Effect of Frozen Storage on the Physical Properties of Corrugated Fibre-Board Master Cartons and Waxed Duplex Cartons

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Deteriorative changes in physical properties of corrugated fibre-board master cartons and waxed duplex cartons during frozen storage under commercial conditions were studied. Such changes due to prolonged exposure of these boards to moisture in the laboratory, effect of repeated wax-coating on the water resisting capacity of the boards and protection provided by increasing wax contents in the boards against water absorption and consequent deterioration in physical properties are reported.

No information is available on the probable deteriorative changes in fibre-board master cartons and waxed deplex cartons employed in frozen storage under commercial conditions. Alterations taking place in physical properties of corrugated fibre-board master cartons and waxed duplex cartons in frozen storage upto 6 months, simulating conditions obtaining in the industry are reported in this communication. Effects of prolonged exposure of these boards to moisture on their physical properties and increasing wax contents in the boards on their water resisting capacities and consequent retension of physical properties have also been studied.

Materials and Methods

Commercial samples of corrugated fibre-board master cartons (unwaxed, 5-ply, B flute, 651 gsm) and waxed duplex cartons used in frozen shrimp export trade were procured from local manufacturers. They were subjected to complete analysis of the properties before commencing the experiment, employing methods reported in the earlier communications (Srinivasa Gopal & Govindan, 1980). Two kg lots of finely crushed ice were packed in the duplex cartons with 100 gauge low density polythene film linings inside. Ten such cartons were arranged in one master carton and wound with 12 mm wide polypropylene straps with the help of a strapping machine. The entire operation was carried out exactly as practised in commercial shrimp freezing factories, excepting for the fact that ice replaced the frozen shrimp. Six such master cartons were got ready and held in frozen storage at –18 to –20°C (R.H. 80–85%). At the end of each month one master carton was withdrawn from the storage, opened, ice emptied and both the master and duplex cartons subjected to complete analysis. Moisture content, bursting strength and puncture resistance were determined in the case of master cartons. In duplex cartons, moisture, bursting strength, puncture resistance, tensile strength and elongation (in the lengthwise direction of the carton) and tearing strength in both machine and cross directions were studied. The studies were continued upto 6 months of frozen storage.

Since absorption of moisture by the carton material is the main cause of deterioration in its properties, samples of both the corrugated and duplex boards (unwaxed) were exposed to moisture on one side for 1, 2 and 3 hours and changes occurring in their physical properties studied. As the quantity of wax impregnated into the material is one of the major decisive factors in its water resisting capacity, corrugated fibre-boards and duplex boards used in frozen shrimp cartons were procured and impregnated with different quantities of wax. This was done by passing pieces of the boards through molten wax once, twice and thrice successively using a wax-coating machine generally employed by commercial carton manufacturers. Changes in properties due to waxing were studied. The

Table 1. *Effect of frozen storage on properties of master cartons (Grammage of the board:651 gsm)*

Period of storage months	Moisture %	Bursting strength kg/sq.cm	Puncture resistance beach units
Nil	6.67	13.5	185
1	14.12	13.5	175
2	14.50	11.5	170
3	14.09	11.5	185
4	15.19	10.0	170
5	14.52	10.2	159
6	19.10	8.2	150

Table 2. *Effect of frozen storage on physical properties of waxed duplex cartons (Grammage of board:* 345 *gsm, Wax content:* 8.5%, *Saponifiable matter:* 2.94%)

Period of storage months	Moisture %	Bursting strength kg/sq. cm	Puncture resistance beach units	Tearing strength Cross direction g	Tearing strength Machine direction g	Tensile strength kgf	Elongation cm/18 cm
Nil	5.45	3.75	21	180	168	16.26	0.6
1	9.19	3.75	20	152	128	10.97	–do–
2	9.54	3.50	20	160	128	11.08	–do–
3	9.60	3.50	20	128	112	9.05	–do–
4	9.60	3.25	20	144	120	10.95	–do–
5	9.70	3.25	19.5	144	120	10.75	–do–
6	9.79	3.25	19	144	120	10.70	–do–

waxed samples of the boards were exposed to moisture for 1, 2 and 3 hours by clamping them in modified specially designed Cobb's apparatus and keeping a height of 4 cm of water above the samples each time. After the exposure periods, the adhering water was removed by a filter paper and changes occurring in all the physical parameters followed.

Results and Discussion

Deteriorative changes taking place in master cartons during frozen storage for 6 months are presented in Table 1. A sudden spurt was observed in the moisture content even after one month of storage. This may be partly attributed to the fact that the cartons were not wax-coated. Thereafter the increase was not so marked till the end of the fifth month. After 6 months a further steep increase was noted. Corresponding decreases occurred in bursting strength and puncture resistance, significant changes in them being registered only after 2 to 3 months of storage. Alterations in these parameters are caused by condensation of moisture on the cartons due to fluctuations of temperature occurring during opening of the frozen storage. Even though moisture uptake is comparatively quicker, the havoc done by it on the physical properties is slower. Moisture in the board is a very important factor affecting physical strength, flexibility, sheet forming characteristics, as also its weight, dimentional stability, rigidity, folding endurance, elasticity and above all its thermal properties. Fall in bursting strength is attributable to loss in strength and toughness of the fibres by the action of moisture. The decrease in puncture resistance is the root cause of frequent puncture of the master cartons held in frozen storage by corners of other cartons, lumbers and forks when they are subsequently handled for transportation.

Table 2 gives the changes in physical properties of waxed duplex cartons during frozen storage for 6 months. The increase in moisture is maximum after the first month in frozen storage. However, the percentage increase is less than that in the former, which may be attributed to the protection offered by the former and the wax coating against moisture penetration and the comparatively lower grammage of the latter (345 gsm.). The fall in bursting strength is only 13.3% after six months compared to 39% in master carton. Puncture resistance decreased by 9.5% during storage. Tearing and tensile strengths were the most affected. The former showed a fall of 20% in cross direction and 28.6% in machine direction in 6 months. Most drastic change was observed in tensile strength, a fall of 34.2% of the original.

Changes in moisture, bursting and tearing strengths and puncture resistance occurring in plain corrugated fibre-boards and duplex boards, when exposed to moisture on one side for varying periods are presented in Table 3.

Prolonged exposure to moisture and its consequent absorption drastically affects all the important physical properties. In commercial practice, duplex cartons are exposed to glazing water both in the case of in-carton freezing and in tray-freezing at the stage of packing. The absorption continues for varying lengths of time until all the free water freezes into ice. Master cartons are usually exposed inadvertently to occasional splashes of glaze water and to wetness of the surface on which they are placed. Condensation of water also occurs on the surface of the master cartons due to fluctuations in temperature of the frozen storage, dripping of water drops from the roof of the storage and during transhipment. Under all these circumstances, water is absorbed into the carton material, causing deterioration in their physical properties.

Table 3. *Changes in physical properties of plain corrugated fibre-board and duplex board during prolonged exposure to moisture*

	Corrugated fibre-board				Duplex board			
Physical properties	A	B	C	D	A	B	C	D
Moisture	6.67	19.35	21.46	22.76	7.55	22.92	25.59	28.21
Bursting strength kg/cm²	11.5	7.5	6.75	6.25	3.40	1.05	0.90	0.65
Puncture resistance beach units	210.0	127.5	117.5	115.0	20.5	10.5	8.5	6.75
Tearing strength g								
Cross direction	...	...	...	...	176.0	64.0	48.0	40.0
Machine direction	...	...	...	...	165.5	56.0	40.0	32.0

A Control (before exposure to water)
B After 1 h exposure to water
C After 2 h exposure to water
D After 3 h exposure to water

Table 4. *Changes in physical properties of corrugated fibre-board and duplex board after repeated wax-coating*

Stage of analysis	Corrugated fibre-board		Duplex board	
	Cobb 30′ value	Wax content %	Cobb 30′ value	Wax content %
Initial (before wax-coating)	108.45	Nil	66.16	Nil
After wax-coating once	87.05	6.68	39.80	11.90
After wax-coating twice	25.06	9.01	32.54	13.77
After coating thrice	19.49	9.84	30.00	16.29

The changes in physical properties of corrugated fibre-board and duplex board brought about by wax-coating once, twice and thrice are presented in Table 4. Wax coating causes significant improvement in the moisture resistance as shown by the decreasing Cobb 30′ values. Wax contents in the boards increase with the number of times they are waxed with simultaneous decrease in Cobb 30′ values. Two wax coating treatments appear to be sufficient to impart desirable degree of water resisting property to the board. The other characteristics of the boards, namely moisture, bursting strength, puncture resistance and tearing strength are not however affected in any way by wax coating.

Table 5 depicts the changes in moisture, bursting strength and puncture resistance of the wax-coated corrugated fibre-boards after exposure to water for 1,2 and 3 hours at one side to a depth of 4 cm. The uptake of water is maximum in the control sample (Table 3), moisture increasing more than three times in three hours, greatest increase occurring in the first hour of exposure. Moisture uptake in the first hour in both twice and thrice coated samples is comparable, while during subsequent continued exposure, the latter exhibits greater resistance (Table 5). This is a very important phenomenon to be reckoned with since moisture condensation on the master cartons takes place to some extent due to fluctuations of temperature and humidity in the frozen storage during opening and closing of the doors and to considerably high degrees while transporting the frozen cargo in insulated vans. The condensed moisture gets absorbed into the carton material weakening its physical properties. This is amply borne out by the drastic falls in bursting strength and puncture resistance values along with increases in moisture contents. It may incidentally be pointed out that wax-coating does not alter these characteristics as they are the inherent properties of the material constituting the board and hence initial values of the control board hold good for the wax-coated samples also prior to exposure to moisture.

Table 5. *Changes in physical properties of corrugated fibre-board (wax coated) due to exposure to water*

Sample	Moisture %	Bursting strength kg/sq.cm	Puncture resistance beach units
Initial values	6.67	11.50	210
Wax-coated once			
A	16.28	7.50	150.0
B	18.24	6.50	130.1
C	19.65	6.50	120.0
Wax-coated twice			
A	7.78	10.0	190.0
B	16.18	8.5	150.0
C	16.58	7.5	137.5
Wax-coated thrice			
A	8.09	9.0	197.5
B	10.22	9.0	185.0
C	12.29	9.0	175.0

A After 1 h exposure to water
B After 2 h exposure to water
C After 3 h exposure to water

Table 6. *Changes in properties of waxed duplex board due to exposure to water*

Sample	Moisture %	Bursting strength kg/sq.cm	Puncture resistance Beach units	Tearing strength g Cross direction	Tearing strength g Machine direction
Initial values	7.55	3.40	20.50	176	165.5
Wax-coated once					
A	16.28	1.75	17.75	120	114
B	19.93	1.40	13.75	104	96
C	22.28	1.25	12.25	100	88
Wax-coated twice					
A	13.90	1.70	18.00	136	120
B	20.00	1.40	17.50	126	113
C	20.92	1.50	13.25	116	96
Wax-coated thrice					
A	13.74	2.40	19.50	144	124
B	18.53	1.40	16.25	128	112
C	20.46	1.50	15.50	120	112

A After 1 h exposure to water
B After 2 h exposure to water
C After 3 h exposure to water

Changes occurring in moisture, bursting strength, puncture resistance and tearing strength in both cross and machine directions in duplex boards coated with different percentages of wax on exposure to water to a depth of 4 cm from one side for 1, 2 and 3 hours are presented in Table 6. The pattern of changes is similar to that in corrugated board. Moisture in the control sample multiplies nearly 4 times after exposure to water for 3 hours (Table 3). Even though the percentages of wax imbibed are comparatively more in duplex boards (Table 4), their water intake is more than that of the corrugated boards with smaller percentages of absorbed wax. Hence the amount of wax alone is not the decisive factor in the matter of fluid absorption. It is known that amount of sizing, sheet density and ash content are some other factors over and above wax content which contribute towards building up resistance against fluid penetration in papers (Anon, 1973). Rates of deterioration in physical properties namely, bursting strength, tearing strength and puncture resistance are comparatively more pronounced in the duplex board along with absorption of water (Table 6).

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