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Application of clay coating for water resistant corrugated packaging

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Abstract

Application of a delaminated kaolin clay base coat onto linerboard provides a barrier coating for a subsequently applied polymer top coat with potential advantages of increased paper stiffness, improved water resistance at reduced polymer overcoat. Motivated by coating material cost reduction, feasibility of the technique is demonstrated by applying a delaminated clay coating on-line followed by an acrylic overcoat and various properties of the resulting coated linerboard measured. Test boxes were made with commercially supplied treated specialty medium using a pilot single facer with modified carrier starch adhesive and manual double-backing. Stacking compression strength retention as affected by the coatings was evaluated after exposure of the various test containers to a high humidity ice-pack test. Results show that good performance of corrugated boxes can be achieved with linerboard facings having a kaolin base coating.

Introduction

Corrugated packaging for the transport of ice-packed poultry or fish, or field packaging of produce often requires a high degree of water resistance such that stacked boxes in transport or storage do not collapse. Traditionally, corrugated boxes were either curtain or cascade coated with petroleum based waxes, a practice no longer acceptable in many situations since waxed cartons are not readily recyclable and premiums must be paid for disposal. Alternatives have become recently available which include aqueous polymer coatings on linerboards and treated medium. The performance of the alternatives have been evaluated in a previous publication [1] which illustrated that the medium must be non-wicking for wet applications. However the cost of polymer coatings exceed that of wax by several times thus pigment containing alternatives displacing polymers were sought and considered in a following paper [2] which suggested that kaolin coatings can be used as a base coating followed by a polymer top coat to replace a conventional doubly coated linerboard.

Increased popularity of white top linerboard for enhanced graphics for corrugated packaging is an increased cost and loss of strength [3] which becomes more important with the trend to lighter weights. Pigments are potentially more effective and less expensive than bleached pulp to achieve desired levels of brightness. Indeed, **Ref. [2]** also demonstrated that application of a clay base coat can add 10 to 15% compression strength which does not occur with coatings containing only polymer. The clay base coat forms a less porous surface allowing a thinner application of polymer top coat resulting in a higher water resistance at a given thin coat weight. The increase in strength is attributed to the high modulus of clay compared to polymer. Thin films of polymer and pigment/polymer blends have been made and their moduli measured confirming the advantage in stiffness that is obtained when using a platy clay coating [4, 5, 6, 7].

In this paper, a delaminated platy clay [8] coating was applied to 205 g/m^2 (42 lbs/msf) unbleached southern softwood kraft linerboard in a laboratory and commercial rod coating facility. A simple coating blend of a styrene-butadiene latex [9] and kaolin clay was made in ratio of 16:100 to make up a solids content of 64% and used throughout the experiments. Coatings were applied with Mayer wire rods via an Industry Tech Autodraw II used for the laboratory work followed by restrained IR drying of the sheets. Linerboard specimens were placed over a resilient foam backing to prevent pooling of the coating in making wire drawdown samples. On-line coating trials consisted using the facilities at Spectra-Coat in Gettysburg, PA., using their wire rod coater under conventional operating conditions. A combination of IR and air impingement drying was used at Spectra-Coat running the webs at 500 feet per minute.

Linerboard properties – effects of coatings

One of the main concerns of coating onto linerboard is surface mottle of the coating since the topography of high basis weight linerboard is invariably rough. Coatings applied previously using a CLC Helicoater at 2000 fpm with a smooth rod showed a high level of mottle which is considered unacceptable from a marketing point of view. Therefore, coatings were applied in stages using rods or various wire sizes since the first coating once dried will provide a better surface for subsequent coating.

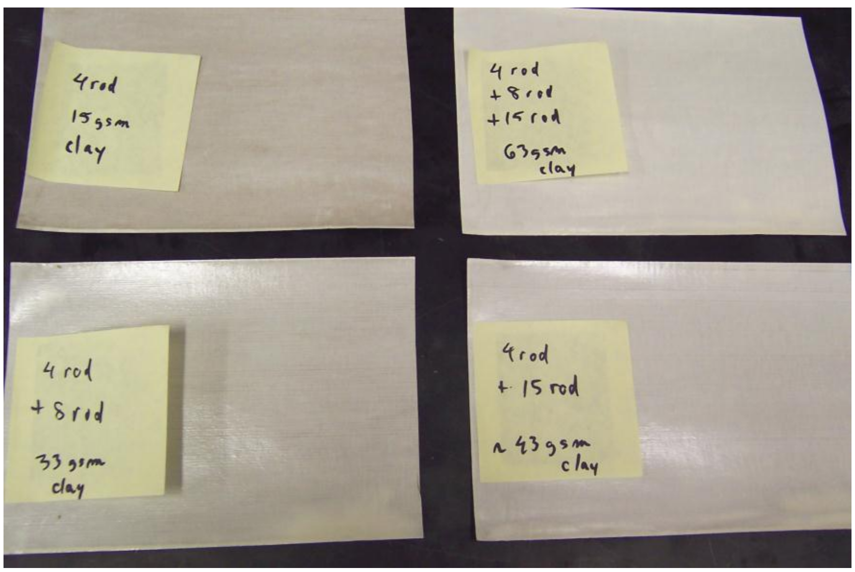

Figure 1. Photographs of wire rod applied kaolin clay coatings on linerboard at various coat weights as indicated.

Fig. 1 shows a photograph of representative rod coated linerboard sheets. All sheets display fine scale streaks along the MD in the coating direction. Mottle is visible from the lightest coating which is 15 gsm (3 lbs/msf) obtained using a single pass with a #4 rod. Other coatweights were obtained using a sequence of a #4 rod coating followed by either a #8 or #15 rod or a combination of both to achieve coat weights 33, 43 and 63 gsm (6.8, 8.8, 12.9 lbs/msf) respectively. Brightness values (Tappi method T 562) were measured to be 47, 59, 62 and 66 in increasing order of coat weight. The clay coatings were followed by a top coat using a single pass of an 8 rod and Spectra-

Kote 763-A commercial acrylic based aqueous coating. Water resistance tests were measured by a 30 minute duration Cobb test (Tappi test method T- 441) the results shown in **Fig. 2** suggest that base coat weights up to 30 gsm (6 lbs/msf) will improve water resistance for the same application of polymer top coat with a wire rod.

A 205 gsm (42 lb/msf) commercial linerboard unbleached kraft with 20% recycle content was run on commercial wire rod coater at Spectra-Kote Gettysburg. The intent was to compare the performance and properties of polymer only coatings versus composite clay and polymer coatings. Usually a coated linerboard will be supplied with a base coating applied with a #4 rod since in the first application the coat weight is largely determined by absorption of the coating in the sheet governed by the sheet porosity and surface roughness. A second coating of polymer is applied over the first dried coating with an 8 rod to form a water resistant barrier. The interest here is to substitute the first base polymer coating with a less expensive kaolin base coating. Coatings applied were: 1) aqueous acrylic 763A with an 8 rod, 2) 763A in a 2 pass sequence: 4 rod application followed by and 8 rod, 3) a base kaolin coating applied with an 8 rod followed by an 8 rod application of 763A, 4) base clay coating applied in 2 stages 4 rod followed by an 8 rod followed by a top coat of acrylic 763A. Coatings 2, 3, and 4 were applied in sequence with drying of the coated sheet in between subsequent applications.

Properties of the commercially rod coated samples are shown in **Table 1**. We note that the water resistance is not as low as obtained in laboratory coatings which is likely due to the fact that the laboratory drawdown wire rod is applied only under the force of its own weight which is about 2.3 lbs and the linerboard rests on a resilient foam backing to prevent pooling. Commercial coater rods and loaded under hydraulic pressure and the backing roll is a relatively harder rubber. The result is that laboratory drawdown coatings tend to be higher on coat weight. Since water resistance is proportional to polymer coat weight a lower water resistance (higher Cobb value) is observed for the same rod number acrylic application when done on a production coater.

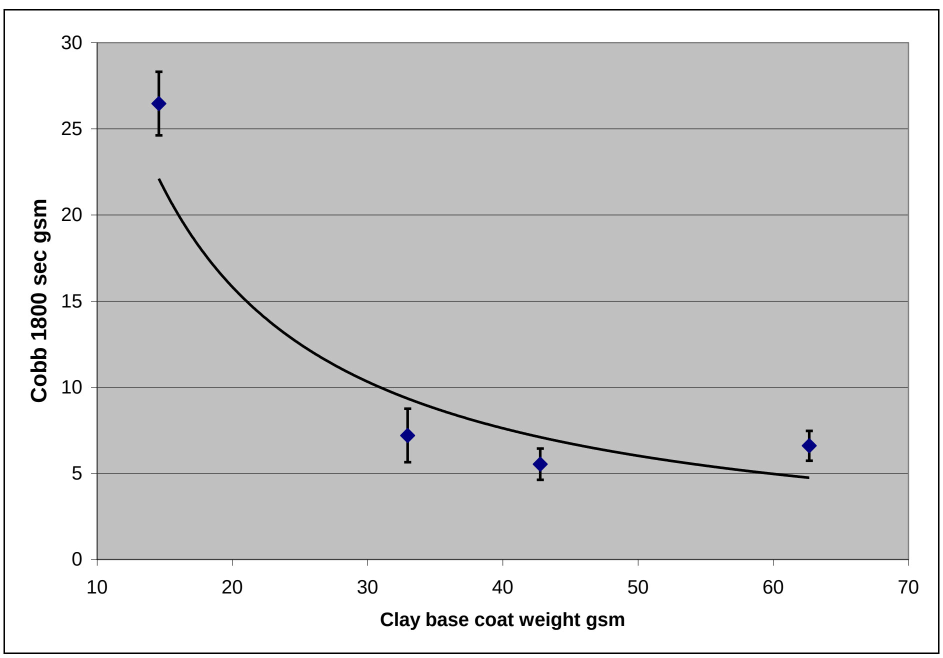

Figure 2. Cobb 1800 s (30 min) water resistance as a function of the kaolin coat weight for laboratory coated linerboard. Error bars represent 95% confidence intervals.

Table 1. Properties of commercially applied rod coated linerboard. E_x and E_y are ultrasonically measured MD and CD moduli respectively.

sample ID	basis wt	caliper	coat wt	clay wt	Cobb	CD STFI	Ex	Ey
	gsm	microns	gsm	gsm	gsm	lb/in	Mpa	Mpa
plain	201.7	283	0		93.4	20.9	5.82	2.67
8 rod 763 A	206	282	4		82.5	22.7	5.69	2.94
4+ 8 rod 763A	210	279	8		36.8	21.6	5.74	2.74
8 rod clay + 8 rod 763A	225	291	23	15	63.8	21.6	5.92	2.94
4 and 8 rod clay + 8 rod 763 A	227.5	289	26	18	68.6	20.6	6.16	2.97
WAM medium	156.5				65			

Table 1 shows that with the production rod coater the polymer and clay coating basis weights are all comparatively modest to those obtained on the laboratory drawdown coated. We note that there do not appear to be pronounced significant gains in CD compression strength that have been observed previously with kaolin coatings applied in a CLC Helicoater [2] as may be expected from the argument of introducing a layer of high modulus into the sheet structure. However, ultrasonic measurements of modulus [10] indicate that there is 3 to 5 % gain once the board is coated the highest increase for the case of the 15 gsm clay base coating. An increase in modulus should result in higher bending stiffness and larger tensile and compressive strengths of the composite material.

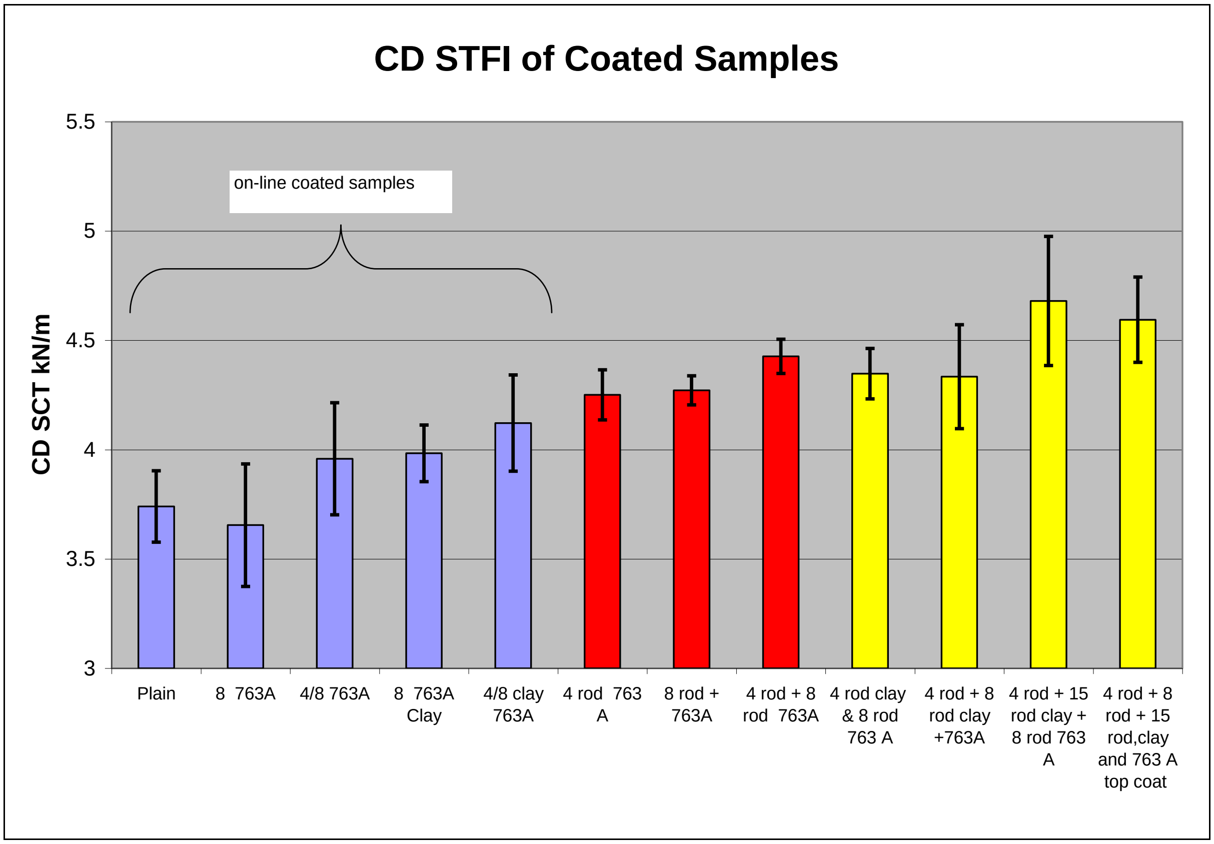

Figure 3. Compression strength for linerboard samples, production and laboratory coated sample sets. Blue bar data are production coated, red bars laboratory drawdown coated with polymer only, yellow bars are laboratory coated with clay base and polymer top coat.

Fig. 3 indicates that in general the addition of a clay base coating can increase the compression strength compared to uncoated or polymer coated paper.

Having a larger kaolin coating did not add to strength nor water resistance in this case. However, clay can contribute positively to providing a more tortuous path for the diffusion of moisture through a coating. Inclusion of pigmented coating may substitute for polyethylene extrusion coated boxes used for shipping frozen meat where a vapor barrier is required to minimize freezer burn. Tappi method T 448 was used to measure the WVTR though the various coatings and the results are summarized in **Fig. 4**. The lowest WVTR values were attained with double coats of polymer however, substituting polymer with clay produced comparable WVTR values which became lower once the clay coat weight became very high.

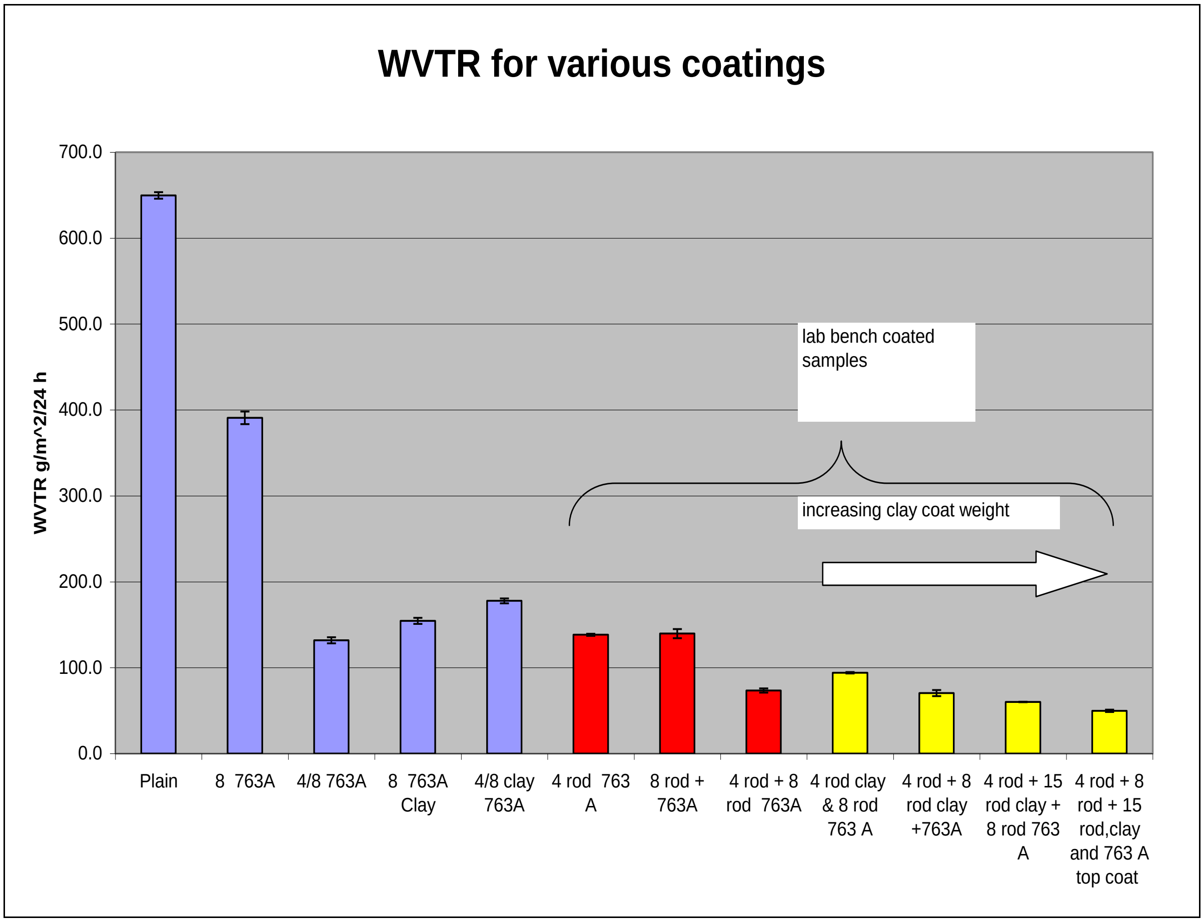

Figure 4. WVTR for various coatings showing the effects of a clay base coat on 42 lb/msf linerboard. Color coding for data bars is the same as for Fig. 3.

The edge crush test (ECT, Tappi method T 839) and 4 point bending stiffnesses (BS, also erroneously called the flexural rigidity of corrugated board in the Tappi method T 820) were measured for the corrugated board sample set using IPST pilot plant facilities as mentioned in more detail in [1]. The medium selected was 161 g/m^2 (33 lb/msf) wax alternative medium [11] which is a commercially available wet-end sized medium with size-press application of aqueous polymer. This medium is combined with the linerboard using a modified primary starch in combination with raw starch in a high shear, high caustic formula customized for this application [12] to ensure good adhesion of the treated medium.

Running coated linerboards through the IPST pilot plant Langston model EX single facer using standard temperature and pressure operating conditions presented no extraordinary difficulties. The single-face flute tip lines show prominently through the coating but this is considered to be inconsequential as the single face linerboard surface remains on the inside of a box. Otherwise there is no other discernible affect of the single facing or double backing on the appearance of the coatings. Test HSC boxes of length width height 7.5 x 8 x 14” were manually assembled using a Langston scoring table with Sauer wide-tip head (45 degree angle) scoring wheels in light contact with polycarbonate flat anvils to minimize score cracking. Kaolin coating when present, did not introduce any observed additional incidences of score cracking. Slots for flaps were made using a pneumatic slotter and templates. Bottom flaps were adhered using conventional hot melt adhesive.

Dimensional stability issues occur with running kaolin coated linerboard for warp and washboarding as they also occur for polymer coated linerboard since the transpiration of water vapor is not as available as it is for uncoated linerboard. This is ameliorated by running the corrugator to run at lower speeds and other means to allow the excess moisture from the adhesive to escape. CD warp of the boards was addressed in our manual box making by stacking the boards under a light load to a 65% RH environment for 24 hours after double backing. Curiously, in examination of the ECT results in **Fig. 5**, it is realized that the addition of coatings of neither polymer nor clay improved the ECT as possibly may be expected from the increases of CD SCT shown in **Fig. 3**.

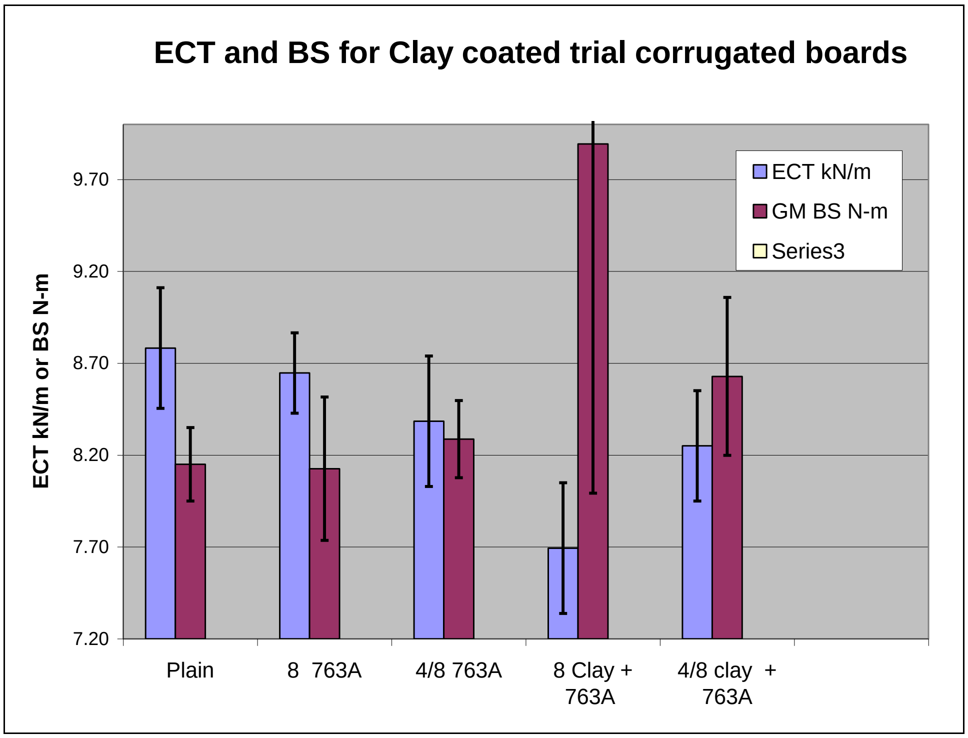

Figure 5. Edge crush (ECT) and 4-point bending stiffness (BS) results for the corrugated board set.

That ECT should decrease with the application of coatings gives credence to the idea that paper becomes weaker with each wetting. However, the increase in bending stiffness for the case the 8 rod applied clay base layer and 8 rod applied top coat is consistent with the observed increase of modulus for this case as measured ultrasonically and shown in **Table 1**. In this case the increase in the geometric mean of the moduli is 12% whereas the bending stiffness increased is 20%. The remaining increase in bending stiffness in this case is likely due to the increase caliper of the coated board in part from the coating thickness and out-of-plane expansion of the board from wetting by application of coating. Just a 3% increase in caliper, which is about 10 microns the thickness of a typical coating, is sufficient to increase the bending stiffness by 9%.

BCT of the coated sample set formed into 14 x 8 x 8" HSC boxes follows the order of ECT since bending stiffness is less of a contributor to BCT than ECT as predicted by the McKee equation [13] The results are shown in **Fig. 6**, where the boxes with applied clay coating have a lower BCT compared to the uncoated linerboard boxes but a comparable BCT to polymer coated boxes. Error bars are 95% confidence intervals for 6 repeats so that overlapping error bars of points do not indicate a statistically significant difference in values.

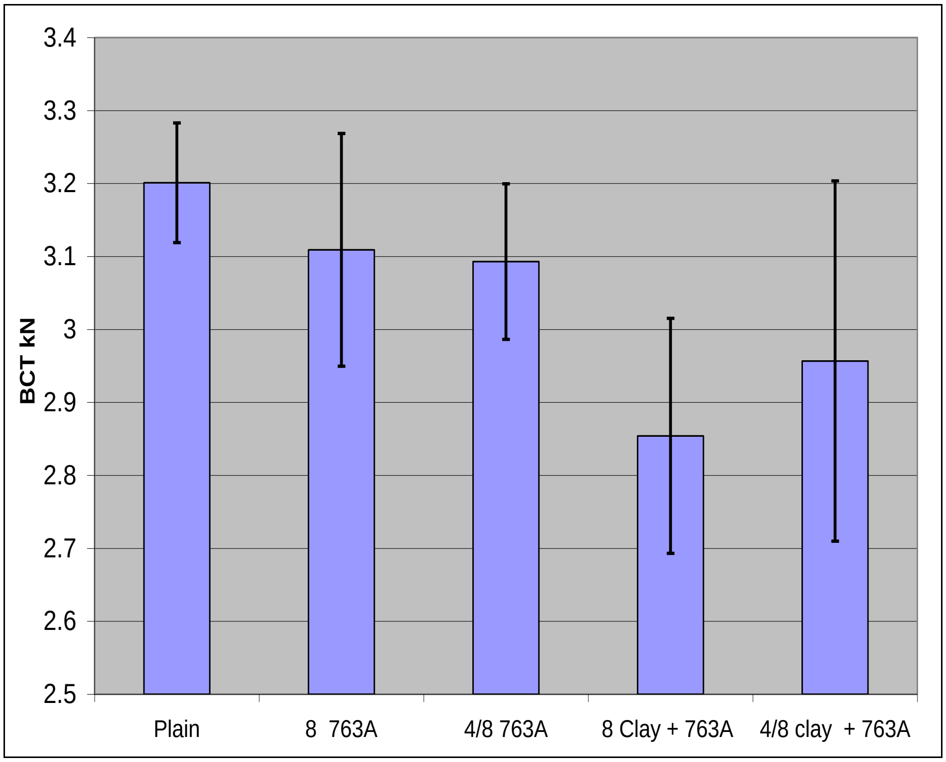

Figure 6. BCT of the on-line coated linerboard test-box sample set.

The HSC box set were placed in a cold storage room which has a temperature of 40 degrees and a humidity of 80% RH for a duration of 72 hours and the BCT retention calculated as a ratio of the BCT after exposure relative to the BCT of unexposed boxes is shown in **Fig. 7**. The high humidity exposure lowers the BCT of uncoated boxes to 37% while the polymer and the combined clay and polymer coated samples retain 45 – 53 % of their original BCT. The order of the relative BCT retention of the various samples is consistent with their measured WVTR performance shown in **Fig. 4**.

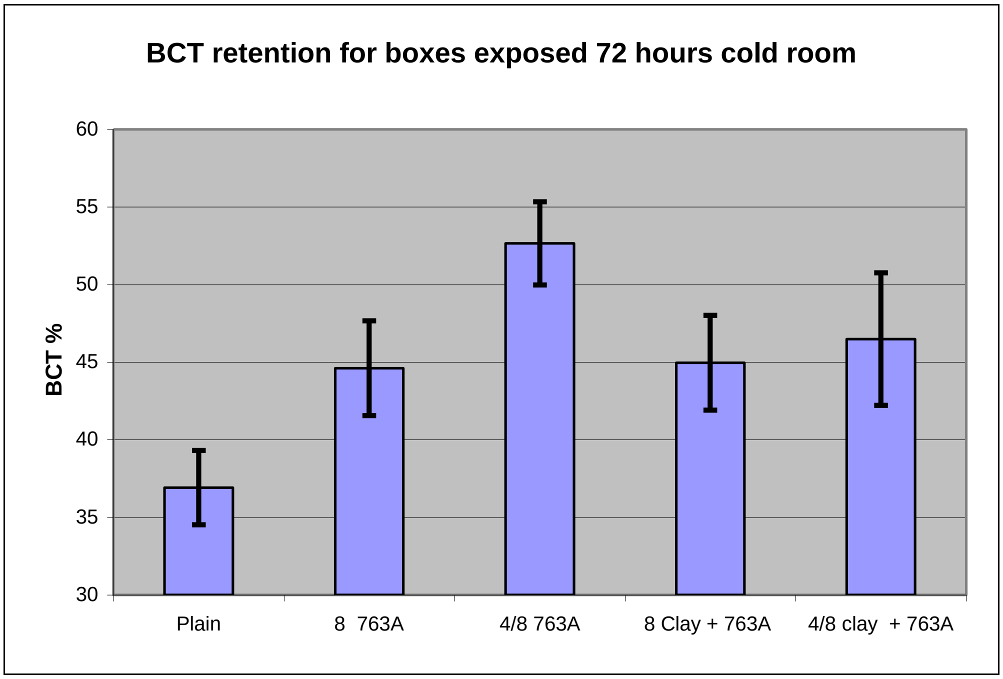

Figure 7. BCT retention of the coated corrugated samples set after exposure to a high humidity cold room environment.

Another set of the test box samples were subjected to an ice-pack test. Each box was filled with crushed ice and left in the cold room for 72 hours. The boxes were supported by rubber stoppers at their bottom corners so that the melt-water from the ice drained away through the bottom flap gaps into pans placed underneath as shown in **Fig. 8**

Figure 8. A subset of the HSC coated linerboard boxes undergoing an ice-pack test in a cold -storage room.

BCT retention for the ice-pack test shows less retention from exposure to the liquid water from the melting ice and likely condensation inside of the flutes between the liners. In this case, the boxes without coated linerboards showed BCT retention of 24% **Fig. 9** whereas the double coated polymer or combination clay and polymer coated boxes showed retention of 31%. These results are comparable to those reported previously [1] using commercially supplied coater linerboard and 26 lb/msf medium where the BCT retention was observed to be 28% compared to curtain coated linerboard with wax impregnated medium that has retention of 66% under the same circumstances. Comparative results using this cold room ice-pack test and previous data from **Ref. [1]** are summarized for various trials in **Table 2**.

Table 2. Summary and comparison of BCT retention performance of various treatments of boxes. Other than the identified commercial samples, all other samples were test boxes made with the single facer at IPST.

Sample type	Decription	Tappi BCT lbs 50% RH	Post cold room % retention	Post ice-pack % retention
Commercial produce pack	white top 51 - 33C WAM	700	71	43
Commercial poultry export	35 - 30C 5 lb/msf waxed liner, WIM medium	710	78	66
IPST WAM	42 SpectraGuard - 26C WAM	786	63	28
Plain WAM	42 - 33C WAM uncoated liners	719	37	24
8 rod trial	42 - 33C WAM coated liner	699	44	23
4/8 rod trail	42 - 33C WAM coated liner	695	53	31
8 rod clay + 8 rod trial	42 - 33C WAM coated liner with clay base	642	45	30
4/8 rod 8 clay + 8 rod trial	42 - 33C WAM coated liner with clay base	667	47	27

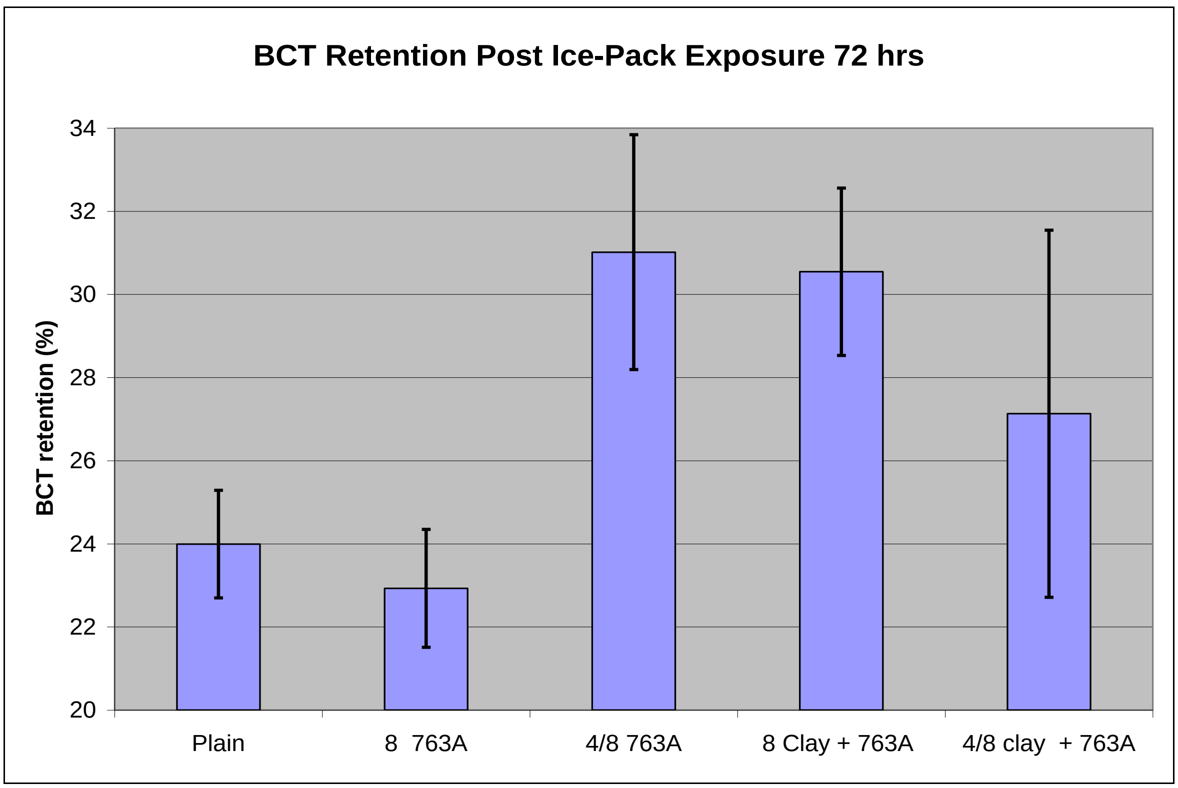

Figure 9. BCT retention for the HSC coated linerboard box set after 72 hours of ice-pack exposure.

Table 2 data shows that a conventional application of curtain coated wax application (sample “commercial poultry export”) has a superior BCT stacking strength retention than any of the alternative treatments investigated including commercial and pilot plant trial. However, the level of stacking strength retention realized by waxed containers may be excessive in many applications and may be instead adequately addressed by the alternative treatments. Moreover, in the ice-pack application, **Table 2** suggests that coating of the linerboards by water resistant coatings only adds a marginal increase in the BCT retention. The principal resistance to moisture in this application is produced by the presence of a water resistant medium. A similar conclusion was reported in **Ref. 4** where similar stacking strength retention was achieved using uncoated linerboards but a medium impregnated with a styrene acrylate copolymer.

Summary

This paper demonstrates that clay coated linerboard can be run on a corrugator with few ill effects regarding the integrity of the coating and surviving converting operations of scoring and folding. Coatings applied with a rod coater of moderate coat weights do not display an objectionable level of mottle and moderate levels of brightness which may be enhanced to desired levels with the addition of brighteners or titanium dioxide. The coating can provide a mottle free white surface more amenable to printed images than unbleached kraft. Moreover, a clay based coating can substitute for a polymer base coating in a two step coating process for waterproofing with no significant deterioration in performance but reduction in material costs. By weight, kaolin is about 3% the cost of polymers; therefore increased usage of pigmented coatings displacing polymers in packaging applications can be expected. Indicated in **Ref 2**. a clay base coating scenario displacing a polymer base coat in a "2 bump" coating process can lower material costs for water resistance applications by 64%.This work has shown that kaolin clay coating offers vapor barrier properties as well which can likely be further optimized in a development program through increased platelet aspect ratio and laminar dispersion.

Acknowledgment

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