AVG	SD	AVG
C7	C2	100% Latex (SB)	12	–	1.5	0.7	13.3	0.3	112.3	0.6	
C8	C3		12	–	2.6	0.7	7.0	0.2	93.1	3.3	64.7
C9	C4		12	–	3.6	1.9	5.3	0.3	93.1	2.0	
C10	C5		12	–	3.8	1.8	4.7	0.5	93.5	4.4	65.0
C11	C2	100% Biowax	12	–	0.6	1.6	8.5	0.4	44.2	3.5	
C12	C3		12	–	0.8	1.2	6.1	0.2	36.9	2.8	96.3
C13	C4		12	–	1.8	2.3	4.7	0.4	28.5	3.2	
C14	C5		12	–	2.8	2.7	4.1	0.4	25.0	2.5	95.2
C15	C2	(70/30) Latex (SB)/ Biowax	12	–	0.8	1.5	12.3	0.6	–	–	
C16	C3		12	–	1.2	1.4	6.6	0.2	77.9	5.0	94.5
C17	C4		12	–	1.6	1.4	4.7	0.4	–	–	
C18	C5		12	–	1.7	2.2	4.7	0.3	60.2	2.9	96.0
C19	C6	100% Latex (SB)	12	–	32.4	3.2	35	1.3	169.0	5.4	–

SB: styrene butadiene; AVG: average; SD: standard deviation; WVTR: water vapor transmission rate; RH: relative humidity.

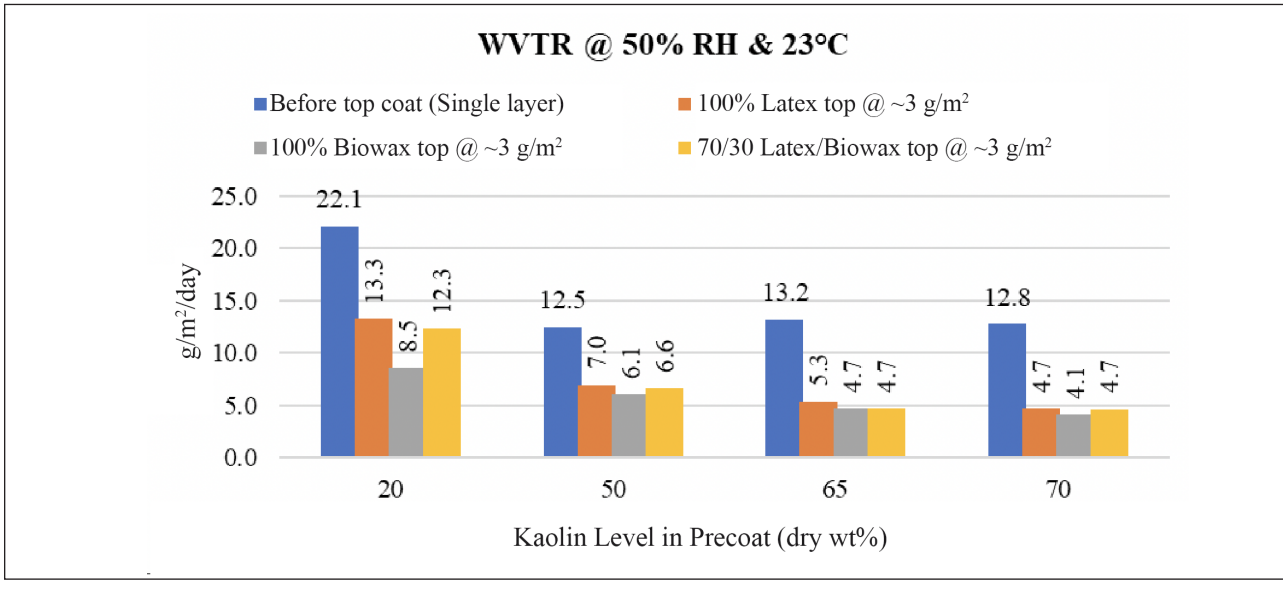
IV. Barrier properties obtained for multi-layer coating systems.



5. Cobb results for the multi-layer coating systems before and after applying various top coats on to different precoats.



6. Influence of various top coats on contact angle and Cobb value.



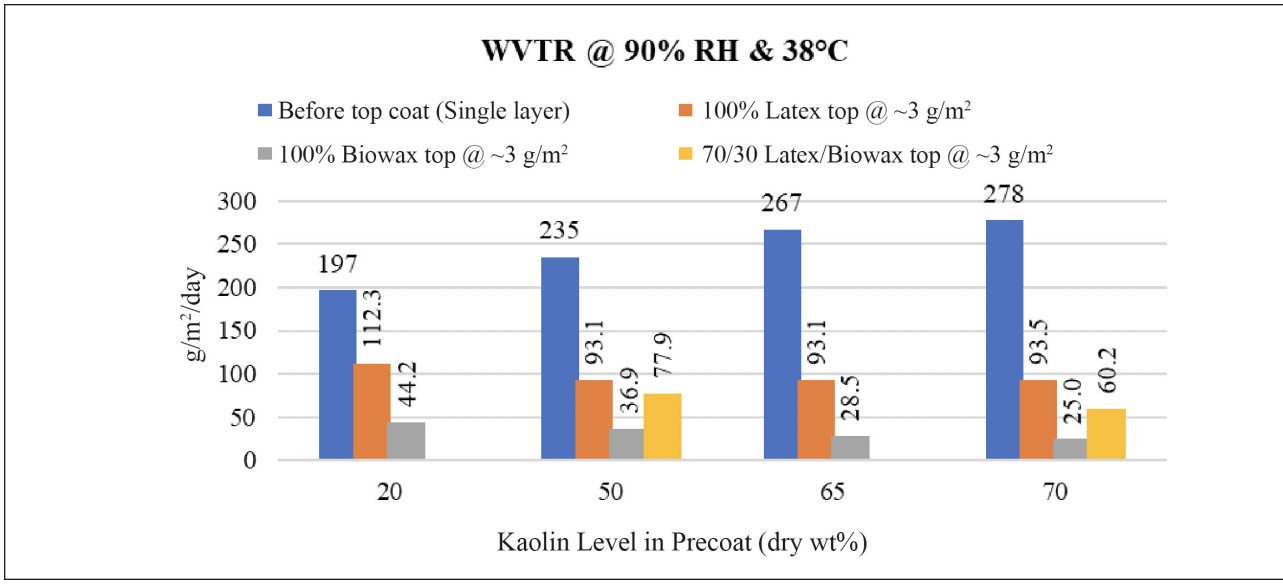
7. The WVTR results at standard conditions for the multi-layer coating systems before and after applying various top coats on to different precoats.

double-coated sheet) without any top coating (data not included) do not provide any improvement in Cobb. Therefore, the Cobb improvements seen for the multi-layer coating systems are not due to the increases in coat weight but primarily due to the type of material used as the top coat.

Contact angle and the corresponding Cobb data for the multi-layer coating systems based on 70/30 clay/latex in precoat (Run Nos. C10, C14, and C18; Table IV) are depicted in **Fig. 6** to explain the trends between Cobb and contact angle. As shown in the figure, the Cobb for the 100% latex top-coated sheets improved without influencing contact angle, while wax and wax/latex blend made the coating hydrophobic and significantly altered both contact angle and Cobb compared to the clay/latex precoated sheets. Similar trends can be observed for the multi-layer coating systems (Run Nos. C8, C12, and C16; Table IV) based on the 50/50 clay/latex in precoat. Although the high contact angle from biowax appears to be helpful in improving barrier performance (against water and water vapor), its influence on downstream processes such as glueability needs investigation.

Water vapor transmission rate for the multi-layer coating systems

The WVTR barrier results obtained at standard conditions (50% RH and 23°C) for the multi-layer coating systems (Run Nos. C7 to C18; Table IV) are presented in **Fig. 7**; the top coat materials (100% latex, 100% bio wax, and 70/30 latex/biowax)



8. The WVTR results at tropical conditions for the multi-layer coating systems before and after applying various top coats on to different precoats.

were applied on to the precoated sheets at each of the clay loading levels of 20%, 50%, 65%, and 70%. As can be seen in Fig. 7, irrespective of the material applied in the top coat, the WVTR values were improved significantly compared to the coated sheets without the top coat. It is important to note that the clay/latex coated sheets at a total coat weight of 16 g/m² (equal to that of the double-coated sheet) without any top coating (data not included) did not provide the same improvement in WVTR.

Therefore, the level of improvements observed for the multi-layer coating systems are not merely due to the increases in coat weight but due to the nature of the material used in the top coat, as observed for Cobb (see previous information).

The WVTR barrier results obtained at tropical conditions (90% RH and 38°C) for the multi-layer coating systems (Run Nos. C8 to C18; Table IV) are presented in **Fig. 8**; the top coat materials (100% latex, 100% bio wax, and 70/30 latex/biowax) were applied on to the precoated sheets at 20%, 50%, 65%, and 70% clay loading levels.

As can be seen in Fig. 8, the results without top coat showed that having 70% clay deteriorated WVTR at tropical conditions. On the other hand, when it comes to top-coated sheets, the WVTR values were improved significantly compared to the coated sheets without the top coat, irrespective of the material being applied in the top coat. Furthermore, the top-coated sheets with 70% clay in precoat exhibited more or less similar to or slightly better results than the 50% clay.

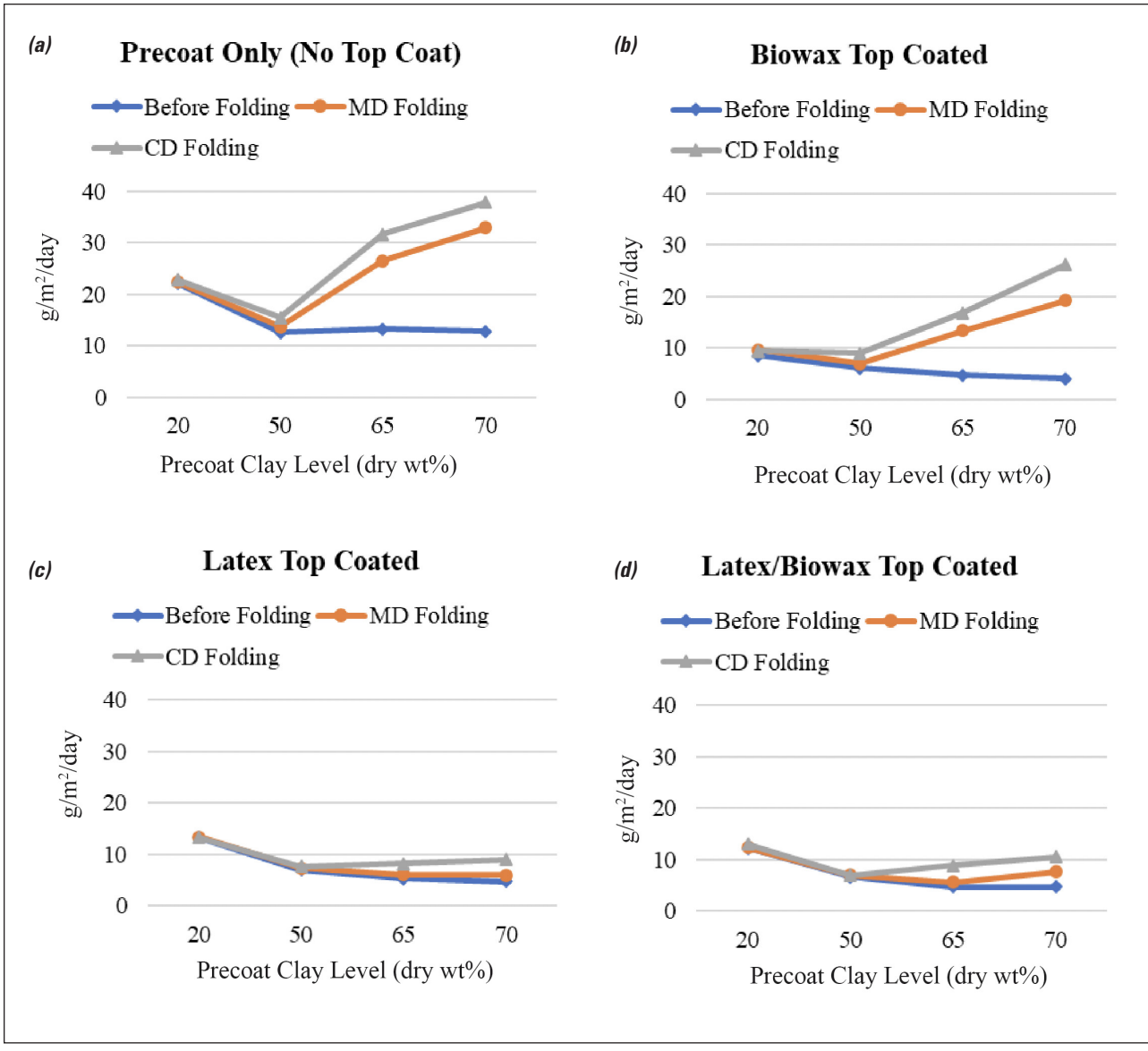
The data clearly show that, unlike for single layer coating systems, once a top coat was applied, having more clay in the precoat does not seem to be detrimental to the WVTR measured at tropical conditions. Additionally, as stated earlier, the WVTR trend observed at tropical conditions in multi-layer coating systems was analogous to the trend observed for Cobb. It is most likely due to the reason explained earlier: the top coat layer applied was able to provide a protective coating surface to prevent the permeation of water vapor under the harsher tropical conditions very similar to the conditions under Cobb testing. Finally, providing a top coat (latex) appears to allow/extend the clay level usage in precoat beyond the CPVC point. This may be evidenced by the good WVTR at tropical conditions obtained at 85% clay (Run No. C-19).

Fold crack barrier integrity for the multi-layer coating systems

The WVTR results (evaluated at standard conditions) obtained for coated sheets folded in MD and CD were compared with the results from non-folded (flat) samples (**Fig. 9a—9d**). The precoated sheets (without any top coat) at 65% and 70% clay levels show a large increase in WVTR of folded vs. never-folded samples, while there was only a minimal change at 20% and 50% clay levels (Fig. 9a). This indicates a good fold crack resistance/barrier for latex-rich coating (20% and 50% clay levels), as opposed to a poorer fold crack resistance at 65% and 70% clay levels.

The results in this study agree with literature findings that high pigment volume decreases fold crack resistance and leads to a decrease in barrier performance [13]. Previous studies also indicated that cracking with high aspect ratio clays can be relatively higher as compared to spherical pigments or low aspect ratio clays and other pigments [12, 14], and one must strike a balance in terms of clay-to-latex ratio.

The biowax top-coated sheets showed a large increase in WVTR between folded and non-folded samples at 65% and 70% clay levels in precoat (Fig. 9b), whereas the 100%



9. (a) Effect of precoat clay level on fold crack barrier regarding WVTR at standard conditions; (b) effect of biowax top coat on fold crack barrier regarding WVTR at standard conditions; (c) effect of latex top coat on fold crack barrier regarding WVTR at standard conditions; and (d) effect of latex/biowax top coat on fold crack barrier regarding WVTR at standard conditions (MD: machine direction; CD: cross-machine direction).

latex top-coated sheets showed a relatively small increase after folding (Fig. 9c).

These results suggest that providing a thin latex top coat significantly improves fold crack resistance, while biowax is inferior in terms of fold crack resistance, because SB latex film is generally much more flexible than wax. The results in this study agree with literature findings that biowax could have a deleterious effect on fold crack [24].

It is worth noting that the absolute WVTR values for the biowax top-coated sheets after folding were still better than the results from single layer precoated sheets after folding. The latex/biowax top-coated sheets (Fig. 9d) showed a lower fold crack resistance vs. the 100% latex top-coated sheets (Fig. 9c), but were much improved over the pure biowax top-coated sheets. Consistent with the observation made for the precoated sheets alone, the top-coated sheets with biowax, latex, or latex/biowax also showed a good fold crack resistance when precoat contained up to 50% clay.

CONCLUSIONS

Coated sheets prepared through a multi-layer approach by applying biowax, latex, or a combination of latex and biowax as top coats on to the precoated (kaolin clay/latex) SBS substrates resulted in both exceptional water resistance (Cobb) and WVTR at tropical conditions (38°C; 90% RH). Application of these top coats also extended the level of

clay to as high as 70% in the precoat without compromising the WVTR value.

An increase of pigment loading in a single layer precoating improved WVTR at standard conditions (23°C; 50% RH) as compared to the 100% latex coating, while the WVTR at tropical conditions (38°C; 90% RH) deteriorated with more clay.

Once a top coat (biowax, latex, or a combination of latex and biowax) was applied, the WVTR trends at tropical conditions got reversed (consistent with the trends in Cobb) and showed an improvement with more clay in the precoat, just as in the case of standard conditions. Thus, maintaining a superior water barrier (Cobb) seems to be essential to improve WVTR at tropical conditions, as the pigment level is increased.

The top coats containing biowax imparted water beading effect (due to increased contact angle), while there was no water beading effect from the latex top. Contact angle increased from about 65 for the latex top coat to about 96 for the biowax top coat. Incidentally, the biowax-containing top coats also resulted in improved water resistance, as well as WVTR, at tropical conditions over the 100% latex top coat. It is possible that the water beading effect from biowax prevents or minimizes the loss of coating integrity under the harsh tropical conditions and helps to reduce permeation.

Fold crack resistance barrier results (as measured by WVTR with and without folding) at 65% and 70% clay levels were notably improved after applying latex or latex/biowax top coats. A pure biowax top coat appears to be inferior to latex-based compounds for fold crack resistance, because SB latex film is generally much more flexible than wax.

Future studies

Future work will focus on evaluating the impact of wax emulsions on heat sealability and blocking resistance. It is expected that the addition of wax emulsions will improve blocking resistance, even at reduced pigment loading.

In addition, the performance of these coating systems will be assessed using an improved and more application-relevant oil and grease resistance (OGR) test method beyond the conventional KIT test.

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ABOUT THE AUTHORS

We chose to study this topic because there has been continued interest in improving barrier coating functionalities, which is currently an active area of investigation. The use of mineral pigments such as kaolin clay to substitute part of the synthetic latex in aqueous barrier coatings is known to control water vapor transmission (WVTR). However, previous research indicated that factors controlling WVTR at tropical conditions may be different from standard atmospheric conditions. This research investigated conditions that govern WVTR at tropical conditions.

Using a biowax emulsion improved water resistance and WVTR at tropical conditions. However, it had a negative influence on fold crack resistance. The issue was resolved by finding an optimum combination of latex and biowax emulsion to strike a balance.

Through this study, we found that an increase of pigment loading in a single layer precoating improved WVTR at standard conditions (23°C; 50% RH) as compared to the 100% latex coating, while the WVTR at tropical conditions (38°C; 90% RH) deteriorated with more clay. It was most interesting to find that both biowax emulsion and latex improve water resistance properties; however, biowax imparted a water beading effect (due to increased contact angle), while there was no water beading effect from the latex top coat.

For mills, this work provides insights required to make proper selection of materials for barrier coating applications and different target barrier properties. Our future work will focus on evaluating the impact of wax emulsions on heat sealability and blocking resistance. It is expected that the addition of wax emulsions will improve blocking resistance, even at reduced pigment loading.

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