Manufacture of Water-Resistant Corrugated Board Boxes for Agricultural Products in the Cold Chain System

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ABSTRACT

For the purpose of developing liner board for water-resistant corrugated board in the cold chain system, several types of base paper for corrugated board were purchased from the market and 6 different boards were produced in the paperboard mill by applying the chemicals on the base paper. Then, water-moisture resistant performance and physical properties of the boards were evaluated and compared each other.
The liner board which is dried at high temperature with pressure by the Condebelt showed a superior performance in strength over conventional liner boards. Strength of the board increased by surface chemical treatment up to 60% of compressive strength and 30% of bursting strength. Starch insolubilization with Ammonium-Zirconium -Carbonate and surface coating with a surface size and a moisture resistant chemical on CK paper showed the best result. Therefore, this method was recommended to produce the outer liner board for water -resistant corrugated board.

INTRODUCTION

A major limitation in using corrugated boxes for the packaging of perishable produce such as fruits and vegetables is that their performance is greatly reduced when wet, or kept at high humidity. Boxes containing agricultural products need to be stored and transported at high humidity and low temperature, so that their contents reach the customer in good condition. In-service failure in these situations is mainly the result of compressive strength reduction caused by dew-forming on the surface of corrugated board liner. Compressive strength reduction becomes more severe when the humidity is cycled such as cold chain system.
From structural mechanics point of view, corrugated board is regarded as a simple sandwich construction at the micro scale, but it represents a complex mechanical behaviour when the surrounding temperature and relative humidity vary. The fiber and fiber network strength, the mechanical properties, and the life of the packaging are greatly reduced with the increase not only of moisture content in the paper but of the relative humidity surrounding the corrugated board.
As reviewed in numerous experimental studies(1,2), chemical treatments have been made for strength enhancement of corrugated boards. However, these treatments, for example, wet-end additives or surface size application were not successful in developing compressive strength and water-resistant property of corrugated boards in the cold chain system because water and moisture could not be prevented from penetrating through air ventilation holes of corrugated boxes for precooling and from weakening the bonding strength of starch adhesive between liner and corrugating medium by the treatments alone.
Therefore, the objectives of this study are to investigate the effectiveness of chemical treatments and properties of the liners to improve the water-resistant performance and mechanical properties of corrugated board boxes for agricultural products in the cold chain system. This has been done by surface treatments of a surface size, a starch insolubilizer, and a water resistant agent on different liner boards, and then by investigating the effect of the chemical treatments and type of liners on the physical properties of boards under the condition simulated the cold chain system.

EXPERIMENTAL

Base papers and chemical treatments

Several types of base paper for corrugated board were purchased from the market and 6 different boards were produced by applying the chemicals on the base paper as shown in Table 1. CK implies a Condebelt dried liner while SK, K. B are conventional liners for corrugated board .

A known volume of the prepared solution containing the required levels of the surface size and starch insolubilized with AZC, which was determined in the previous studies(3,4), was applied to two sides of a base paper using a size press in Dong-Il Paper Ansan Mill.

The specifications of the chemicals used in this study is shown in Table 2.

Table 1. Base papers and treatments used in the experiment

No	Base papers	Treatments
1	CK180	No
2	CK180	Moisture resistance
3	CK180	Moisture resistance +Starch insolubilization
4	CK180	Moisture resistance + Surface sizing + Starch insolubilization
5	K180	Moisture resistance
6	K180	Starch insolubilization
7	K180	No
8	SK180	Moisture resistance
9	SK180	No
10	B160	No

Table 2. Specifications of chemicals used in the experiment

	Moisture resistant agent	Starch insolubilizer	Surface size
Chemical composition	Acryl derivative	AZC	Modified acryl copolymer
Solid(%)	40.0	30.0	35.0
pH	9.0	10.0	4.0
Viscosity (cPs)	200	10	1000

Size press coating condition

The coating conditions of the surface size is shown in Table 3.

Table 3. Surface coating condition at size press

Item	Condition
Starch type	Tapioca oxidized starch
Conc. of starch sol'n(%)	10
Speed(m/min)	550
Nip pressure(kg/cm)	50
Spraying pressure(bar)	2.5
Spraying height(mm)	500
S/P coating weight(L/min)	157
Starch coating weight(%)	4(one side : 2%)
Chemical dosage(%)	5

Moisture-resistant chemical treatment

A part(No.2, 3, 4, 5, and 8) of base papers as mentioned above was transferred to an air-knife coater and 6g/m^2 of moisture-resistant agent was applied on the top side of the base paper. The operating condition of the air-knife coater is shown in Table 4.

Table 4. Operating condition of air-knife coater

Item	Condition
Coating speed(m/min)	200
Dryer type	Air flotation dryer
Drying temperature(℃)	160
Coating weight(one side)(g/m^2)	6

Measurement of physical properties

After conditioning of corrugated base papers in a chamber under three different relative humidities(50, 65 and 80%) respectively at a constant temperature(20℃), the physical properties such as basis weight, moisture content, density, bursting strength, compressive strength(ring crush), water vapor transmission rate, and water absorbency were determined by ISO and TAPPI standard methods.

RESULTS & DISCUSSION

Basis weight

Most papers except No. 10 appeared to be more than 180 g/m^2 in grammage at 65% relative humidity(RH) as shown in Fig. 1. No. 4 paper represented the highest basis weight among 10 papers at 65% RH since it was coated with 3 different chemicals. The grammage increase of No. 4, when RH was increased to 80% from 65%, was the lowest, which means the superior water-moisture resistance of the paper.

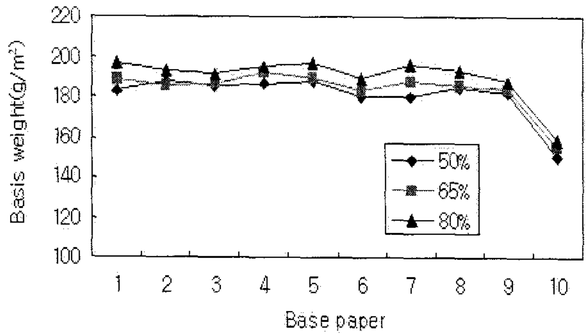

Fig. 1. Changes of basis weight of base paper by relative humidity.

Moisture content

There were little difference of moisture content between CK papers at 50% RH. At higher RH(80%), the moisture content of No. 4 paper represented the lowest value as shown in Fig. 2, which is due to better moisture resistance performance of the paper than others. The good moisture resistant performance of No. 4 paper can be interpreted not only by the effect of chemical treatments but by the property of CK paper which is dried by the Condebelt process with higher sheet density, surface smoothness and humidity resistance than conventionally dried ones.

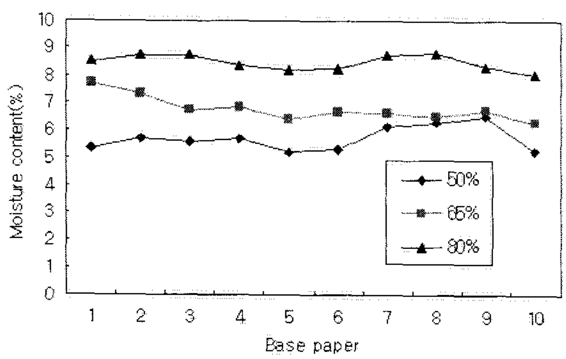

Fig. 2. Changes of moisture content of base paper by relative humidity.

Density

The Condebelt drying process, which was originally designed for improved drying rate, has been found to have a wide range of positive effects on sheet properties mainly because it dries the web at such a elevated pressure and temperature which are not attainable in conventional cylinder drying. The z-directional pressure and temperature have been found to plasticize not only cellulose and hemicellulose but also lignin, which increases fiber flattening, web densification and interfiber bonding(5,6). Furthermore, the Condebelt dryer dries the sheet in a such a fully restraint condition that improves cross machine direction stiffness, which is critical for compresssive strength of corrugated containers(7).

CK paper represented the highest density followed by K, SK and B papers in the order as shown in Fig. 3. The higher density of CK was due to the Condebelt drying which is performed at high temperature and pressure. Since the density of paper is proportional to compressive and tensile strength of the paper, CK was thought to be more suitable for the liner for corrugated boards.

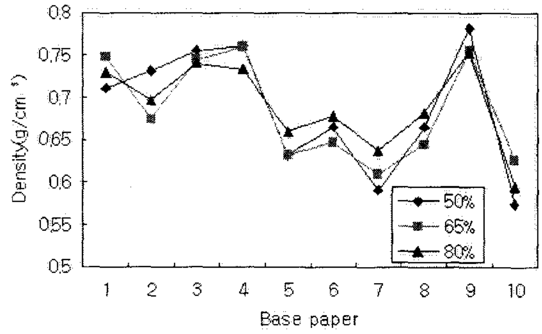

Fig. 3. Changes of density of base paper by relative humidity.

Water vapor transmission rate

Moisture resistance treatment on the surface of outer liner was the most critical factor to water vapor transmission rate of corrugated board with the comparison of the results of No. 5, 6 and 7 papers as shown in Fig. 4. A single use of starch insolubilizer or surface size was not enough to enhance the moisture resistance of paper remarkably. Using the treatments mentioned above in conjunction with moisture resistance treatment represented an additional increase of moisture resistance of paper compared to the single treatment.

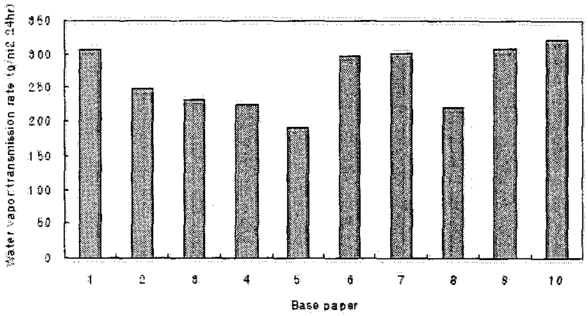

Fig. 4. Changes of water vapor transmission rate of base paper by relative humidity.

Compressive strength

CK paper showed the highest compressive strength followed by SK, K and B paper in that order. Insolubilization of starch adhesive(No. 3, 6) was the most influential treatment to improve compressive strength of paper at 50% RH as shown in Fig. 5. At higher RH(80%), No. 4 paper treated with starch insolubilizer, moisture resistant agent and surface size represented the

best result. There were little improvement of the compressive strength from the water resistance treatment alone on paper except CK paper. Compressive strength were able to be increased by 10%(RH 50%) ~ 60%(RH 80%) depending on the chemical treatments, and it's effect is proportional to the extent of RH.
Moisture resistance treatment was not effective in minimizing the compressive strength decrease with the increase of RH, while starch insolubilization was very effective for the same purpose(No. 6, 7).

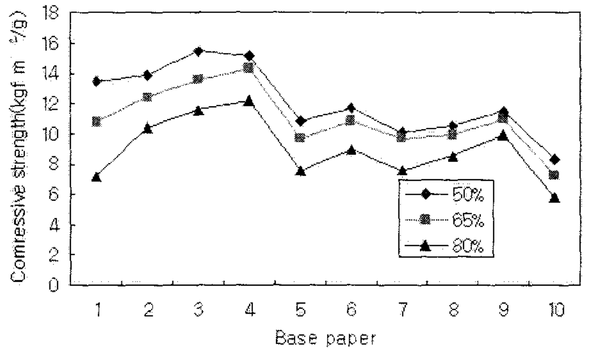

Fig. 5. Changes of compressive strength of base paper by relative humidity.

Burst strength

SK paper showed slightly higher burst strength than CK paper. Starch adhesive insolubilization increased burst strength of paper the most among the treatments as shown in Fig. 6. With CK paper, burst strength could be increased by 30%(RH 50%) by chemical treatments. The increase rate was the highest at 50% RH and in inverse proportion to RH. Contrary to the results of compressive strength, moisture resistance and starch insolubilization treatment were effective in minimizing the compressive strength decrease with the increase of RH(No. 5, 6 and 7).

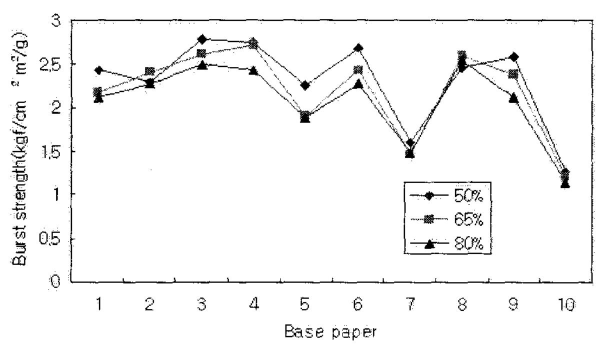

Fig. 6. Changes of burst strength of base paper by relative humidity.

Water absorbency

Cobb value was greatly influenced by the moisture resistance treatment, while starch insolubilization and surface sizing treatments were ineffective. Regardless of base paper, moisture resistance treated papers represented a sharp decrease in Cobb value and little changes with the increase of RH as shown in Fig. 7.

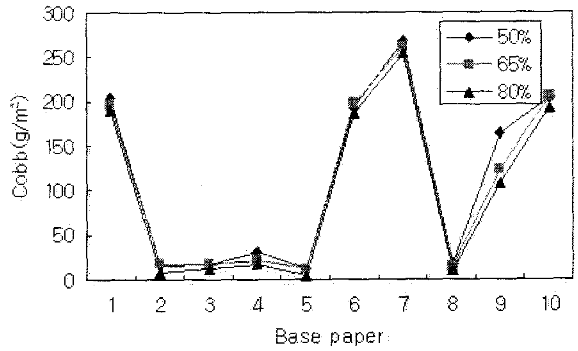

Fig. 7. Changes of water absorbency of base paper by relative humidity.

CONCLUSION

To develope liner board for water resistant corrugated board in the cold chain system, several types of base paper for corrugated board were purchased from the market and 6 different boards were produced in the mill by applying chemical treatments including moisture resistance, starch insolubilization, and surface sizing, chosen in the previous studies, on different base papers. Then water-moisture resistance and physical properties of the boards kept under the varied relative humidities were evaluated and compared each other.
The liner board dried by the Condebelt showed a superior performance in strength over conventional liner boards. Strength of the board increased by surface chemical treatment up to 60% of compressive strength and 30% of burst. Starch insolubilization with Ammonium-Zirconium Carbonate and surface coating with a surface size and a moisture resistant chemical on CK paper showed the best performance. Therefore this method was recommended to produce the outer liner board for water resistant corrugated board.

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